Volume 8

Draft Supplemental Recirculated Environmental Impact Report REVISIONS to Title 19-KERN COUNTY ZONING ORDINANCE – (2020 A), Focused on Oil and Gas Local Permitting

SCH# 2013081079

Draft Environmental Impact Report
REVISIONS to Title 19-KERN COUNTY ZONING ORDINANCE – (2015 C)
Focused on Oil and Gas Local Permitting
2018 Draft Supplemental EIR

Kern County Planning and Natural Resource Department
2700 M Street, Suite 100
Bakersfield, CA 93301-2370
(661) 862-8600

August 2020

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2018 Draft Supplemental EIR

Kern County Planning and Natural Resource Department
2700 M Street, Suite 100
Bakersfield, CA 93301-2370
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Technical Assistance by:
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August 2020

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PLANNING AND NATURAL RESOURCES DEPARTMENT

Planning
Community Development
Administrative Operations

August 21, 2018 File: SEIR Oil and Gas

ADDRESSEE LIST (See Distribution List)

RE: Draft Supplemental Environmental Impact Report for Approved Amendments to Title 19 – Kern County Zoning Ordinance (2015-C) Focused on Oil and Gas Local Permitting

Dear Interested Party:

Kern County has prepared a Draft Supplemental Environmental Impact Report (SEIR) for approved amendments to Title 19 of the Kern County Zoning Ordinance (2015C) (Ordinance) focused on Oil and Gas local permitting for text amendments to various chapters, which include site development standards and permitting procedures for oil and gas exploration, extraction, operations, and production activities in unincorporated Kern County. The County certified a final Environmental Impact Report (EIR), and approved the amendments to the Ordinance, on November 9, 2015.

Several parties filed lawsuits challenging the adequacy of the certified EIR, and the cases were consolidated before Judge Eric Bradshaw of the Kern County Superior Court (*Vaquero Energy, Inc. et al. v. County of Kern et al.*, *King & Gardiner Farms LLC v. County of Kern et al.*, and *Committee for a Better Arvin et al. v. County of Kern et al.*, Kern County Superior Court Case No. BCV-15-101645, consolidated with Case Nos. BCV-15-101666 and BCV-15-101679). On April 20, 2018, the Court issued a judgment (Judgment) that upheld the EIR in its entirety except for requiring supplemental analysis under the California Environmental Quality Act (CEQA) for two issues: (i) impacts to rangeland/grazing land, and (ii) impacts from road paving as a potential future means of mitigation to reduce designated air emissions. The Judgment did not vacate any portion of the Ordinance or the EIR. Pursuant to the Judgment, the Court issued a writ of mandate (Writ) to the County that states:

> (a) Within 45 days from service of the writ of mandate, County shall transmit to the San Joaquin Valley Air Pollution Control District copies of this court's Ruling, this judgment, and the related peremptory writ of mandate.
>
> (b) Consistent with the Ruling and the procedures set forth in CEQA and CEQA Guidelines, County shall prepare such analysis as is necessary to address the EIR's deficient analysis of the Project's (i) environmental impacts to rangeland/grazing land, and (ii) environmental impacts from road paving as an air emissions mitigation measure ("Supplemental Analysis"). In the event the Supplemental Analysis determines that any such environmental impacts are potentially significant, the Supplemental Analysis shall identify feasible

mitigation measures and/or alternatives to mitigate or avoid such impacts consistent with CEQA's requirements, unless County makes findings of infeasibility and overriding considerations as provided by CEQA.

(c) Upon completion of the Supplemental Analysis described in Part 2(b) above, County shall: (i) reconsider its approval of the Project and its Statement of Overriding Considerations adopted in connection with that project, in light of any new information in the Supplemental Analysis, and (ii) take any and all further action that may be necessary to bring the approval of the project and the related findings and mitigation monitoring and reporting program into compliance with CEQA.

Consistent with the Writ, the Kern County Planning and Natural Resources Department, as Lead Agency, has prepared a draft Supplemental Environmental Impact Report (SEIR), pursuant to CEQA Guidelines Section 15162, to address potential environmental impacts to rangeland/grazing land. Cattle and sheep grazing have historically occurred, and are expected to continue within the project area, including at locations affected by future oil and gas operations under the amended Ordinance. As required by the Court, the SEIR will address the project's potential environmental impacts to grazing/rangelands and identify feasible mitigation measures and/or alternatives to mitigate or avoid impacts determined to be potentially significant.

Consistent with CEQA, the County may also make findings of infeasibility and overriding considerations for any such impacts. The certified EIR provided a comprehensive analysis of all probable environmental effects of the project, and the Judgment upheld the EIR in its entirety except for the two narrow issues discussed above. The Vaquero Judgment did not vacate any portion of the Ordinance or the EIR.

Enclosed is a CD which contains a copy of the Draft Supplemental Environmental Impact Report. A public hearing will be scheduled before the Kern County Planning Commission to receive comments on the document on November 8, 2018 at 7:00 pm or soon thereafter, Chambers of the Board of Supervisors, First Floor, Kern County Administration Center, 1115 Truxtun Avenue, Bakersfield, California.

Comments may be submitted to the Kern County Planning and Natural Resources Department at 2700 M Street, Suite 100, Bakersfield, California 93301 or Loreleio@kerncounty.com.

Sincerely,

Lorelei H. Oviatt, AICP Director
Kern County Planning and Natural Resources Department

DRAFT SUPPLEMENTAL ENVIRONMENTAL IMPACT REPORT
NOTICE OF AVAILABILITY FOR PUBLIC REVIEW

This is to advise that the Kern County Planning and Natural Resources Department has prepared a Supplemental Environmental Impact Report (EIR) for the project identified below. As mandated by State law, the minimum public review period for this document is 45 days. The document and documents referenced in the Draft EIR are available for review at the Planning and Natural Resources Department, 2700 "M" Street, Suite 100, Bakersfield, CA 93301.

A public hearing has been scheduled with the Kern County Planning Commission to receive comments on the document on: **November 8, 2018** at 7:00 p.m. or soon thereafter, Chambers of the Board of Supervisors, First Floor, Kern County Administrative Center, and 1115 Truxtun Avenue, Bakersfield, California.

The comment period for this document closes on **October 4, 2018**. Testimony at future public hearings may be limited to those issues raised during the public review period either orally or submitted in writing by 5:00 p.m. the day the comment period closes. Comments may be provided to the Planning and Natural Resources Department, 2700 M Street, Ste 100, Bakersfield, Ca, 93301 Loreleio@co.kerncounty.com

Project Title: Supplemental Environmental Impact Report for Approved Amendments to Title 19 – Kern County Zoning Ordinance (2015 C) Focused on Oil and Gas Local Permitting.

Project Location: Unincorporated Kern County. The project boundary (Local Permitting Boundary Area) encompasses approximately 3,700 square miles (approximately 2.3 million acres) and generally includes the San Joaquin Valley Floor portion of Kern County, up to an elevation of 2,000 feet. The boundary includes: west side – the San Luis Obispo County line; north side- the Kings and Tulare county lines, east side – the 2,000-foot elevation contours, squared off to the nearest section line; and south side – the northern boundary of the Los Padres National Forest...

Project Description: Kern County has prepared a Draft Supplemental Environmental Impact Report (SEIR) for approved amendments to Title 19 of the Kern County Zoning Ordinance (2015C) (Ordinance) focused on Oil and Gas local permitting for text amendments to various chapters, which include site development standards and permitting procedures for oil and gas exploration, extraction, operations, and production activities in unincorporated Kern County. The County certified a final Environmental Impact Report (EIR), and approved the amendments to the Ordinance, on November 9, 2015.

Several parties filed lawsuits challenging the adequacy of the certified EIR, and the cases were consolidated before Judge Eric Bradshaw of the Kern County Superior Court (*Vaquero Energy, Inc. et al. v. County of Kern et al.*, *King & Gardiner Farms LLC v. County of Kern et al.*, and *Committee for a Better Arvin et al. v. County of Kern et al.*, Kern County Superior Court Case No. BCV-15-101645, consolidated with Case Nos. BCV-15-101666 and BCV-15-101679). On April 20, 2018, the Court issued a judgment (Judgment) that upheld the EIR in its entirety except for requiring supplemental analysis under the California Environmental Quality Act (CEQA) for two issues: (i) impacts to rangeland/grazing land, and (ii) impacts from road paving as a potential future means of mitigation to reduce designated air emissions. The Judgment did not vacate any portion of the Ordinance or the EIR. Pursuant to the Judgment, the Court issued a writ of mandate (Writ) to the County that states:

(a) Within 45 days from service of the writ of mandate, County shall transmit to the

San Joaquin Valley Air Pollution Control District copies of this court's Ruling, This judgment, and the related peremptory writ of mandate.

(B) Consistent with the Ruling and the procedures set forth in CEQA and CEQA Guidelines, County shall prepare such analysis as is necessary to address the EIR's deficient analysis of the Project's (i) environmental impacts to rangeland/grazing land, and (ii) environmental impacts from road paving as an air emissions mitigation measure ("Supplemental Analysis"). In the event the supplemental analysis determines that any such environmental impacts are potentially significant, the Supplemental Analysis shall identify feasible mitigation measures and/or alternatives to mitigate or avoid such impacts consistent with CEQA's requirements, unless County makes findings of infeasibility and overriding considerations as provided by CEQA.

(c) Upon completion of the Supplemental Analysis described in Part 2(b) above, County shall: (i) reconsider its approval of the Project and its Statement of Overriding Considerations adopted in connection with that project, in light of any new information in the Supplemental Analysis, and (ii) take any and all further action that may be necessary to bring the approval of the project and the related findings and mitigation monitoring and reporting program into compliance with CEQA.

Consistent with the Writ, the Kern County Planning and Natural Resources Department, as Lead Agency, has prepared a draft Supplemental Environmental Impact Report (SEIR), pursuant to CEQA Guidelines Section 15162, to address potential environmental impacts to rangeland/grazing land. Cattle and sheep grazing have historically occurred, and are expected to continue within the project area, including at locations affected by future oil and gas operations under the amended Ordinance. As required by the Court, the SEIR will address the project's potential environmental impacts to grazing/rangelands and identify feasible mitigation measures and/or alternatives to mitigate or avoid impacts determined to be potentially significant.

Consistent with CEQA, the County may also make findings of infeasibility and overriding considerations for any such impacts. The certified EIR provided a comprehensive analysis of all probable environmental effects of the project, and the Judgment upheld the EIR in its entirety except for the two narrow issues discussed above. The Vaquero Judgment did not vacate any portion of the Ordinance or the EIR.

Anticipated Significant Impacts on Environment: Original EIR: Aesthetics, Agricultural Resources, Air Quality, Biological Resources, Cultural Resources, Greenhouse Gas, Energy, Hydrology and Water Quality and Utilities and Services.

Document can be viewed online at: https://kernplanning.com/planning/kern-county-oil-gas-permitting/

For further information please contact: Lorelei Oviatt, Director at Loreleio@kerncounty.com or (661) 862-8866.

LORELEI OVIATT, AICP, Director
Planning and Natural Resources Department

To be published once only on next available date and as soon as possible

Arvin Tiller
Bakersfield Californian
Daily Independent
Daily Midway Driller
Delano Record
Kern Valley Sun
Tehachapi News
Lamont Reporter
Mojave Desert News
Mountain Enterprise
News Review
Rosamond Weekly News
Shafter Press
Wasco Tribune

LHO: cm (08/20/2018)

cc: County Clerk (2) (with fee)
Environmental Status Board
Sierra Club/Kern Kaweah Chapter
LiUNA/Arthur Izzo
All Supervisorial District
California Native Plant Society/Kern Chapter
Kern County Archaeological Society
Native American Heritage Pres. Council/Kern County
Center on Race, Poverty and Environment (2)

Zoning Ordinance SEIR - Oil & Gas - Final WO #13284
I:\Planning\WORKGRPS\WP\LABELS\ OG ZO - SEIR - Oil & Gas All Contacts - Final.docx
Sc 05/24/18 (sc 08/13/18)

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Maricopa, CA 93252

City of Arvin
P.O. Box 548
Arvin, CA 93203

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Bakersfield, CA 93301

California City Planning Dept
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California City, CA 93515

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Delano, CA 93216

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Shafter, CA 93263

City of McFarland
401 West Kern Avenue
McFarland, CA 93250

City of Ridgecrest
100 West California Avenue
Ridgecrest, CA 93555

City of Wasco
764 E Street
Wasco, CA 93280

City of Taft
Planning & Building
209 East Kern Street
Taft, CA 93268

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Tehachapi, CA 93561-1722

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Los Angeles, CA 90012

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P.O. Drawer "L"
Independence, CA 93526

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Hanford, CA 93230

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Santa Barbara, CA 93101

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San Bernardino, CA 92415-0182

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San Luis Obispo, CA 93408

U.S. Bureau of Land Management
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Bakersfield, CA 93308-6837

Tulare County Planning & Dev Dept
5961 South Mooney Boulevard
Visalia, CA 93291

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Ventura, CA 93009-1740

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Los Padres National Forest
6755 Hollister Avenue, Suite 150
Goleta, CA 93117

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Ridgecrest, CA 93555

China Lake Naval Weapons Center
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Mail Stop 4001
China Lake, CA 93555

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195 East Popson Avenue
Edwards AFB, CA 93524

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Western Reg Office/
Airport Div - Room 3000
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Lawndale, CA 90261

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Cerritos, CA 90701

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Sacramento, CA 95825-1846

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Ventura, CA 93003

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San Francisco, CA 94105

U.S. Dept of Agriculture/NRCS
5000 California Avenue, Ste 100
Bakersfield, CA 93309-0711

U.S. Army Corps of Engineers
P.O. Box 997
Lake Isabella, CA 93240

State Air Resources Board
Stationary Resource Division
P.O. Box 2815
Sacramento, CA 95812

So. San Joaquin Valley Arch Info Ctr
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9001 Stockdale Highway
Bakersfield, CA 93311

Caltrans/Dist 6
Planning/Land Bank Bldg.
P.O. Box 12616
Fresno, CA 93778

Caltrans/Dist 9
Planning Department
500 South Main Street
Bishop, CA 93514

Caltrans/
Division of Aeronautics, MS #40
P.O. Box 942873
Sacramento, CA 94273-0001

Caltrans/
Division of Structures
Attn: Jim Roberts
P.O. Box 1499
Sacramento, CA 95807

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1400 10th Street, Room 222
Sacramento, CA 95814

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Director's Office
801 "K" Street, MS 24-01
Sacramento, CA 95814-3528

State Dept of Conservation
Division of Oil & Gas
4800 Stockdale Highway, Ste 108
Bakersfield, CA 93309

State Dept of Conservation
Division of Oil & Gas
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Sacramento, CA 95814-3530

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Headquarters
801 "K" Street, MS 12-30
Sacramento, CA 95814

State Dept of Conservation
Office of Land Conservation
801 "K" Street, MS 18-01
Sacramento, CA 95814

State Dept of Conservation
Office of Mine Reclamation
801 "K" Street MS 09-06
Sacramento, CA 95814-3529

State Dept of Conservation
Div Recycling Cert. Sec.
801 "K" Street, MS 19-01
Sacramento, CA 95814

State Mining and Geology Board
801 K Street, MS 20-15
Sacramento, CA 95814

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Bakersfield - Library
9001 Stockdale Highway
Bakersfield, CA 93309

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James W. Reed, Jr.
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Mail Stop 17
Sacramento, CA 95814

California Fish & Wildlife
1234 East Shaw Avenue
Fresno, CA 93710

State Dept of Food & Agriculture
1220 "N" Street
Sacramento, CA 95814

California Highway Patrol
Planning & Analysis Division
P.O. Box 942898
Sacramento, CA 94298-0001

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Attention Susan Stratton
P.O. Box 942896
Sacramento, CA 95296-0001

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Sacramento, CA 95812-4025

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Angeles District - Mojave Desert Sector
15701 E. Avenue M
Lancaster, CA 93535

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Division of Drinking Water
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Bakersfield, CA 93309

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Control Board/Central Valley Region
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Fresno, CA 93706-2020

Sequoia National Forest
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Lake Isabella, CA 93240-3810

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Sacramento, CA 95825-8202

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Environmental Protection Agency
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San Joaquin Dist.
3374 East Shields Avenue, Room A-7
Fresno, CA 93726

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Sacramento, CA 94236

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Sacramento, CA 95812

Kern County
Agriculture Department

Kern County Airports Department

County Clerk

Kern County Administrative Officer

Kern County Engineering, Surveying, & Permit Svs/Floodplain

Kern County Engineering, Surveying, & Permit Svs/Survey

Kern County
Env Health Services Department

Kern County Fire Dept
Brian Marshall, Fire Chief

Kern County Fire Dept
Derek Tisinger, Fire Marshal

Kern County Fire Dept
Dave Goodell

Kern County Library/Beale
Local History Room

Kern County Library/Beale
Sherry Gomez

Kern County Museum
3801 Chester Avenue
Bakersfield, CA 93301

Kern County Parks & Recreation

Kern County Sheriff's Dept
Administration

Kern County Roads Department

Kern County
Waste Management Department

Kern County ESS Dept/
Code Compliance Div

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Inyokern, CA 93527

Mojave Town Council
Bill Deaver, President
P.O. Box 1113
Mojave, CA 93502-1113

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Rosamond, CA 93560

Tehachapi Municipal Advisory Council
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Bakersfield, CA 93309

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Bakersfield, CA 93302-0058

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Delano, CA 93215

San Joaquin Valley
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South Fork Mosquito Abatement Dist
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Kernville, CA 93238-1298

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Lindsay, CA 93247-1715

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Tehachapi, CA 93561

Southern California Edison
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Ridgecrest, CA 93555

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Planning Dept.
25625 West Rye Canyon
Valencia, CA 91355

Southern California Gas Co
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Bakersfield, CA 93308

Southern California Gas Co
Transportation Dept
9400 Oakdale Avenue
Chatsworth, CA 91313-6511

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Bakersfield, CA 93305

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Tule River Indian Tribe
Neal Peyron, Chairperson
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Bakersfield, CA 93314-9025

Carol Vaughn
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Ridgecrest, CA 93555

Clifford, Jenkins & Brown
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Bakersfield, CA 93301

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Tehachapi, CA 93581

Crimson Resource Management
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Bakersfield, CA 93309

Cummings Valley Protective Association
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Tehachapi, CA 93581

Center on Race, Poverty
& the Environmental/
CA Rural Legal Assistance Foundation
1012 Jefferson Street
Delano, CA 93215

Eight Bar Ranch
Jon and Helen Lantz
11300 Cameron Canyon Road
Mojave, CA 93501

Fairview Ranch Owners Assoc
P.O. Box 1024
Tehachapi, CA 93561

Eric Anderson
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Fairmont Town Council
Attn: Barbara Rogers
P.O. Box 2320
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Native American Heritage Council
Preservaton
of Kern County/Gene Albitre
3401 Aslin Street
Bakersfield, CA 93312

Rosamond Skypark
Attn: George Fischer
4000 Knox Avenue
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State Dept of Parks/Hungry Valley
PO Box 1360
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Kern Equestrians for Preservation of Trails
Attn: Carolyn Belli
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Kern River Valley Revitalization, Inc.
Attention: Kris Cardoza, Secretary
P.O. Box 83
Bodfish, CA 93205

Kern River Watermaster
P.O. Box 81435
Bakersfield, CA 93380-1435

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Mojave, A 93501

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941 E. Ridgecrest Blvd
Inyokern, CA 93555

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321 West "C" Street
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Kern County Library
Arvin Branch
201 Campus Drive
Arvin, CA 93203

WZI, Inc.
1717 - 28th Street
Bakersfield, CA 93301

Kern County Library
Boron Branch
26967 Twenty Mule Team Road
Boron, CA 93516

Kern County Library
Buttonwillow Branch
116 Buttonwillow Avenue
Buttonwillow, CA 93206

Kern County Library
Baker Branch
1400 Baker Street
Bakersfield, CA 93305

Kern County Library
Delano Branch
925 - 10th Street
Delano, CA 93215

Kern County Library
Frazier Park Branch
3015 Mount Pinos Way
Frazier Park, CA 93225

Kern County Library
California City Branch
9507 California City Boulevard
California City, CA 93505

Kern County Library
Kernville Branch
48 Tobias Street
Kernville, CA 93238

Kern County Library
Kern River Valley Branch
7054 Lake Isabella Boulevard
Lake Isabella, CA 93240

Kern County Library
Holloway/Gonzales Branch
506 East Brundage Lane
Bakersfield, CA 93307

Kern County Library
Jackson/McFarland Branch
500 Kern Avenue
McFarland, CA 93250

Kern County Library
Mojave Branch
16916 1/2 Highway 14, Space D2
Mojave, CA 93501

Kern County Library
Lamont Branch
8304 Segrue Road
Lamont, CA 93241

Kern County Library
Rathburn Branch
200 West China Grade Loop
Bakersfield, CA 93308

Kern County Library
Ridgecrest Branch
131 East Las Flores
Ridgecrest, CA 93555

Kern County Library
Northeast Branch
3725 Columbus Avenue
Bakersfield, CA 93306

Kern County Library
Shafter Branch
236 James Street, Ste 2
Shafter, CA 93263

Kern County Library
Southwest Branch
8301 Ming Avenue
Bakersfield, CA 93311

Kern County Library
Wanda Kirk/Rosamond Branch
3611 Rosamond Boulevard
Rosamond, CA 93560

Kern County Library
Tehachapi Branch
1001 West Tehachapi Blvd - Suite 400
Tehachapi, CA 93561

Kern County Library
Wasco Branch
1102 Seventh Street
Wasco. CA 93280

Kern County Library
Taft Branch
27 Emmons Park Drive
Taft, CA 93268

Bear Mountain Rec & Parks Dist
P.O. Box 658
Lamont, CA 93241

Buttonwillow Rec & Parks Dist
P.O. Box 434
Buttonwillow, CA 93206-9320

Kern County Library
Wofford Heights Branch
6400-B Wofford Boulevard
Wofford Heights, CA 93285

Tehachapi Valley Rec & Parks Dist
P.O. Box 373
Tehachapi, CA 93561

State Dept of Parks/Hungry Valley
PO Box 1360
Lebec, CA 93243

Tehachapi Parks & Recreation Dist
P.O. Box 373
Tehachapi, CA 93561

Shafter Rec & Parks Dist
700 East Tulare Avenue
Shafter, CA 93263

West Side Rec & Parks Dist
P.O. Box 1406
Taft, CA 93268

Bakersfield City Parks & Rec Dept
4101 Truxtun Avenue
Bakersfield, CA 93301

So. San Joaquin Muni Utility Dist
P.O. Box 279
Delano, CA 93216

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309 Campus Drive
Arvin, CA 93203

Rosamond Community Serv Dist
3179 - 35th Street West
Rosamond, CA 93560

California City Public Works Dept
8190 California City Blvd.
California City, CA 93505

State Dept of Public Utilities Commission
505 Van Ness Avenue, Rm 2003
San Francisco, CA 94102-3214

Boron Community Service Dist
P.O. Drawer B
Boron, CA 93516

Enos Lane Public Utility Dist
P.O. Box 22198
Bakersfield, CA 93390

Desert Lake Community Service District
P.O. Box 567
Boron, CA 93516

East Niles Community Serv Dist
P.O. Box 6038
Bakersfield, CA 93306

Inyokern Community Serv Dist
P.O. Box 1418
Inyokern, CA 93527

Frazier Park Public Utility Dist
P.O. Box 1512
Frazier Park, CA 93225

Golden Hills Community Serv Dist
P.O. Box 637
Tehachapi, CA 93581

Lost Hills Utility Dist
P.O. Box 249
Lost Hills, CA 93249

Lake Isabella Community Serv Dist
P.O. Box 647
Lake Isabella, CA 93240

Lamont Public Utility Dist
8624 Segrue Road
Lamont, CA 93241

Wasco Public Works Dept
801 - 18th Street
Wasco, CA 93280

Mojave Public Utility Dist
15844 "K" Street
Mojave, CA 93501

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5000 California Avenue, Suite 100
Bakersfield, CA 93309

Shafter-Wasco Irrigation Dist
P.O. Box 1168
Wasco, CA 93280-8068

Stallion Springs Community Services Dist
28500 Stallion Springs Drive
Tehachapi, CA 93561

Semi Tropic Water Storage Dist
P.O. Box Z
Wasco, CA 93280

Stockdale Mutual Water Co
P.O. Box 788
Bakersfield, CA 93302

Quail Valley Water Dist
3200 21st Street, Ste 401
Bakersfield, CA 93301

Aerial Acres Water System
19161 Alma Street
Edwards, CA 93523

Rosedale-Rio Bravo Water Dist
P.O. Box 20820
Bakersfield, CA 93390-0820

Superior Mutual Water Co
19474 Enos Lane
Bakersfield, CA 93312-9501

Tehachapi-Cummings Co Water Dist
P.O. Box 326
Tehachapi, CA 93561

Arvin-Edison Water Storage Dist
P.O. Box 175
Arvin, CA 93203

Alta Sierra Mutual Water Co
10502 Sequoia Drive, No. 11
Wofford Heights, CA 93285

Antelope Valley-East Kern
Water Agency
6500 West Avenue N
Palmdale, CA 93551

Bella Vista Water Co
Attention Gerald Hyneman
P.O. Box 15309
Weldon, CA 93283

Ashe Water Dist
Dept of Water Resources
4101 Truxtun Avenue
Bakersfield, CA 93309

Bakersfield City Water Resource Dept
1000 Buena Vista Road
Bakersfield, CA 93311

Bodfish Water Co
P.O. Box 842
Lake Isabella, CA 93240

Belridge Water Storage Dist
21908 Seventh Standard Road
McKittrick, CA 93251

Berrenda Mesa Water Dist
14823 Highway 33
Lost Hills, CA 93249-9734

Buttonwillow County Water Dist
P.O. Box 874
Buttonwillow, CA 93206

Brock Mutual Water Co
12001 Brockridge Court
Bakersfield, CA 93309

Buena Vista Water Storage Dist
P.O. Box 756
Buttonwillow, CA 93206

Cawelo Water Dist
17207 Industrial Farm Road
Bakersfield, CA 93308-9801

Tejon-Castaic Water Dist
P.O. Box 1000
Lebec, CA 93243

Casa Loma Water Co
1016 Lomita Drive
Bakersfield, CA 93307

Edmonston Acres Muni Water Co
25465 Barbara Street
Arvin, CA 93203

California Water Service Co
3725 South "H" Street
Bakersfield, CA 93304

North of the River Rec & Parks Dist
405 Galaxy Avenue
Bakersfield, CA 93308

Erskine Creek Water Co
P.O. Box 656
Lake Isabella, CA 93240

Edgemont Acres Water Co
P.O. Box 966
North Edwards, CA 93523

Edmonston Acres Muni Water Co
25465 Barbara Street
Arvin, CA 93203

Vaughn Water Co.
10014 Glenn Street
Bakersfield, CA 93312

Friant Water Users Authority
854 North Harvard Avenue
Lindsay, CA 93247-1715

Goose Lake Water Co
16232 Palm Avenue
Bakersfield, CA 93314

Gosford Road Water Assoc
13958 Gosford Road
Bakersfield, CA 93313

West Kern Water Dist
P.O. Box 1105
Taft, CA 93268-1105

Wheeler Ridge-Maricopa Water Dist
12109 Highway 166
Bakersfield, CA 93313-9630

Indian Wells Water
Management Committee
P.O. Box 1329
Ridgecrest, CA 93556

Greenfield County Water Dist
551 Taft Highway
Bakersfield, CA 93307

Indian Wells Valley Water Dist
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Ridgecrest, CA 93556

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5001 California Avenue, Suite 102
Bakersfield, CA 93309-1692

Kern Delta Water Dist
501 Taft Highway
Bakersfield, CA 93307

Kern River Valley Water Co
P.O. Box 1260
Lake Isabella, CA 93240

Lamont Storm Water Dist
P.O. Box 543
Lamont, CA 93241

Kern Water Bank Authority
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Bakersfield, CA 93311

Lake of the Woods
Mutual Water Co.
7025 Cuddy Valley Road
Frazier Park, CA 93225

Davenport Mutual Water Assn
P.O. Box 1503
Rosamond, CA 93560

La Hacienda Water Co, Inc.
P.O. Box 60679
Bakersfield, CA 93386-0679

Lebec County Water Dist
P.O. Box 910
Lebec, CA 93243

Mettler County Water Dist
1822 Steven Drive
Bakersfield, CA 93313

Los Angeles Dept of Water & Power
111 North Hope Street, Rm 1121
Los Angeles, CA 90012

Lost Hills Water Dist
1405 Commercial Way, Suite 125
Bakersfield, CA 93309

North Kern Water Storage Dist
P.O. Box 81435
Bakersfield, CA 93380-1435

Mountain Mesa Water Co
12707 Highway 178
Lake Isabella, CA 93240

North Edwards Water Dist
13001 Claymine Road
North Edwards, CA 93523

Olcese Water Dist
P.O. Box 60679
Bakersfield, CA 93386-0679

North of the River Muni Water Dist
P.O. Box 5638
Bakersfield, CA 93388-5638

Oildale Mutual Water Co
P.O. Box 5638
Bakersfield, CA 93388

Rand Communities Co Water Dist
P.O. Box 198
Randsburg, CA 93554

Pinion Pines Mutual Water Co
1467 Tecuya Street
Frazier Park, CA 93225

Metro Water Dist of So CA
Ms. Rebecca De Leon
Environmental Planning Team
700 N. Alameda Street, US3-230
Los Angeles, CA 90012

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309 Campus Drive
Arvin, CA 93203

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44811 Date Avenue, #G
Lancaster, CA 93534-3136

Kern Valley Resource Cons Dist
P.O. Box 58
Weldon, CA 93283

Eastern Kern Resource Cons Dist
300 South Richmond Road
Ridgecrest, CA 93555-4436

Lerdo School Dist
331 Shafter Avenue
Shafter, CA 93263

Lost Hills Union School Dist
P.O. Box 158
Lost Hills, CA 93249

Midway School Dist
P.O. Box 39
Fellows, CA 93224

Mojave Unified School Dist
3500 Douglas
Mojave, CA 93501

Mountain View School Dist
8201 Palm Avenue
Lamont, CA 93241

Muroc Unified School Dist
17100 Foothill Avenue
North Edwards, CA 93523

Norris School Dist
6940 Calloway Drive
Bakersfield, CA 93312

Pond Union School District
29585 Pond Road
Wasco, CA 93280-9772

Richland-Lerdo Union School Dist
331 Shafter Avenue
Shafter, CA 93263

Rio Bravo-Greeley Union School Dist
6521 Enos Lane
Bakersfield, CA 93314

Rosedale Union School Dist
2553 Old Farm Road
Bakersfield, CA 93312

Semi Tropic School Dist
25300 Highway 46
Wasco, CA 93280-9540

Shafter High School Dist
526 Mannel Avenue
Shafter, CA 93263

Sierra Sands Unified School Dist
113 Felspar
Ridgecrest, CA 93555

South Fork Union School Dist
5225 Kelso Valley Road
Weldon, CA 93283

Southern Kern Unified School Dist
P.O. Box CC
Rosamond, CA 93560

Standard School Dist
1200 North Chester Avenue
Oildale, CA 93308

Taft City School Dist
820 North 6th Street
Taft, CA 93268

Taft Union High School Dist
701 7th Street
Taft, CA 93268

Tehachapi Unified School Dist
300 S Robinson Street
Tehachapi, CA 93561

Vineland School Dist.
8701 Weedpatch Highway
Bakersfield, CA 93307

Wasco Union High School Dist
P.O. Box 250
Wasco, CA 93280

Wasco Union Elementary School Dist
639 Broadway
Wasco, CA 93280

Maricopa Unified School Dist
955 Stanislaus Street
Maricopa, CA 93252

Arvin High School
900 Varsity Street
Arvin, CA 93203

Bakersfield City School Dist
Education Center
1300 Baker Street
Bakersfield, CA 93305

Beardsley School Dist
1001 Roberts Lane
Bakersfield, CA 93308

Blake School Dist
P.O. Box 53
Woody, CA 93287

Panama-Buena Vista School Dist
4200 Ashe Road
Bakersfield, CA 93313

Buttonwillow Union School Dist
42600 Highway 58
Buttonwillow, CA 93206

Caliente Union School Dist
12400 Caliente Creek Road
Caliente, CA 93518

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29 Emmons Park Drive
Taft, CA 93268

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1720 Norwalk Street
Delano, CA 93215-1456

Delano Union School Dist.
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Delano, CA 93215

DiGiorgio School Dist
Route 1, Box 34
Arvin, CA 93203

Edison School Dist
P.O. Box 368
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P.O. Box 876
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Tupman, CA 93276

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Fruitvale School Dist.
7311 Rosedale Highway
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1825 Shafter Road
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2100 Chester Avenue
Bakersfield, CA 93301

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601 Second Street
McFarland, CA 93250

Kern Valley High School
3340 Erskine Creek Road
Lake Isabella, CA 93240

Kernville Union School Dist
3240 Erskine Creek Road
Lake Isabella, CA 93240

Lakeside Union School Dist
14535 Old River Road
Bakersfield, CA 93311

Lamont School Dist
8201 Palm Avenue
Lamont, CA 93241

Maple School Dist
29161 Fresno Avenue
Shafter, CA 93263

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U.S. Army
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Fort Irwin, CA 92310

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4117 Barrett Road
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OXY
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Jardin Comunitario
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654 Vasquez Avenue
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Sacramento, CA 95825

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Notice of Completion & Environmental Document Transmittal

Mail to: State Clearinghouse, P. O. Box 3044, Sacramento, CA 95812-3044 (916) 445-0613
For Hand Delivery/Street Address: 1400 Tenth Street, Sacramento, CA 95814

SCH # 2013081079

Project Title: Supplemental Environmental Impact Report for Approved Amendments to Title 19 – Kern County Zoning Ordinance (2015 C) Focused on Oil and Gas Local Permitting.

Lead Agency: Kern County Planning and Natural Resources Department
Contact Person: Lorelei H. Oviatt
Mailing Address: 2700 "M" Street Suite 100
Phone: (661) 862-8866
City: Bakersfield Zip: 93301-2323 County: Kern

Project Location: County: Kern City/Nearest Community: Multiple
Cross Streets: n/a Zip Code: 93301
Lat. / Long.: Total Acres: Approximately 2.3 million square acres
Assessor's Parcel No.: Multiple Section: Multiple Twp.: Multiple Range: Multiple Base:
Within 2 Miles: State Hwy #: 99, 58, 43, 46, 119, 223, 204, 33 Waterways: Kern River
Airports: Multiple Railways: Multiple Schools: Multiple

Document Type:

CEQA: ☐ NOP ☐ Early Cons ☐ Neg Dec ☐ Mit Neg Dec ☐ Draft EIR ☒ Supplement/Subsequent EIR (Prior SCH No.) ☐ Other
NEPA: ☐ NOI ☐ EA ☐ Draft EIS ☐ FONSI
Other: ☐ Joint Document ☐ Final Document ☐ Other

Local Action Type:

☐ General Plan Update ☐ General Plan Amendment ☐ General Plan Element ☐ Community Plan
☐ Specific Plan ☐ Master Plan ☐ Planned Unit Development ☐ Site Plan
☐ Rezone ☐ Prezone ☐ Use Permit ☐ Land Division (Subdivision, etc.)
☐ Annexation ☐ Redevelopment ☐ Coastal Permit ☒ SEIR for Adopted Ordinance

Development Type:

☐ Residential: Units Acres
☐ Office: Sq.ft. Acres Employees
☐ Commercial: Sq.ft. Acres Employees
☐ Industrial: Sq.ft. Acres Employees
☐ Educational
☐ Recreational
☐ Water Facilities: Type MGD
☐ Transportation: Type
☐ Mining: Mineral
☐ Power: Type MW
☐ Waste Treatment: Type MGD
☐ Hazardous Waste: Type
☒ Other: Oil and Gas Exploration and Production

Project Issues Discussed in Document:

☐ Aesthetic/Visual ☐ Agricultural Land ☐ Air Quality ☐ Archeological/Historical ☐ Biological Resources ☐ Coastal Zone ☐ Drainage/Absorption ☐ Economic/Jobs
☐ Fiscal ☐ Flood Plain/Flooding ☐ Forest Land/Fire Hazard ☐ Geologic/Seismic ☐ Minerals ☐ Noise ☐ Population/Housing Balance ☐ Public Services/Facilities
☐ Recreation/Parks ☐ Schools/Universities ☐ Septic Systems ☐ Sewer Capacity ☐ Soil Erosion/Compaction/Grading ☐ Solid Waste ☐ Toxic/Hazardous ☐ Traffic/Circulation
☐ Vegetation ☐ Water Quality ☐ Water Supply/Groundwater ☐ Wetland/Riparian ☐ Wildlife ☐ Growth Inducing ☐ Land Use ☐ Cumulative Effects
☒ Other Grazing land with oil and gas exploration and extraction

Present Land Use/Zoning/General Plan Designation: Developed and undeveloped land in Kern County. Current Zoning Classifications and General Map Code Designations to remain the same.

Project Description: The action consists of the preparation of a Supplemental Environmental Impact Report (SEIR) for approved amendments to Title 19 of the Kern County Zoning Ordinance (2015C) (Ordinance) focused on Oil and Gas local permitting in the valley area, for text amendments to various chapters, which include site development standards and permitting procedures for oil and gas exploration, extraction, operations, and production activities in unincorporated Kern County. The County certified a final Environmental Impact Report (EIR), and approved the amendments to the Ordinance, on November 9, 2015.

Reviewing Agencies Checklist

Lead Agencies may recommend State Clearinghouse distribution by marking agencies below with and "**X**".
If you have already sent your document to the agency please denote that with an "**S**".

S	Air Resources Board		Office of Emergency Services
	Boating & Waterways, Department of	S	Office of Historic Preservation
S	California Highway Patrol		Office of Public School Construction
	CalFire	S	Parks & Recreation
S	Caltrans District # 6 & 9		Pesticide Regulation, Department of
S	Caltrans Division of Aeronautics	x	Public Utilities Commission
S	Caltrans Planning (Headquarters)	S	Regional WQCB # Central Valley
	Central Valley Flood Protection Board		Resources Agency
	Coachella Valley Mountains Conservancy		S.F. Bay Conservation & Development Commission
	Coastal Commission		San Gabriel & Lower L.A. Rivers and Mtns Conservancy
	Colorado River Board		San Joaquin River Conservancy
S	Conservation, Department of		Santa Monica Mountains Conservancy
	Corrections, Department of		State Lands Commission
	Delta Protection Commission		SWRCB: Clean Water Grants
	Education, Department of		SWRCB: Water Quality
S	Energy Commission		SWRCB: Water Rights
S	Fish & Game Region # Fresno		Tahoe Regional Planning Agency
S	Food & Agriculture, Department of	S	Toxic Substances Control, Department of
	General Services, Department of	S	Water Resources, Department of
	Health Services, Department of		
	Housing & Community Development		Other _____
S	Integrated Waste Management Board		Other _____
S	Native American Heritage Commission		

Local Public Review Period (to be filled in by lead agency)

Starting Date August 21, 2018 Ending Date October 4, 2018

Lead Agency (Complete if applicable):

Consulting Firm: _____
Address: _____
City/State/Zip: _____
Contact: _____
Phone: _____

Applicant: _____
Address: _____
City/State/Zip: _____
Phone: _____

Signature of Lead Agency Representative: /s/ **Date:** August 21, 2018

Authority cited: Section 21083, Public Resources Code. Reference: Section 21161, Public Resources Code.

Draft
Supplemental Environmental Impact Report

SCH # 2013081079

SUPPLEMENTAL ENVIRONMENTAL IMPACT REPORT FOR APPROVED AMENDMENTS to the KERN COUNTY ZONING ORDINANCE – 2015 (C) FOCUSED ON OIL AND GAS LOCAL PERMITTING

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Chapter 1
Introduction and Summary

1.1 Introduction

This Draft Supplemental Environmental Impact Report (DSEIR) has been prepared by Kern County (County), the California Environmental Quality Act (CEQA) lead agency, to evaluate the significance of potential impacts to rangeland/grazing land from approved amendments to Title 19 of the Kern County Zoning Ordinance (2015C) (Ordinance). The approved Ordinance amendments focus on Oil and Gas local permitting and text amendments to various chapters, which include site development standards and permitting procedures for oil and gas exploration, extraction, operations, and production activities in unincorporated Kern County.

On November 9, 2015, the Kern County Board of Supervisors approved a revised and amended Zoning Ordinance for oil and gas activities, certified a final Environmental Impact Report (certified EIR) for the Ordinance amendments and revisions, and adopted a Mitigation Monitoring and Reporting Plan (MMRP) in accordance with CEQA Guidelines Section 15090 *et seq.* The Ordinance, the MMRP, and future oil and gas activities subject to the Ordinance, are referred to as the "Project" in this DSEIR. The Project Area encompasses 3,700 square miles (approximately 2.3 million acres) and generally includes the San Joaquin Valley Floor portion of Kern County up to an elevation of 2,000 feet. The boundary includes: west side – the San Luis Obispo County line; north side- the Kings and Tulare county lines; east side – the 2,000-foot elevation contours, squared off to the nearest section line; and south side – the northern boundary of the Los Padres National Forest. The Project is described in more detail in Chapter 3, Project Description, of this DSEIR.

1.2 Project Environmental Review

To initiate the Zoning Amendments and Project EIR for the Project, a Notice of Preparation/Initial Study (NOP/IS) (State Clearinghouse No. 2013081079) was circulated for a 30-day public review period beginning on August 30, 2013 and ending on September 30, 2013. Based on the analysis contained in the Initial Study and comments received in response to the NOP/IS, a Draft EIR (DEIR) was prepared and circulated for a public review period, beginning on July 8, 2015. The initial comment and review period was extended to September 11, 2015. The DEIR considered all of the topical issues in Appendix G of the CEQA Guidelines, including potential project and cumulative impacts to aesthetics and visual resources, agricultural and forest resources, air quality, biological resources, cultural and paleontological resources, geology and soils, greenhouse gas emissions and global climate change, hazards and hazardous materials/public health risks, hydrology and water quality, land use and planning, mineral resources, noise, population and housing, public services, recreation, transportation and traffic, and utilities and service systems. The DEIR also considered and evaluated the consequences of project implementation and potential project alternatives in accordance with CEQA.

On November 9, 2015, the Kern County Board of Supervisors certified the EIR and adopted the Mitigation Monitoring and Reporting Program (MMRP) with findings in conjunction with the approval of the revised amended Zoning Ordinance for oil and gas activities. The certified EIR determined that certain impacts would be significant and unavoidable after implementation of the MMRP, including impacts to or from: the existing visual character or quality of the site and its

surroundings; a new source of substantial light or glare; cumulative aesthetic impacts; cumulative agricultural or forest resources impacts; objectionable odors affecting a substantial number of people; contributing to a cumulatively considerable net increase of any criteria pollutant for which the project region is nonattainment under an applicable federal or state ambient air quality standard; cumulative biological resources impacts; cumulative historical, archaeological, or paleontological resources and human remains impacts; conflicts with any applicable plan, policy, or regulation adopted for the purpose of reducing greenhouse gas emissions; cumulative greenhouse gas emissions impacts; the substantial depletion of groundwater supplies or interference with groundwater recharge; contributing to cumulative hydrology and water quality impacts; sufficient water supplies available to serve the project; and cumulative utilities and service systems impacts.

Concurrently with the certification of the EIR, adoption of the MMRP and approval of the Ordinance, the County Board of Supervisors adopted findings of fact in support of its determinations regarding significant impacts in accordance with CEQA Guidelines Section 15091 and a statement of overriding considerations for project impacts that were determined to be significant and unavoidable in accordance with CEQA Guidelines Section 15093. The MMRP is included as Appendix A to this DSEIR. The certified EIR, including the DEIR and Final Environmental Impact Report (FEIR), the revised and amended Zoning Ordinance for oil and gas activities, the findings of fact in support of the significance determinations, and the statement of overriding considerations adopted by the Board of Supervisors on November 9, 2015 are available for review during normal business hours at the Kern County Planning and Natural Resources Department, 2700 "M" Street, Suite 100, Bakersfield, CA 93301. Electronic format versions of these documents can also be accessed on the Kern County website at: https://kernplanning.com/final-environmental-impact-report-revisions-kern-county-zoning-ordinance-2015-c-focused-oil-gas-local-permitting/. Further information regarding electronic format access to the Project's environmental documents and the revised and amended Zoning Ordinance for Oil and Gas activities is provided in Chapter 2, Documents Incorporated by Reference, of this DSEIR.

1.3 Project EIR Litigation

Several parties filed lawsuits challenging the adequacy of the certified EIR, and the cases were consolidated before Judge Eric Bradshaw of the Kern County Superior Court (*Vaquero Energy, Inc. et al. v. County of Kern et al., King & Gardiner Farms LLC v. County of Kern et al.*, and *Committee for a Better Arvin et al. v. County of Kern et al.*, Kern County Superior Court Case No. BCV-15-101645, consolidated with Case Nos. BCV-15-101666 and BCV-15-101679). On April 20, 2018, Judge Bradshaw issued a judgment (Judgment) that upheld the EIR but required supplemental analysis under CEQA for: (i) impacts to rangeland/grazing land, and (ii) impacts from road paving as a potential future measure to reduce designated air emissions in lieu of paying a portion of the required air mitigation measure fee. The Judgment did not vacate any portion of the Ordinance or the certified EIR. The Court issued a writ of mandate to the County requiring the following:

(a) Within 45 days from service of the writ of mandate, County shall transmit to the San Joaquin Valley Air Pollution Control District copies of this court's Ruling, this judgment, and the related peremptory writ of mandate.

(b) Consistent with the Ruling and the procedures set forth in CEQA and CEQA Guidelines, County shall prepare such analysis as is necessary to address the EIR's deficient analysis of the Project's (i) environmental impacts to rangeland/grazing land, and (ii) environmental

impacts from road paving as an air emissions mitigation measure ("Supplemental Analysis"). In the event the Supplemental Analysis determines that any such environmental impacts are potentially significant, the Supplemental Analysis shall identify feasible mitigation measures and/or alternatives to mitigate or avoid such impacts consistent with CEQA's requirements, unless County makes findings of infeasibility and overriding considerations as provided by CEQA.

(c) Upon completion of the Supplemental Analysis described in Part 2(b) above, County shall: (i) reconsider its approval of the Project and its Statement of Overriding Considerations adopted in connection with that project, in light of any new information in the Supplemental Analysis, and (ii) take any and all further action that may be necessary to bring the approval of the project and the related findings and mitigation monitoring and reporting program into compliance with CEQA.

The Judgment and writ of mandate are attached as Appendix B of this DSEIR.

1.4 Road Paving for Air Quality Mitigation

On May 16, 2018, the County transmitted a copy of the Judgment to the San Joaquin Valley Air Pollution Control District (District) as directed by the Court. The letter from the County to the District transmitting the Judgment is attached as Appendix C of this DSEIR. As discussed in the letter, road paving was identified in the County's staff report and in the Project EIR as an example of a potential future offset for particulate matter emissions that could potentially be undertaken by a permit applicant under the revised and amended Zoning Ordinance for oil and gas activities in lieu of paying some portion of the air quality mitigation fee required by Mitigation Measure (MM) 4.3-8 in the MMRP. The County's transmittal letter to the District clarifies that road paving is not an approved air quality mitigation measure in the Project EIR, the MMRP or the Ordinance. An Emission Reduction Agreement (ERA) was executed by the County and the District in August 2016 that sets forth the required procedures for considering road paving and other potential direct applicant emission reduction activities in lieu of paying some portion of the required air quality mitigation fee. SJVAPCD 2016. Pursuant to the ERA, road paving could have been accepted as an emission reduction measure if and only if in the future both the District and the County accepted a future applicant request for an approved protocol for quantifying the emission reduction benefits of road paving.

The County's transmittal letter to the District confirms that any Project applicant request for recognition of emission reduction offsets for road paving will require future discretionary approvals by the County and District, and will further trigger the need for additional environmental review and compliance with CEQA. Additionally, the letter informs the District that the County has declined to approve road paving as a potential future applicant air emission offset without such additional review and future discretionary decisions. Any future road paving request must first be submitted to the County, which will coordinate with the District and complete the CEQA process inclusive of public notice and outreach, prior to making a determination as to whether or under what conditions road paving would be eligible as a direct applicant emission reduction activity at the conclusion of the additional required CEQA process. There has been no applicant request to allow road paving as an emission reduction offset, there is no reasonably foreseeable such applicant request, and any future decision to evaluate or allow road paving would require public notice and comment, a detailed consideration of environmental impacts as well as additional mitigation, and create a further opportunity to seek judicial review of any such future decision.

On May 31, 2018, the County issued a Notice of Preparation (NOP) for this DSEIR in accordance with CEQA. A copy of the NOP is attached as Appendix D to this DSEIR. The NOP states that because road paving is not authorized as an air emission offset in either the Ordinance or Project EIR, no changes to the Ordinance or EIR are required by the Judgment. Consequently, further consideration of road paving in the Project EIR is not included in this DSEIR. The County conducted a public scoping meeting for the DSEIR on June 15, 2018 and also received written comments during the DSEIR scoping comment period through July 2, 2018. These scoping comment letters are also included in Appendix D.

Several parties submitted oral and written comments related to potential road paving impacts during the public comment period. As discussed in the County's transmittal letter to the District, the County will not accept road paving as an offset for particulate matter emissions for any permit applicant under the revised and amended Zoning Ordinance for Oil and Gas activities without subsequent environmental review for any such offset in full compliance with CEQA. The certified EIR, MMRP and the Ordinance do not authorize road paving as an offset for particulate matter emissions for any permit applicant under the revised and amended Zoning Ordinance for Oil and Gas activities. In addition, as noted in a scoping comment, the District (which relied on the certified EIR when it adopted the ERA) may not utilize funds collected pursuant to the ERA to fund road paving as an offset for particulate matter emissions under the revised and amended Zoning Ordinance for Oil and Gas activities without subsequent environmental review in full compliance with CEQA.

Concurrently with the certification (if approved by the Board of Supervisors) of this DSEIR, the Kern County Natural Resources and Planning Department will recommend that the Board adopt a resolution further clarifying the inapplicability of road paving as a potential air quality mitigation measure under the certified EIR, MMRP and the Ordinance. The recommended resolution would request Board of Supervisors' confirmation that the County will not accept road paving as an offset for particulate matter emissions for any oil and gas permit applicant under the Ordinance without subsequent and complete environmental review for any such offset in full compliance with CEQA.

1.5 Rangeland/Grazing Land Analysis

As discussed in the May 31, 2018 NOP (see Appendix D), the County determined that a DSEIR would be prepared to address the deficiencies in the EIR identified by the Court with respect to the significance of potential impacts to rangeland/grazing land in the Project Area. Comments on grazing/rangeland issues were received by the County from certain of the EIR litigants during the public scoping meeting for the DSEIR conducted on June 15, 2018 and during the DSEIR scoping comment period through July 2, 2018. NOP comment letters are also included in Appendix D.

Scoping notice comments on grazing and rangeland included the following:

(a) potential soil and water impacts affecting livestock watering, water supply and water and soil quality;
(b) air, noise and light pollution;
(c) cumulative impacts to rangeland;
(d) the determination of the significance of potential project and cumulative impacts to rangeland and an analysis of feasible alternatives and mitigation if such impacts are determined to be significant;
(e) the importance of rangeland to the County; and

(f) potential effects from the potential future fee purchase of rangeland by oil and gas operators and from split estates affecting ranching operations.

After the close of the Scoping Plan comment period, the County also received a comment letter from a major livestock ranching operator located in the western portion of the Project Area. The comments included the following:

(a) oil and gas development has almost no impact on grazing in the area where the ranch operates;
(b) oil and gas activity increases available grazing land because the ranch is able to use oil and gas properties that are not under production;
(c) forage on most well pads begins to recover within three years of completion; and
(d) any loss of grazing land from oil and gas production would be insignificant.

Chapter 1, Overview and Summary, of this DSEIR provides an overview of the Project's environmental analysis; the Project EIR litigation and Judgment and writ of mandate issued by the Court; the fact that road paving is not authorized by the certified EIR, the approved Ordinance or the MMRP and will not be accepted by the County as mitigation for any activity subject to the Ordinance without subsequent CEQA review and discretionary approval; and a summary of comments received by the County related to the analysis of grazing/rangeland impacts in response to the NOP.

Chapter 2, Documents Incorporated by Reference, identifies documents incorporated by reference into this DSEIR and the availability of these documents and this DSEIR for review at the Kern County Natural Resources and Planning Department and in electronic format online.

Chapter 3, Project Description, provides a summary of the Project location, the future oil and gas activities subject to the amended Ordinance, the locations where future oil and gas activities authorized by the Ordinance may occur within the Project Area identified by "tiers" (which correspond with the historical concentration and intensity of these operations and Project Subareas), and the MMRP.

Chapter 4, Rangeland/Grazing Land, evaluates the environmental and regulatory setting for grazing and rangeland uses in the Project area, the thresholds of significance for evaluating the potential significance of Project impacts to grazing and rangeland uses, the significance of potential project and cumulative impacts to grazing and rangeland uses, and the need for mitigation for any such impacts found to be significant. As discussed in more detail in Chapter 4, based on the best available evidence of historical grazing and rangeland uses, and using a highly conservative estimate of potential oil and gas impacts that could be authorized under the Ordinance over the next 25 years, the analysis concludes that oil and gas activities would not have a significant impact or contribute to a cumulatively significant impact on rangeland/grazing land resources, and accordingly that no new mitigation measures are appropriate for rangeland/grazing land impacts.

Chapter 5, Consequences of Project Implementation, discusses the consequences of Project implementation.

Chapter 6, Alternatives, discusses alternatives to the Project. Although there are no significant adverse impacts to rangeland/grazing land resources, Chapter 6 evaluates two alternatives with the potential to further reduce the less than significant impact. The first alternative considers the impact of banning grazing on Tier 1 lands, the portions of the Project Area that are most intensively used for oil and gas activities. The second alternative is consistent with the remedy proposed by

petitioners in the Project EIR litigation prior to entry of the Judgment, which is banning oil and gas activities on rangeland/grazing lands. The first alternative results in significantly worse environmental impacts than the amended Ordinance and the second alternative is infeasible.

Chapter 7, Response to Comments, is reserved for responses to comments on the DSEIR.

Chapter 8, Organizations and Persons Consulted, provides information about the organizations and persons consulted by the County to prepare this DSEIR.

Chapter 9, Preparers, provides information about the DSEIR preparers.

Chapter 10, Bibliography, provides a bibliography of documents cited in the DSEIR.

Chapter 2
Documents Incorporated by Reference

2.1 Documents Incorporated by Reference

In accordance with Section 15150 of the State CEQA Guidelines to reduce the size of the report, the following documents are hereby incorporated by reference into this DSEIR and are available for public review at the Kern County Natural Resources and Planning Development (see Section 2.2) as well as in electronic format online where indicated:

Draft Environmental Impact Report for Revisions to the Kern County Zoning Ordinance–2015 (C) Focused on Oil and Gas Local Permitting, SCH # 2013081079 Volume 1, Chapters 1 through 11 (July 2015). The Project DEIR was circulated for public review and comment from July 8, 2015 to September 11, 2015. The DEIR is available in electronic format online under the Volume 1 heading on the Kern County website at: https://kernplanning.com/environmental-doc/environmental-impact-report-revisions-kern-county-zoning-ordinance-2015-c-focused-oil-gas-local-permitting/.

Draft Environmental Impact Report, Volume 2, Appendices A through Appendices W (July 2015). The Project DEIR includes studies and analyses attached as Appendices A through W. The DEIR appendices are available in electronic format online under the Volume 2 heading on the Kern County website at: https://kernplanning.com/environmental-doc/environmental-impact-report-revisions-kern-county-zoning-ordinance-2015-c-focused-oil-gas-local-permitting/.

Final Environmental Impact Report for Revisions to the Kern County Zoning Ordinance–2015 (C) Focused on Oil and Gas Local Permitting, SCH # 2013081079 Volume 3, Chapter 7, Responses to Comments (September 2015). Volume 3 of the Project FEIR includes responses to comments submitted on the DEIR as well as FEIR Appendix B-1, Appendix D-1, Appendix M-1, Appendix M, Appendix S-1, Appendix T-1, Appendix V-1 and Appendix V-2. Volume 3 of the FEIR is available in electronic format online under the Volume 3 heading on the Kern County website at: https://kernplanning.com/environmental-doc/environmental-impact-report-revisions-kern-county-zoning-ordinance-2015-c-focused-oil-gas-local-permitting/.

Final Environmental Impact Report for Revisions to the Kern County Zoning Ordinance–2015 (C) Focused on Oil and Gas Local Permitting, SCH # 2013081079 Volume 4, Chapter 7, Responses to Comments (September 2015). Volume 4 of the FEIR includes supplemental information for responses to comments on the DEIR, responses to document references submitted to the County, and an additional global response to comments. Volume 4 of the FEIR is available in electronic format online under the Volume 4 heading on the Kern County website at: https://kernplanning.com/environmental-doc/environmental-impact-report-revisions-kern-county-zoning-ordinance-2015-c-focused-oil-gas-local-permitting/.

Final Environmental Impact Report for Revisions to the Kern County Zoning Ordinance–2015 (C) Focused on Oil and Gas Local Permitting, SCH # 2013081079 Volume 5, Chapter 12, (November 2015). The project FEIR was certified by the Kern County Board of Supervisors on November 9, 2015. Volume 5 of the FEIR is the Final Environmental Impact Report Consolidation, which includes (a) the text of the amended zoning ordinance as proposed by staff

for consideration by the Kern County Board of Supervisors; (b) the final set of mitigation measures proposed by staff to the Board; (c) consolidated clarifications, amplifications, and insignificant modifications to the DEIR Volumes 1 and 2 described in Chapter 7, Responses to Comments, Volume 3 of the FEIR; (d) consolidated written comments received by the County after the DEIR comment period; and (e) staff-initiated clarifications, amplifications, and insignificant modifications to EIR Volumes 1, 2, and 3, that were made following the September 25, 2015 publication of FEIR Volume 3, Chapter 7, Responses to Comments. FEIR Volume 5 also includes FEIR Appendix M-2, Appendix M-3, Appendix M-4, Appendix V-3, and Appendix W-1. Volume 5 of the FEIR is available in electronic format online under the Volume 5 heading on the Kern County website at: https://kernplanning.com/environmental-doc/environmental-impact-report-revisions-kern-county-zoning-ordinance-2015-c-focused-oil-gas-local-permitting/.

Findings of Fact in Support of Determinations Related to Significant Environmental Impacts, State CEQA Guidelines Section 15091, Revisions to the Kern County Zoning Ordinance – 2015(C), Final Environmental Impact Report SCH # 2013081079 (November 2015). The Kern County Board of Supervisors adopted Findings of Fact in support of the determination of significant environmental impacts in conjunction with the certification of the Project EIR and in accordance with CEQA Guidelines Section 15091 on November 9, 2015. The adopted Findings of Fact is available in electronic format online on the Kern County website at: https://psbweb.co.kern.ca.us/planning/pdfs/eirs/oil_gas/oil_gas_FOF_final.pdf.

Statement of Overriding Considerations, State CEQA Guidelines Section 15093, for Revisions to the Kern County Zoning Ordinance – 2015(C) Final Environmental Impact Report SCH # 2013081079 (November 2015). The Kern County Board of Supervisors adopted a Statement of Overriding Considerations on November 9, 2015 in conjunction with the certification of the Project EIR and in accordance with CEQA Guidelines Section 15093 on November 9, 2015. The adopted Statement of Overriding Considerations is available in electronic format online on the Kern County website at: https://psbweb.co.kern.ca.us/planning/pdfs/eirs/oil_gas/oil_gas_SOC_final.pdf.

Kern County Zoning Ordinance. The current Kern County Zoning Ordinance, including the Ordinance amendments and revisions approved by the Board of Supervisors for Oil and Gas activities on November 9, 2015, is available in electronic format online on the Kern County website at: https://kernplanning.com/planning/planning-documents/zoning-ordinance/.

Revised Amended Draft (11/9/2015) Chapter 19.98 Oil and Gas Activities, A summary of the final amendments and revisions to the Zoning Ordinance approved by the Board of Supervisors on November 9, 2015 is available in electronic format online on the Kern County website at: https://psbweb.co.kern.ca.us/planning/pdfs/eirs/oil_gas/oil_gas_ZO_ch19.98_final.pdf.

Kern County General Plan. The current Kern County General Plan was approved in 2004 and is available in electronic format online on the Kern County website at: https://kernplanning.com/planning/planning-documents/general-plans-elements/.

2.2 Availability of the DSEIR and Documents Incorporated by Reference

This DSEIR is being distributed directly to agencies, organizations, and interested groups and persons for comment during a 45-day formal review period in accordance with Sections 15163(c) and 15087 of the State CEQA Guidelines. This DSEIR and the full administrative record for the

SEIR, including the Project and the certified EIR and all studies and documents incorporated by reference (see Section 2.1) are available for review during normal business hours Monday through Friday at the Kern County Planning and Community Development Department, located at:

Kern County Planning and Natural Resources Department
2700 "M" Street, Suite 100 Bakersfield, CA 93301-2370
Phone: (661) 862-8600, Fax: (661) 862-8601

2.3 Responsible and Trustee Agencies

Projects or actions undertaken by the lead agency, in this case the Kern County Natural Resources and Planning Department, may require subsequent oversight, approvals, or permits from other public agencies in order to be implemented. Other such agencies are referred to as *"responsible agencies"* and *"trustee agencies."* Pursuant to Sections 15381 and 15386 of the State CEQA Guidelines, as amended, responsible agencies and trustee agencies are defined as follows:

- A *"responsible agency"* is a public agency that proposes to carry out or approve a project, for which a lead agency is preparing or has prepared an EIR or Negative Declaration. For the purposes of CEQA, the term *"responsible agency"* includes all public agencies other than the lead agency that have discretionary approval power over the project (Section 15381).
- A *"trustee agency"* is a state agency having jurisdiction by law over natural resources affected by a project that are held in trust for the people of the State of California (Section 15386).

The various public, private, and political agencies and jurisdictions with a particular interest in the project include, but are not limited to, the following:

Federal Agencies

- U.S. Fish and Wildlife Service (USFWS);
- U.S. Army Corps of Engineers (USACE);
- U.S. Environmental Protection Agency (EPA);
- U.S. Department of the Interior, Bureau of Land Management (BLM), Bakersfield Field Office;
- Federal Aviation Administration (FAA); and
- U.S. Department of Agriculture (USDA).

State Agencies

- California Air Resources Board (CARB);
- California Department of Conservation Division of Oil, Gas, & Geothermal Resources (DOGGR);
- California Department of Fish and Wildlife (CDFW);
- California Department of Public Health;
- California Department of Toxic Substance Control (DTSC);
- California Energy Commission (CEC);
- California Highway Patrol (CHP);
- California Public Utilities Commission (CPUC);

- California Native American Heritage Commission (NAHC); California Office of Historic Preservation;
- California State Lands Commission (CSLC);
- Governor's Office of Planning and Research (OPR);
- Regional Water Quality Control Board, Central Valley District (CVRWQCB); and State Water Resources Control Board (SWRCB).

Local Agencies

- San Joaquin Air Pollution Control District (SJAPCD);
- Kern Council of Governments (COG);
- Kern County Waste Management Department (KCWMD);
- Kern County Engineering, Surveying, and Permit Services Department;
- Kern County Fire Department (KCFD);
- Kern County Planning and Community Development Department (KCPCDD);
- Kern County Public Works Department;
- Kern County Roads Department;
- Kern County Planning Commission; and
- Kern County Board of Supervisors.

2.4 Sources

The sources and references used in the preparation of this draft SEIR are listed in Chapter 10, Bibliography, and are available for review during normal business hours at the:

Kern County Planning and Natural Resources Department
2700 "M" Street, Suite 100 Bakersfield, CA 93301-2370
Phone: (661) 862-8600, Fax: (661) 862-8601

Chapter 3
Project Description

3.1 Introduction

As discussed in Chapter 1 of this DSEIR, on November 9, 2015 the Kern County Board of Supervisors approved the Project Zoning Ordinance amendments focused on Oil and Gas local permitting, certified the Project EIR, and adopted the Project MMRP (see Appendix A of this DSEIR). In subsequent litigation, the certified EIR was upheld but supplemental analysis was required on impacts to rangeland.[1] This DSEIR has been prepared by the County to provide an analysis of the significance of potential Project grazing/rangeland impacts as required by the Judgment and writ of mandate. The April 20, 2018 Judgment did not vacate any portion of the Ordinance or the certified EIR.

The approved amendments to Chapter 19.98 (Oil and Gas Production) and related chapters of the Kern County Zoning Ordinance to include additional provisions for local permitting of oil and gas activities were requested by the California Independent Petroleum Association (CIPA), the Independent Oil Producers Agency (IOPA), and the Western States Petroleum Association (WSPA) (collectively, the "Project Proponents") in January 2013. Under Chapter 19.112, amendments to the text of the Zoning Title of the Kern County Zoning Ordinance can only be initiated by the Kern County Board of Supervisors. The request was considered in a public hearing before the Board of Supervisors on January 22, 2013, and the Board directed Natural Resources and Planning Department staff to proceed with processing the requested amendments and to review and revise other relevant references in the Zoning Ordinance as required. As discussed in Section 2.1 of this DSEIR, the Revised Amended Draft (11/9/2015) Chapter 19.98 Oil and Gas Activities incorporated by reference in this DSEIR provides a summary of the Zoning Ordinance amendments and revisions for Oil and Gas activities approved by the Board of Supervisors on November 9, 2015. The Project includes the amended and revised Ordinance, the approved MMRP (see Appendix A), and the implementation of future oil and gas activities expected to be undertaken pursuant to the Ordinance.

3.2 Project Area

The Project Area is located in the western half of Kern County as shown on Figure 3-1 and encompasses 3,700 square miles (approximately 2.3 million acres) and generally includes the San Joaquin Valley Floor portion of Kern County up to an elevation of 2,000 feet. The boundary includes: west side – the San Luis Obispo County line; north side- the Kings and Tulare county lines; east side – the 2,000-foot elevation contours, squared off to the nearest section line; and south side – the northern boundary of the Los Padres National Forest. The Project Area boundary is

[1] In addition, the Judgment required supplemental analysis for use of road paving as a potential mitigation measure for air quality impacts (see Appendix B of this DSEIR). As discussed in Section 1.4 of this DSEIR, road paving is not authorized by the certified EIR, the Ordinance or the MMRP and will not be accepted by the County as mitigation for any activity subject to the oil and gas amendments to the Ordinance without additional and complete CEQA review.

based on information regarding areas with potential or confirmed oil and gas resources within the County's jurisdiction.

Although the Project Area encompasses 3,700 square miles, the EIR impact analysis includes only unincorporated County land. Therefore, the analysis includes unincorporated County land within the 409-square-mile Metropolitan Bakersfield Planning Area (a joint planning area containing both County and City land), but excludes all adjacent City of Bakersfield land. The EIR analysis also excludes all other city jurisdictions, such as Taft, Delano, Shafter, Arvin, McFarland, Maricopa, and Wasco. Lands under the jurisdiction of various state and federal agencies, including the BLM, USFWS, and the California State Lands Commission, are also included within the 3,700-square-mile Project Area but are excluded from the EIR impact analysis. Ancillary equipment and land uses (e.g., pipelines and access roads on unincorporated County lands) are included in the Project Area, analyzed in the EIR, and regulated by the County even though such equipment and land uses may serve wells on non-jurisdictional County lands (e.g., incorporated cities or federal/state lands). The EIR conservatively assumes that all new well activities in Kern County would occur within the portion of the Project Area subject to the County's jurisdiction. Non-jurisdictional portions of the Project Area are included as part of the cumulative impacts analysis.

In order to facilitate detailed analysis, the Project EIR divides the Project Area into three Project Subareas, the Western Subarea, the Central Subarea and the Eastern Subarea, based on

environmental characteristics, existing land uses, and existing and planned oil and gas production activities. The subarea boundaries generally reflect major transportation corridors. The locations of the three Project Subareas are shown on Figure 3-2.

The Western Subarea consists of 1,714 square miles (1,096,840 acres) and is generally bounded by the Kern County border on the north and west, Los Padres National Forest on the south, and by Interstate 5 (I-5) on the east. The Western Subarea contains many of the large-scale oil and gas extraction-level operations in the Project Area, and includes 37 active oil and gas fields. Five of these oil and gas fields are the largest in California by production volume. The Western Subarea also includes dispersed agricultural operations and unincorporated areas around the cities of Taft and Maricopa.

The Central Subarea consists of 1,025 square miles (656,003 acres) and is generally bounded by the Kern County border on the north, by I-5 on the west, and State Route 65 and State Route 223 on the East. The Central Subarea contains 21 active oil and gas fields, some with large-scale production activity. The Central Subarea contains some of the County's deepest wells, with oil operations co-locating with predominant agricultural activities in this Subarea. The Central Subarea contains parts of the unincorporated Metropolitan Bakersfield area and includes unincorporated areas around the cities of Shafter, Delano, Wasco, and McFarland.

The Eastern Subarea consists of 953 square miles (over 600,000 acres) and is generally bounded by the County border on the north, State Route 65 and State Route 223 on the west, and mountain ranges on the east and the south. The Eastern Subarea contains 20 active oil and gas fields along with several large-scale oil and gas production areas, such as the Kern River Oilfield north of the City of Bakersfield. The Eastern Subarea includes parts of the unincorporated Metropolitan Bakersfield area and unincorporated areas around the city of Arvin.

Kern County is the largest oil producing county in the state. According to the DOGGR, in 2012, Kern County, with nearly 43,000 active oil and gas, dry gas, and gas storage wells, contained 78% of all active wells in California. In addition, 80% of all oil and natural gas produced in California

came from wells in Kern County. The first commercially developed oilfield in Kern County was the McKittrick Field, which was developed in 1898. Development was facilitated by existence of the Southern Pacific Railroad from Bakersfield to McKittrick. The Kern River Field, north of Bakersfield, was established in 1899 with the discovery of oil at that time. By 1903, 796 wells produced almost 17 million barrels of oil from the Kern River Field. In the mid-1930s, several valley oilfields were found in large anticlines in Miocene oil sands beneath the valley floor. These discoveries were made following the advent of the reflection seismograph. Discoveries included Ten Section, Greeley, Rio Bravo, North Coles Levee, South Coles Levee, and Strand.

Kern County is located within District # 4 of DOGGR, now referred to as the "Inland District." A total of 100 active or abandoned "Administrative Oilfields" (AOFs), which are delineated by DOGGR under applicable state regulations, are located on County jurisdictional lands within the Project Area. As shown in Figure 3-3, the AOFs vary widely in size, from 0.2 square mile (the Kernsumner and Temblor East wellfields) to the Midway-Sunset Oilfield, which includes 99.7 square miles. The boundaries of the AOFs are referred to as "Administrative Boundaries." Oil and gas production also occurs outside of AOFs. Figure 3-3 shows each AOF within the Western, Central, and Eastern Subarea and indicates whether the AOF is active or has been abandoned.

The Project EIR describes locations within and immediately adjacent to DOGGR's Administrative Boundary areas as "Core Areas." The Core Areas are used to approximate the locations where the majority of future oil and gas activities is likely to occur in the Project Area. For purposes of administering zoning requirements within and adjacent to DOGGR's Administrative Boundaries, Core Areas were defined by making the following adjustments, as applicable, to each DOGGR Administrative Boundary, to administratively manage County zoning requirements in oil and gas production areas: (1) each area within a DOGGR Administrative Boundary was first defined as a "Core Area" for oil and gas production purposes; (2) adjacent areas within DOGGR Administrative Boundaries were combined into a single Core Area; (3) Consistent with County zoning practice, the irregular boundaries of each Core Area were "squared off" and defined by the nearest Section and quarter Section lines; (4) to accommodate the probability of continued expansion at the edges of these known producing areas, the Core Area was extended at least one-half Section from the DOGGR Administrative Boundary; (5) to accommodate known oil production activities that are adjacent to but not yet within a DOGGR Administrative Boundary, the Core Area was expanded to include adjacent Sections that either contained at least two wells in the Section, or contained two wells within a 640-acre area of the Section; and (6) where the Core Area mapping process resulted in isolated islands or narrow strips of lands between Core Areas, the Core Area was combined to eliminate these orphaned areas. Historically, more than 95% of oil and gas production occurs within DOGGR's Administrative Boundaries. The Project EIR assumes that the same percentage of production would occur in the Core Areas in the future. The Core Area locations within the Project Area are shown on Figure 3-4.

Oil and gas production in Kern County varies in intensity, depending on historic uses, surrounding land uses and zoning designations, and the quality of other potential land uses (e.g., agricultural land). As part of the project-level EIR analysis, both Core and non-Core areas within the Project Area were further divided into five (5) tiers based on existing and zoned land uses. Each Tier 1 through Tier 5 is defined in Section 19.98.030 of the Kern County Zoning Ordinance as follows:

A. Tier 1 Area is defined as all areas in which oil and gas activity is the primary land use. The existing well and activity densities preclude almost all other uses except for passive uses such as grazing.

B. Tier 2 Area is defined as all areas that are classified Exclusive Agriculture (A) or Limited Agriculture (A-1) Districts, have agriculture as the primary surface land use, and are not included in Tier 1.

C. Tier 3 Area is defined as other areas not within a Tier 1 Area that are located in one of the following zone districts:

- Natural Resource (NR)
- Recreation Forestry (RF)
- Light Industrial (M-1)
- Medium Industrial (M-2)
- Heavy Industrial (M-3)
- Floodplain Primary (FPP)
- Drilling Island (DI)
- Zone Districts that have the Petroleum Extraction (PE) Combining District

D. Tier 4 Area is defined as areas not within Tier 1, 2, or 3, that include at least one of the following zone districts:

- Estate (E)
- Low–Density Residential (R-1)
- Medium-Density Residential (R-2)
- High-Density Residential (R-3)
- Commercial Office (CO)
- Neighborhood Commercial (C-1)
- General Commercial (C-2)
- Highway Commercial (CH)
- Open Space (OS)
- Platted Lands (PL)
- Mobilehome Park (MP)

Authorized oil and gas activities in Tier 4 are subject to approval of a conditional use permit in accordance with 19.104 of the Ordinance.

E. Tier 5 includes all current and future Specific Plan boundaries either adopted with a Special Planning (SP) District or which include specific provisions for oil and gas operations. Oil or gas exploration and production activities would be allowed with a conditional use permit or as permitted by the regulations contained within the adopted Specific Plan in Tier 5 areas.

F. All other areas not defined as Tier 1-5 Areas within the Oil and Gas Production Area are considered non-jurisdictional because they are not within the jurisdiction of Kern County, including land owned by the United States, State of California or land within an incorporated city, unless under the authority of a written agreement with the Board of Supervisors. The regulations set forth in the Zoning Ordinance pertain only to accessory structures, facilities or uses that are physically connected to, provide access or services to, or otherwise support, oil and gas activities in these non-jurisdictional Areas.

The locations of each Tier within the Project Area, as depicted in Figure 19.98.015 of the Kern County Zoning Ordinance, are shown in Figure 3-5.

Table 3-1 summarizes the Project Area acreage by Tier and Project Subarea as well as in non-jurisdictional lands.

Table 3-1: Project Area Acres by Tier, Subarea and Non-Jurisdictional Land

Tier	Western Subarea	Central Subarea	Eastern Subarea	Total
Tier 1	163,227	3,002	40,518	206,747
Tier 2	800,443	523,071	467,789	1,791,303
Tier 3	2,043	2,801	11,359	16,203
Tier 4	5,423	10,413	18,614	34,450
Tier 5	772	0	1,740	2,512
Non-jurisdictional land and "other" land (includes schools, cemeteries, hospitals, and road/freeway rights-of-way)	124,934	116,715	69,869	311,519
TOTAL	1,096,842	656,003	609,889	2,362,734

Sources: Project DEIR, Table 3-4 and Table 4.4-73. Totals may not add due to rounding.

3.3 Project Overview

The Project consists of the approved amendments to Title 19 of the Kern County Zoning Ordinance, Chapter 19.98 (Oil and Gas Production) and related sections of the Kern County Zoning Ordinance, the implementation of future oil and gas development activities expected to be undertaken pursuant to the amended Ordinance, and the MMRP.

Kern County Zoning Ordinance Amendments and Revisions

On November 9, 2015, the Kern County Board of Supervisors amended sections of the Kern County Zoning Ordinance relating to oil and gas drilling, including but not limited to Chapter 19.98 (Oil and Gas Production), to address oil and gas exploration and operation activities in greater detail, by:

a) Establishing updated development and implementation standards and conditions to address environmental impacts of pre-drilling exploration, well drilling, and the operation of wells and other oil and gas production-related equipment and facilities, including exploration, production, completion, stimulation, reworking, injection, monitoring, and plugging and abandonment; and

b) Establishing new "Oil and Gas Conformity Review" and "Minor Activity Review" ministerial permit procedures for County approval of future well drilling and operations to ensure compliance with the updated development and implementation standards and conditions and provide for ongoing tracking and compliance monitoring.

As discussed in Section 2.1 of this DSEIR, approved updates to all sections of the Zoning Ordinance related to oil and gas exploration and production are identified in the Revised Amended Draft (11/9/2015) Chapter 19.98 Oil and Gas Activities incorporated by reference in this DSEIR. The following description outlines the changes made to the Zoning Ordinance.

a) Chapter 19.98 has been comprehensively overhauled to remove the "Unrestricted Drilling" section and to update the "Drilling by Ministerial Permit" and "Drilling by Conditional Use

Permit" sections. This update requires that all new oil and gas wells for exploration or production obtain approval from the Kern County Natural Resources and Planning Department prior to commencing drilling.

b) The Tier system described in Section 3.2 of this DSEIR and in Section 3.4.4 of the Project DEIR, has been incorporated into Chapter 19.98 to address the different land uses and zone districts where oil and gas activities occur. The Tier system is made up of 5 distinct Tiers, including, Tier 1 Areas – primarily existing oil and gas activities and passive uses such as grazing; Tier 2 Areas – primarily existing agricultural activities; Tier 3 Areas – primarily existing industrial development; Tier 4 Areas – primarily existing urban development (CUP Required); and Tier 5 Areas – consisting of existing and future adopted Specific Plans. The Tier areas within the Project Area are depicted on Figure 3-5.

c) An Oil and Gas Conformity Review is required as part of the "Drilling by Ministerial Permit" Section to allow for comprehensive review of all drilling activities. The review requires consistent, comprehensive mitigation based on defined Tiers of surrounding land uses, as specified in the amended Ordinance and in the MMRP. An application package must be submitted that includes a site plan and written documentation assuring compliance with all applicable Development and Implementation Standards and Conditions, including the MMRP.

d) A Minor Activity Review is required as part of the "Drilling by Ministerial Permit" Section, to allow for comprehensive review of minor oil and gas activities. The review requires consistent, comprehensive mitigation based on defined Tiers of surrounding land uses, as specified in the amended Ordinance and in the MMRP. An application package must be submitted with written documentation assuring compliance with all applicable Development and Implementation Standards and Conditions, including the MMRP.

e) The Development and Implementation Standards and Conditions Section has been updated to require compliance with all applicable mitigation measures in the MMRP and additional regulatory requirements as set forth in the Project EIR. Some of these new standards include: setbacks from sensitive receptors, reductions in overall footprint of drilling areas, new screening requirements, and measures to avoid or reduce impacts to resources such as biological and cultural areas, groundwater and air quality, as specified in the amended Ordinance.

f) For all Oil and Gas Conformity Review Site Plans submitted to the County, the Applicant is required to submit a signature block and statement as part of the Application package. The signature block provides for the signatures of the Applicant and, if different, the Mineral Owner. In addition, for activities occurring on split estate lands, where the Land/Surface Owner is different from the Mineral Owner, the signature block provides for the signature of the Land/Surface Owner. For applications submitted with the required signature block and statement, the first review by the County takes place within seven business days. If the County finds the application to be incomplete and requests additional information, the second review takes place within three business days upon receipt of the requested information.

g) The new ordinance also includes a separate application processing procedure for applications on split estate lands that are lacking a signature block signed by the Land/Surface Owner. For applications submitted without the required signature block and statement, the review process will take 30 days to allow time for surface owner

consultation, with an automatic 30-day second review period. Should the applicant obtain the Land/Surface Owner's signature during either 30-day review period, the application will be processed within seven days thereafter. However, applications will not be rejected for lack of a signature by the Land/Surface Owner.

h) A new fee structure has been included to ensure that all mitigation is complied with and that the County will be sufficiently staffed to review all new applications and enforce the requirements.

i) Other Sections of the Zoning Ordinance have been updated to ensure consistency with the new requirements in the MMRP and the Project EIR. These Sections include: 19.08 – Interpretations and General Standards, 19.48 – Drilling Island (DI) District, 19.50 – Floodplain Primary District, 19.66 – Petroleum Extraction (PE) Combining District, 19.81 - Outdoor Lighting (Dark Skies Ordinance), 19.88 – Hillside Development, 19.102 – Permit Procedures, and 19.108 – Nonconforming Uses, Structures, and Lots.

Project Oil and Gas Activities

The Project EIR conservatively assumes that over a 25 year planning horizon an average of 2,697 new producing wells per year could be drilled in the Project Area and subject to permitting under the amended and revised Ordinance. The level of well drilling in any given year may be higher or lower than this average, consistent with the variations in well drilling activities that have historically occurred due to market and other conditions. "Producing wells" refers to oil and gas, dry gas, dry hole and liquid petroleum gas wells. Each of the wells drilled may be associated with a number of other oil and gas activities. For purposes of the Project EIR, oil and gas activities have been divided into two sets of components: (1) construction activities, which may include but are not limited to geophysical surveys, access road and well pad construction, drilling, well completion and testing, distribution line construction, well re- working and workovers, well decommissioning, and well abandonment; and (2) operational activities, which may include but are not limited to geophysical monitoring, produced fluids and natural gas treatment, water management, well stimulation treatment, enhanced oil recovery activities, and water and waste gas injection via injection well.

Wells may also need to be "re-worked" during the operating life span of the well, to adjust for evolving field conditions or new technologies (e.g., well stimulation). Finally, decommissioning and abandonment involves well abandonment and plugging activities. Accordingly, while construction activities are considered separately from operational activities because of their limited duration, activities categorized as "construction" occur continually throughout exploration, development, production, and closure. Exploration, development, production, and closure involve the following short-term construction activities. At a particular site, these activities may take place in the order listed below or in a different sequence:

- Geophysical Surveys;
- Well Pad Preparation;
- Testing;
- Access Road Construction;
- Electrical Distribution Line and Substation Construction;
- Drilling;
- Well Completion;
- Construction of Oil, Gas Treatment Facilities;

- Construction of Water Treatment Facilities;
- Steam Generator Construction;
- Construction of Tankage and Containment Structures;
- Pipeline Installation;
- Construction of Sumps, Evaporation Ponds and Percolation Ponds;
- Installation of Produced Water Injection Wells;
- Construction of Fencing;
- Administrative Facility Construction;
- Well Re-Working and Workovers;
- Well Stimulation;
- Decommissioning and Abandonment; and
- Reactivation of Idle Wells.

During well operations, when oil is being produced, the following routine operations and maintenance activities may occur at well locations:

- Geophysical Monitoring;
- Treatment of Produced Water, Oil and Gas;
- Water Management;
- Enhanced Oil Recovery (EOR) Activities;
- Injection Wells (Class II Fluids);
- Sumps;
- Percolation and Evaporation Ponds;
- Vegetation Control;
- Spill Prevention, Control, and Countermeasure (SPCC) Procedures;
- Non-Hazardous Solid Waste Management;
- Well, Pipeline, Tank and Vessel Testing and Maintenance;
- Centralized Oil/Water Separation;
- Steam Generators;
- Electric Distribution Line and Substation Maintenance;
- Access Road Maintenance;
- Distribution of Crude Oil; and
- Administrative Building and Personnel Housing.

In addition to oil and gas wells, installation and operation of ancillary equipment and facilities are integral components of oil and gas exploration and production. All wells, for example, are connected by pipelines to tanks that separate oil from the other extracted liquids (primarily "produced water" from the same geologic strata as the oil or gas, along with water and additives that may be injected as steam or liquid to help extract the oil). Wells also have monitoring devices, and may have electric and telecommunication equipment, and waste gas collection lines.

"Tank farms" that include tanks for separating oil and water, and storing oil and water, typically serve several wells and vary in size and distance from wells. Produced water collected in tanks is typically re-used for further extraction purposes, stored in surface impoundments where it percolates into groundwater and/or evaporates, or disposed of by injection well. Some produced water requires treatment prior to reuse for extraction, or disposal, and some produced water is treated and reclaimed for other purposes.

Extraction technologies include injecting large volumes of water (water flooding), steam (steam flooding) or other liquids or gases into production strata, and managing the time that each well is active and idle to maximize the recovery efficiency. Additional ancillary equipment and facilities required for these enhanced recovery methods include producing steam, and pressurizing steam or water, typically through larger cogeneration plants serving the wellfields where these techniques are utilized. Personnel conducting wellfield construction, maintenance and operating activities are typically dispatched from centralized facilities (most located in Bakersfield), although some workers are staffed onsite, especially at larger oilfields.

As discussed in DEIR Chapter 3, Project Description, and DEIR Appendix F, the amount of land required for new well pad construction varies in the Project Area, primarily due to differences in the depth to formation. In general, the deepest wells are located in the Central Subarea, and the shallowest wells are located in the Eastern Subarea. The Project EIR ground disturbance impacts from new oil and gas activities in the Project Area are estimated for each Project Subarea by dividing the total observed disturbance acreage by the number of production wells in the 10 largest oil fields located in each Subarea. This methodology accounts for well pad size and ancillary disturbance variability—such as tanks, roads, and administrative facilities—that reflects construction and operational conditions in each Subarea. The observed average disturbance per production well in each Subarea was further increased to provide a conservative assessment of potential Project impacts. Under this methodology, the disturbance acreage per new production well is 2 acres in the Western Subarea, 3 acres in the Central Subarea, and 1.2 acres in the Eastern Subarea. These estimates assume that each new well would require new land disturbance for well pad construction, ancillary facilities, access, infrastructure and other construction and operational activities. The actual level of new disturbance associated with each production well would be lower in the event that, as is likely to occur in more developed oil fields, existing disturbed areas, such as existing roads, ancillary facilities, and infrastructure, are used under future conditions.

Table 3-2 summarizes the annual number of new production wells that could occur in each Tier and Subarea in the Project Area and evaluated in the Project EIR.

Table 3-2
Number of New Producing Wells per Year by Tier and Subarea

Tier	Western Subarea	Central Subarea	Eastern Subarea	Total
Tier 1	1,630	100	700	2,430
Tier 2	74	20	75	169
Tier 3	15	6	50	71
Tier 4	10	5	10	25
Tier 5	1	-	1	2
TOTAL	**1,730**	**131**	**836**	**2,697**

Source: Project DEIR, Table 4.4-70

Table 3-3 summarizes the annual acres of potential ground disturbance that the Project EIR conservatively assumes would occur in each Tier and Subarea in the Project Area based on the disturbance factors described in the Project EIR (DEIR, Appendix F) and the annual number of new production wells summarized in Table 3-2.

Table 3-3
New Disturbed Acres per Year by Tier and Subarea

Tier	Western Subarea	Central Subarea	Eastern Subarea	Total
Tier 1	3,260	300	840	4,400
Tier 2	148	60	90	298
Tier 3	30	18	60	108
Tier 4	20	15	12	47
Tier 5	2	-	1	3
TOTAL	3,460	393	1,003	4,856

Source: Project DEIR, Table 4.4-71

Project MMRP

The Kern County Board of Supervisors adopted the Project MMRP on November 9, 2015 in conjunction with the approval of the amended and revised Ordinance and the certification of the Project EIR. The MMRP established approximately 88 new mitigation requirements (several of which incorporate multiple additional measures) applicable to all oil and gas activity in the Project Area subject to the amended Ordinance. None of the mitigation measures required by the MMRP were applicable to oil and gas activity under the Kern County Zoning Code prior to the amendment of the Ordinance on November 9, 2015.

In addition to other measures, MMRP mitigation measure 4.4-16 requires, for the first time in the history of Kern County, a minimum level of compensatory mitigation for all new ground disturbance from all oil and gas activities, including within rangeland/grazing land, subject to the amended Ordinance. Unless otherwise mitigated to a comparable or greater level under agreements with other state or federal resource agencies or by other means as set forth in the MMRP, all new ground disturbance in all Project Area Tiers must be mitigated at a 1.0 to 1.0 ratio (one-acre of new disturbance requires one-acre of mitigation) except in Tier 1 areas that contain existing oil and gas activity disturbance of 70% or more, which must be mitigated at a 1.0 to 0.5 ratio (one-acre of new disturbance requires one-half acre of mitigation).

The MMRP is included in Appendix A of this DSEIR.

3.4 Project Objectives

The County has defined the following objectives for the Project:

- Update the County's Zoning Ordinance to include additional procedures and compliance standards that address changes in laws and regulations by other agencies, and technological advancements within the oil and gas industry, for the purpose of reducing or eliminating potential significant adverse environmental impacts, to the extent feasible, of future oil and gas activities and, thereby, ensure that current County ordinances reflect the County's interest in protecting the health, safety and general welfare of residents and visitors.
- Encourage ongoing economic development by the oil and gas industry that creates quality, high paying jobs and promotes capital investment in Kern County, which enables

the County to invest in capital improvement projects and social programs, which benefit County residents, retail businesses, and capital industries, which ensures the County's fiscal stability.

- Continue Kern County's ongoing commitment to consult and cooperate with federal, state, regional, and local agencies by periodically reviewing adopted regulations to ensure the long-term viability of Kern County's resources.
- Continue to improve and streamline current energy regulations and increase County monitoring and involvement in state and federal energy legislation.
- Protect areas of important mineral, petroleum, and agricultural resource potential for future use by promoting sustainability and encouraging Best Management Practices (BMPs), which are mutually beneficial, through strategic short and long range planning.
- Ensure the protection of environmental resources by emphasizing the conservation of productive agricultural lands, the encouragement of planned urban growth, the promotion of clean air strategies to address existing air quality issues, and the promotion of long-term water conservation strategies which will ensure the quality and adequacy of surface and groundwater supplies for future growth of all of Kern County's industries.
- Contain new development within an area large enough to meet generous projections of foreseeable need but in locations that will not impair the economic strength derived from residential developments, agriculture, rangeland, mineral resources, or diminish the other amenities that exist in Kern County.

The Project Proponents have defined the following objectives for the Project:

- Create an effective regulatory and permitting process for oil and gas exploration and production that can be relied on by the County of Kern, as well as the DOGGR and other responsible agencies.
- Achieve an efficient and streamlined environmental review and permitting process for all oil and gas operations covered by the proposed Project.
- Provide for economically feasible and environmentally responsible growth of the Kern County oil and gas industry.
- Develop industry-wide best practices, performance standards, and mitigation measures that ensure adequate protection of public health and safety and the environment.
- Increase oil and gas exploration and production in Kern County as a means of reducing California's dependence upon foreign sources of energy.
- Increase oil and gas exploration and production in Kern County as a means of increasing employment opportunities and economic prosperity for Kern County's residents, businesses, and local government.

3.5 Cumulative Projects

CEQA requires that an EIR evaluate a project's cumulative impacts. Cumulative impacts are the project's impacts combined with the impacts of other related past, present, and reasonably foreseeable future projects. As set forth in the CEQA Guidelines, the discussion of cumulative impacts must reflect the severity of the impacts, as well as the likelihood of their occurrence; however, the discussion need not be as detailed as the discussion of environmental impacts attributable to the project alone. As stated in CEQA, Public Resources Code, Section 21083(b) (2), "a project may have a significant effect on the environment if the possible effects of a project are individually limited but cumulatively considerable."

According to Section 15355 of CEQA Guidelines:

Cumulative impacts refer to two or more individual effects, which, when considered together, are considerable and which compound or increase other environmental impacts.

(a) The individual effects may be changes resulting from a single project or a number of separate projects.

(b) The cumulative impact from several projects is the change in the environment, which results from the incremental impact of the project when added to other closely related past, present, and reasonable foreseeable probable future projects. Cumulative impacts can result from individually minor but collectively significant projects taking place over a period of time (CCR, Title 14, Division 6, Chapter 3, §15355).

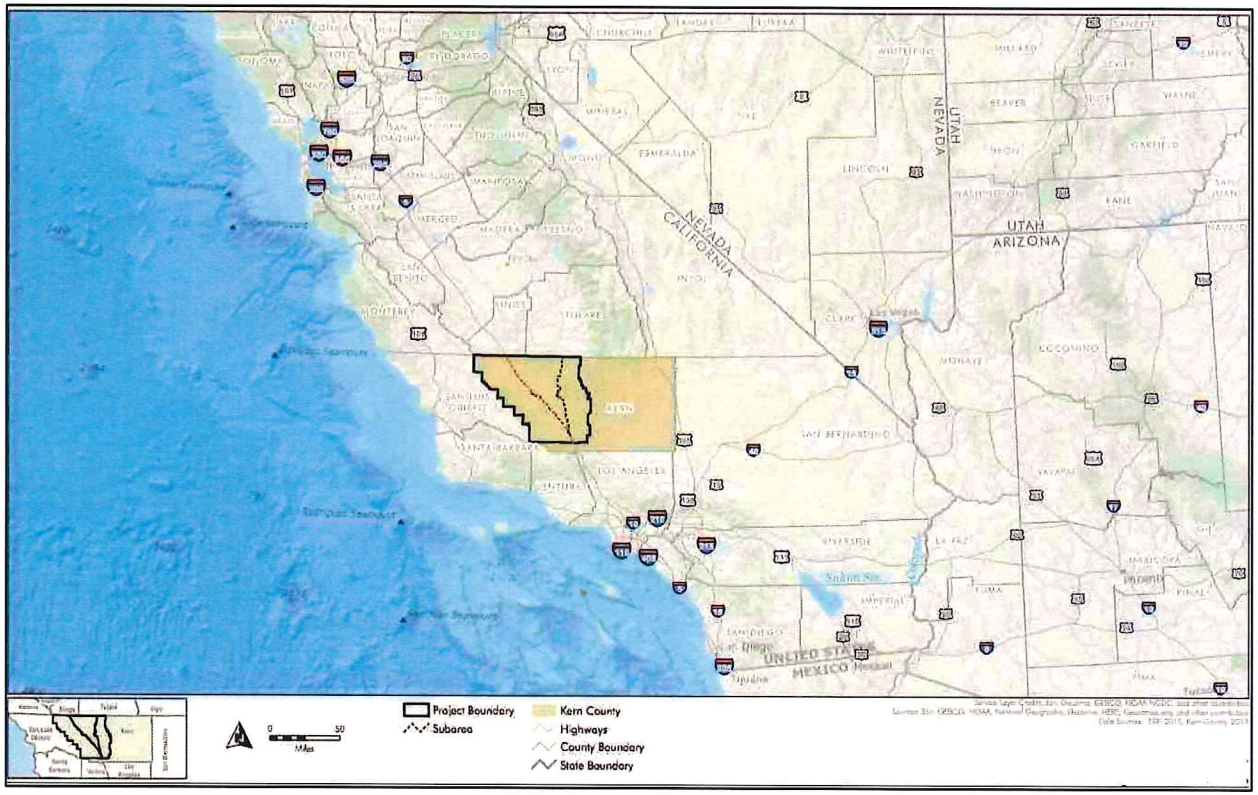
In addition, as stated in CEQA Guidelines, it should be noted that:

> The mere existence of significant cumulative impacts caused by other projects alone shall not constitute substantial evidence that the proposed project's incremental effects are cumulatively considerable (CCR, Title 14, Division 6, Chapter 3, Section 15064[h][4]). "Cumulatively considerable" means that the incremental effects of an individual project are significant when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects.

The cumulative impact discussion in this DSEIR is provided at the end of the technical analysis contained within Chapter 4, under "Impacts and Mitigation Measures." As set forth in the CEQA Guidelines, related projects consist of "closely related past, present, and reasonable foreseeable probable future projects that would likely result in similar impacts and are located in the same geographic area" (CCR, Title 14, Division 6, Chapter 3, Section 15355).

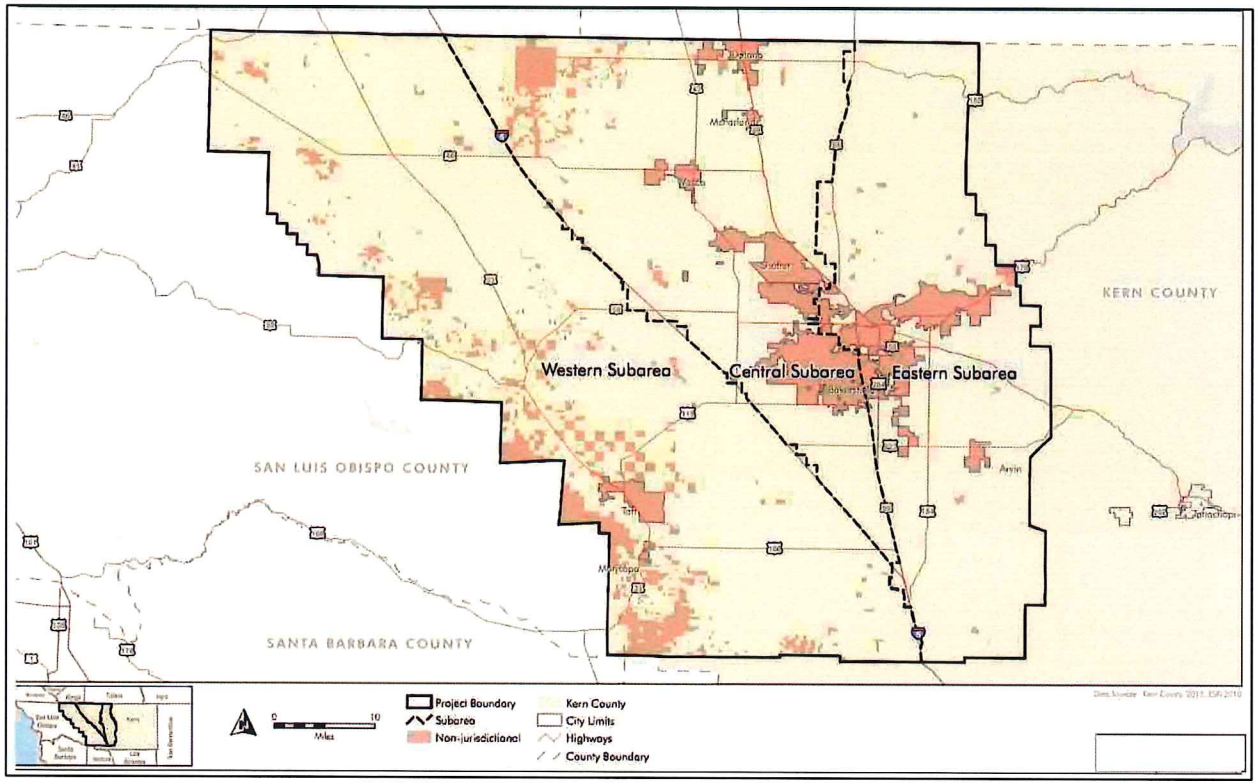
An adequate discussion of significant cumulative impacts must include either a list of past, present, and probable future projects producing related or cumulative effects, or a summary of projections from an adopted local, regional, or statewide plan, related planning document, or related environmental document that describes conditions contributing to the cumulative effect (CEQA Guidelines Section 15130(b)(1)). This cumulative analysis in the Project EIR uses the plan/projection approach as the Project EIR, and includes both the Kern County General Plan and the regional growth plan and projections included in the Kern Council of Government Regional Transportation Plan/Sustainable Communities Strategy approved in 2014. This SEIR is based on the same cumulative project criteria used in the EIR where applicable. As discussed in Chapter 2, Documents Incorporated by Reference, this DSEIR incorporates by reference the cumulative impact considerations in the Project EIR and related documents certified by the Kern County Board of Supervisors on November 9, 2015.

Figure 3-1
Project Area Regional Location



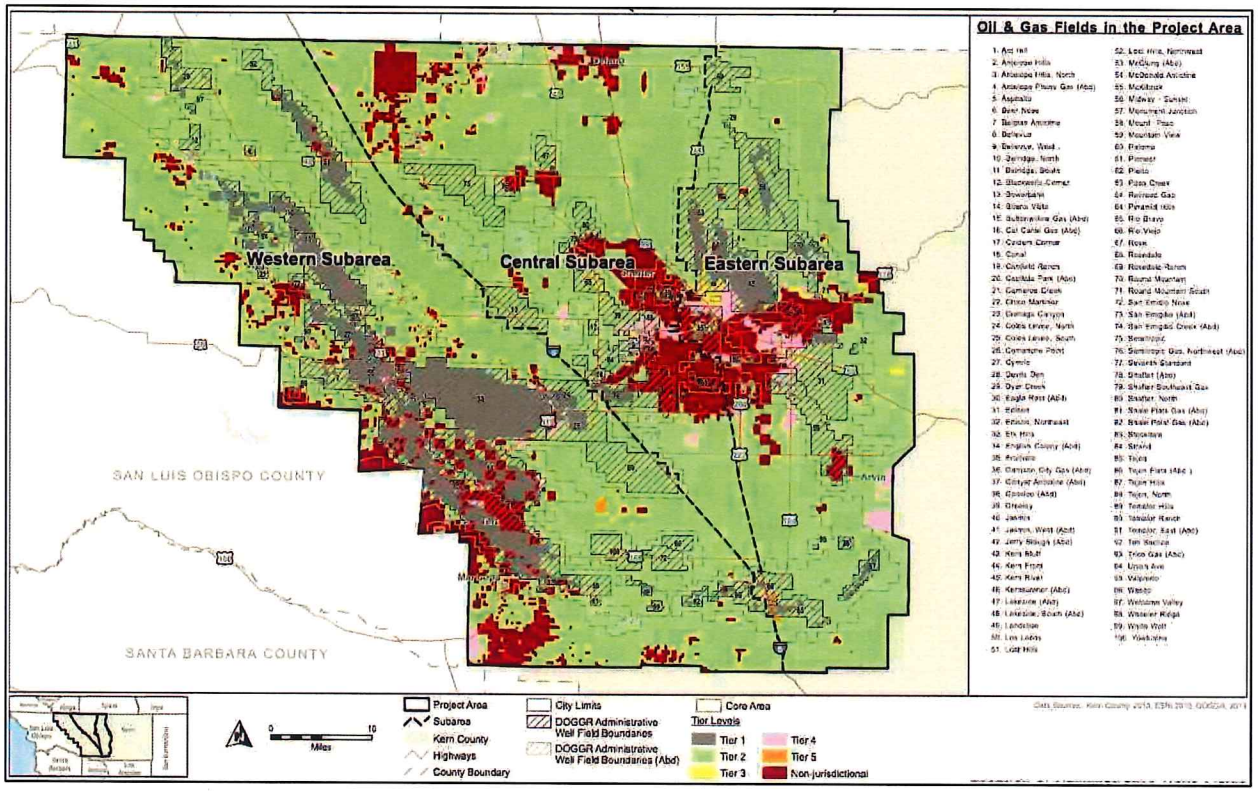
Source: Project EIR, Figure 3-2

Figure 3-2
Project Subareas



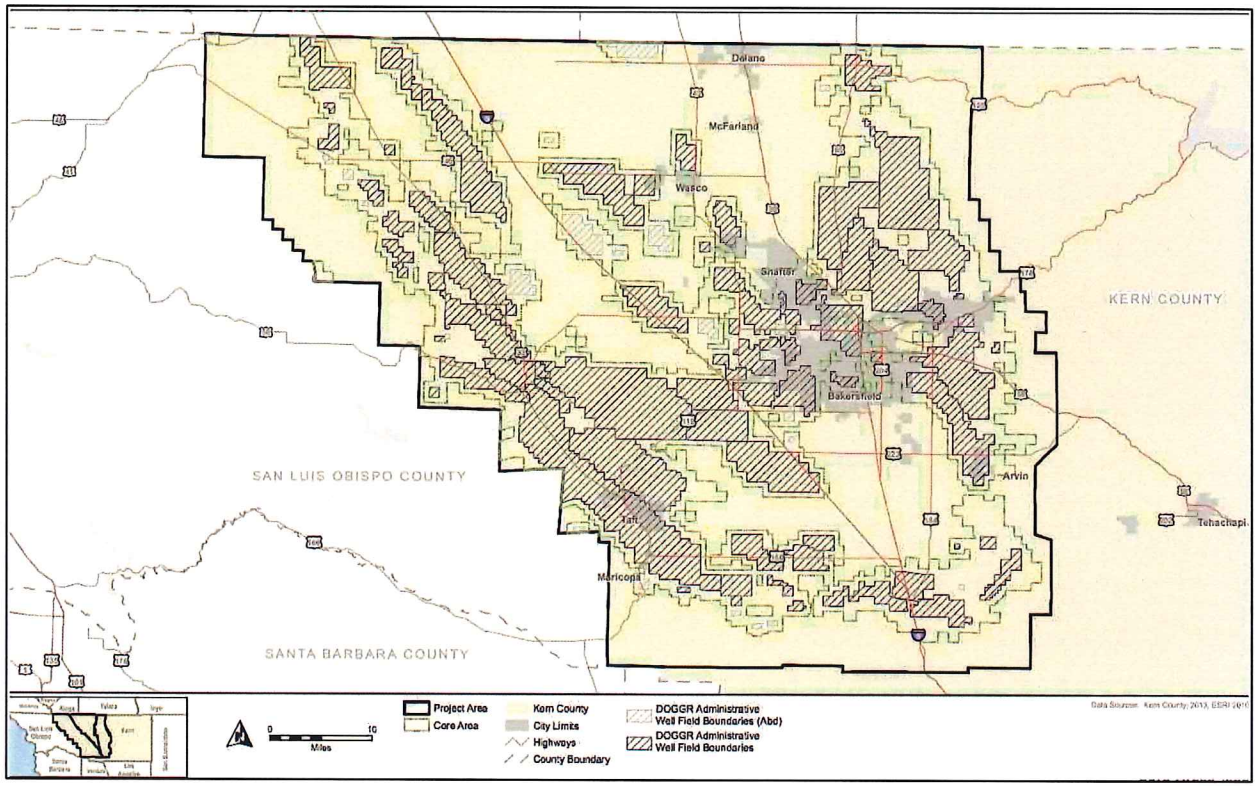
Source: Project EIR, Figure 3-1

Figure 3-3
Administrative Oilfields in the Project Area by Subarea and Oilfield Status (active or abandoned)



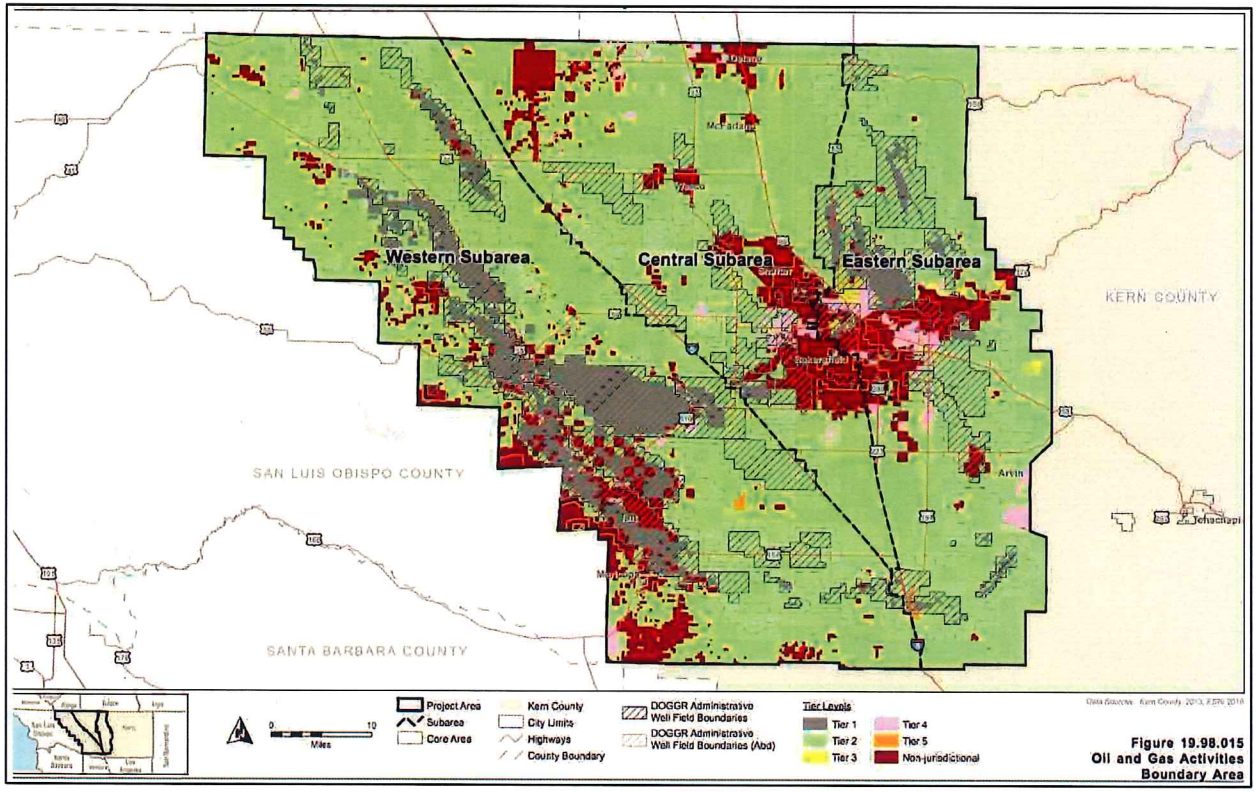
Source: Project EIR, Figure 3-3

Figure 3-4
Oil and Gas Core Area Locations



Source: Project EIR, Figure 3-5

Figure 3-5
Oil and Gas Activity Tiers 1-5 Locations
Figure 19.98.015 of the Kern County Zoning Ordinance



Source: Kern County Zoning Code Figure 19.98.015.

Chapter 4
Rangeland/Grazing Land

4.1 Introduction

As discussed in Section 1.4, the April 18, 2018 Judgment and writ of mandate issued by the Court directs the County to "prepare such analysis as is necessary to address the EIR's deficient analysis of the Project's (i) environmental impacts to rangeland/grazing land, and (ii) environmental impacts from road paving as an air emissions mitigation measure ("Supplemental Analysis")." (see Appendix B). Road paving is not authorized by the Project EIR, the revised and amended Ordinance for oil and gas activities, and the MMRP, and the Kern County Natural Resources and Planning Department will recommend that the Kern County Board of Supervisors adopt a resolution clarifying that road paving will not be accepted as an offset for air quality mitigation for activities subject to the Ordinance without additional, full and complete CEQA review and approval.

The certified EIR provides a comprehensive analysis of potential impacts to biological resources, including biological resources located within all rangeland/grazing land located in each Project Tier and Project Subarea, based on the land disturbance factors discussed in Chapter 3, Project Description, of the Project EIR and this DSEIR. The land disturbance factors were also used to evaluate potential impacts to Important Farmland mapped by the California Department of Conservation Farmland Mapping and Monitoring Program (FMMP) in accordance with Appendix G of the CEQA Guidelines.[2] All of these farmlands are located in Tier 2 of each Project Subarea as defined in Kern County Zoning Ordinance Section 19.98.030(B). Finally, the Project EIR evaluates impacts related to hazards and hazardous materials, ground and surface water quality impacts, light and noise, as well as each of the other topics set forth in Appendix G of the CEQA Guidelines applicable to all portions of the Project Area, including rangeland/grazing land in each Tier and Project Subarea. The April 18, 2018 Judgment and writ of mandate upheld all of these portions of the certified EIR, and did not vacate any portion of the Ordinance or the certified EIR.

In contrast to agricultural resources, such as prime farmland or timberlands, Appendix G of the CEQA Guidelines does not discuss or include a threshold for evaluating potential impacts to rangeland/grazing land. Kern County has not adopted a CEQA threshold for impacts to rangeland/grazing land. Consequently, the Project EIR did not specifically and separately evaluate the significance of potential impacts to rangeland/grazing land resources within each Tier and Project subarea based on the land disturbance factors used to evaluate other topical areas in the Project EIR. The purpose of this DSEIR is to address the deficient analysis of potential impacts to rangeland/grazing land as required by the April 18, 2018 Judgment and writ of mandate.

The following sections:

(a) provide additional information about the environmental and regulatory setting of grazing/rangeland resources in the Project Area;

[2] "Important Farmland," as determined by the Department of Conservation, includes Prime Farmland, Farmland of Statewide Importance, Unique Farmland, and Confined Animal Agriculture, which occur in the Project Area and were evaluated in the Project EIR. DEIR pages 4.2-15 *et seq.*

(b) provide a supplemental analysis of potential impacts to rangeland/grazing land by Tier and Project Subarea based on the land disturbance methodology used in the Project EIR;

(c) develop a threshold for evaluating the significance of potential rangeland/grazing land impacts and complete the supplemental analysis of same;

(d) evaluate the significance of potential Project and cumulative impacts to rangeland/grazing land; and

(e) consider the need for mitigation for any impacts found to be significant.

4.2 Environmental Setting

This section provides information about the extent and characteristics of rangeland/grazing land, the nature and history of grazing land uses, and trends in grazing activity in California and Kern County.

4.2.1 Rangeland/Grazing Land in California

The California Forest and Rangeland Resources Assessment and Policy Act of 1977, California Public Resources Code Section 4789.2(i), defines "rangeland" as "land on which the existing vegetation, whether growing naturally or through management, is suitable for grazing or browsing of domestic livestock for at least a portion of the year. Rangeland includes any natural grasslands, savannas, shrublands (including chaparral), deserts, wetlands, and woodlands (including Eastside ponderosa pine, pinyon, juniper, and oak) which support a vegetative cover of native grasses, grass-like plants, forbs, shrubs, or naturalized species." The California Department of Conservation FMMP biennially maps agricultural and other land use acreage within the state in accordance with California Government Code Section 65570. The FMMP mapping categories include "grazing land," which is defined as "[l]and on which the existing vegetation is suited to the grazing of livestock. This category is used only in California and was developed in cooperation with the California Cattlemen's Association, University of California Cooperative Extension, and other groups interested in the extent of grazing activities." FMMP 2015.

The California Department of Forestry and Fire Protection, Fire and Resource Assessment Program (FRAP) produces periodic assessments of California's forest and rangeland resources in accordance with California Public Resources Code Section 4789 and, since 2008, additional requirements added by federal agricultural law. The most recently published FRAP assessment was published in 2010 and indicates that California rangelands, as defined in PRC Section 4789.2(i), make up approximately 57 percent of all California land. According to the 2010 assessment, approximately 34 million acres (34 percent) of California is actively grazed, primarily on private lands. FRAP 2010. The FMMP survey coverage currently includes about 49.1 million acres of California. An estimated 19,228,787 acres of the survey area were classified as grazing land during the 2010-2012 mapping cycle. FMMP 2015.

The 2010 FRAP assessment suggests that, over the period 1986-2000, an average of about 15,500 acres per year of rangeland formerly used for grazing stock may have been converted to other uses statewide. FRAP 2010. Compared to the FRAP assessment, the FMMP survey estimates show that about 321,523 acres of grazing land and 1.173 million acres of Important Farmland were converted within the FMMP survey area from 1984 to 2014. Since 2006, however, the FMMP shows that grazing land increased by more 100,000 acres in the program survey area continued to occur.

FMMP 2018a. The increased amount of grazing land documented by the FMMP since 2006 appears to be largely due to the reclassification of formerly irrigated farmland to grazing land after the farmland was determined to be fallow for three consecutive 2-year survey cycles. The expansion of grazing land acreage in the FMMP survey data was particularly notable in the southern San Joaquin Valley, including Kern County, which is discussed in more detail below. FMMP 2015.

The average quality of California grazing lands varies substantially in accordance with rainfall, soils, temperatures and elevation among other factors. As reported in the 2010 FRAP assessment, and shown in Figure 4-1, grazing land within the Project Area is almost all of medium forage quality (average production of about 801 to 1,400 pounds per acre per year). FRAP 2010. DSEIR Appendix E, which summarizes rangeland/grazing land conditions in the Project Area, the also concludes that the non-native dominated annual grasslands in the Project Area have lower forage value. The state's high quality foraging land is generally located in cooler, wetter coastal regions extending from Santa Barbara County to Marin County, and along the elevated areas that fringe the Central Valley to the north of Kern, Kings and Tulare counties (see Figure 4-1).

In recent years, the FMMP has documented that grazing land acreage appears to be declining in higher quality foraging locations while remaining stable or increasing in the southern San Joaquin Valley. From 2010-2012, for example, the FMMP survey data show that Kern and Kings counties gained over 40,000 acres of grazing land meeting the program's definition for livestock use. In contrast, the 2010-2012 FMMP survey documented that grazing land acreage declined in Contra Costa, Alameda, Marin, Madera, Merced, Monterey, Sacramento, San Joaquin, Santa Barbara, Santa Cruz, Sonoma and Stanislaus counties. FMMP 2015.

4.2.2 Rangeland/Grazing Uses in California

Livestock grazing has occurred in California since at least the Spanish colonial period, when European animals and grasses were introduced to the region. Though the Spanish did not extend livestock management into the Central Valley, Native Americans drove domestic livestock into the valley and, by 1819, were breeding their own stock in growing herds. Barry 2006. Grazing activity rose significantly in response to the gold rush and California statehood in 1850, which led to rapid population increases and substantial growth in demand for food, including meat. The number of cattle quadrupled and sheep rose by 60 times in 1850-1860 alone, with the number of cattle peaking at 3 million in 1862. Praplan 2018. Livestock herds were decimated, however, by the state's historically worst flooding event in 1862, which created a 300 square mile lake in the Central Valley and forced the state legislature to abandon Sacramento for 18 months. The flood was followed immediately by a major drought, and ranching operations began to consolidate as struggling operators sold their herds and land to wealthier investors. Burcham 1981.

A notable consequence of the rapid livestock expansion and subsequent flood- and drought-induced contraction of livestock in the state was the almost complete replacement of native perennial grasslands and related native vegetation by non-native, largely Mediterranean annual grasses. As summarized by a leading California rangeland historian, "Few places on earth, if any, have had such rapid, large scale replacement of native herbaceous vegetation by alien plants within so short a time. To a large degree it was accomplished within the 20 years between 1845 and 1865." Burcham 1981. According to the Livestock Advisor and Director of Santa Clara County for the University of California Cooperative Extension, in a normal rainfall year, California's non-native annual grasses and forbs (herbaceous flowering plants) produce large amounts of biomass that, in some areas, may exceed two tons of grass per acre. Unless this biomass is reduced via fire, grazing and/or mowing, it accumulates year after year until it decays. In addition to enhanced fire risks,

non-native annuals can produce a thick layer of thatch or mulch that eliminates growing space for native plants and habitat for some native animals. O'Connor 2017.

An analysis of the non-native vegetative cover in Project Area rangeland/grazing land is attached as Appendix E to this DSEIR. The analysis shows that Project Area rangeland/grazing land is dominated by non-native grasses with comparatively low foraging value. Atmospheric nitrogen deposition rates in the Project Area are also among the highest in the state. The increased vegetation cover associated with the non-native annual vegetation and high atmospheric nitrogen deposition potentially degrades the suitability of natural habitats utilized by special status species, including the blunt-nosed leopard lizard and some kangaroo rat species. Many of the ground-dwelling special status species in the Project Area require bare ground or shorter vegetation heights typical of pre-European shrub-dominated vegetation types.

Grazing in California continued to develop and compete with agricultural expansion in the state, starting in the late 1800s as wheat was planted on a widespread basis, and with land for urban development, particularly after World War II. As shown in Figure 4-2, sheep production has substantially declined since the 1940s, when more than 2 million breeding ewes[3] were in the state, to just over 250,000 by 2010. Rising labor costs, foreign competition, regulatory constraints, and a significant reduction in demand for lamb meat throughout the country contributed to the decline. FRAP 2010. In 2005, the U.S. Department of Agriculture implemented a lamb replacement and retention payment program in an effort to arrest the industry's decline, but dry conditions in many states did not allow operators to sustain larger flocks over time. The domestic industry in the country, and in California, has continued to decline, and imports have expanded to meet much of current U.S. demand. Praplan 2018.

As shown in Figure 4-2, as measured by breeding animals, cattle operations in the state have been more stable than sheep ranching, and the number of breeding cows for milk and dairy production (dairy cows) has significantly increased.[4] Statewide inventories of beef cows have fallen from high levels in the 1980s but remain above the levels in the state prior to the early 1950s.

The cattle industry in California has primarily consisted of cow-calf and stocker operations. Cow-calf ranches typically maintain a breeding herd of cows, replacement heifers (young cows), and bulls. The breeding herd produces calves, which are generally sold after weaning. Some of the calves may be retained to replenish or increase the breeding herd. Cow-calf cattle graze on vegetation produced in the state's annual rangelands and are typically not confined or housed in feedlots. Stocker operations raise weaned heifer or steer calves or yearlings on rangeland or other roughage. Generally, stocker cattle are purchased from other ranches, or out of state producers, following weaning in the fall and are wintered on low quality feed until new forage develops in the spring. Stocker cattle are normally marketed or transported to feedlots at the end of the grazing season. Stull 2007. The reduction in beef cattle operations indicated in Figure 4-2 has been attributed to several factors, including declining profit margins in the state, increased import competition, lack of ranch operator generational succession, regulatory costs, the concentration of meat preparation and packing operations in out of state locations, the withdrawal or limitation of grazing rights on public land, the expansion of environmental preserves that prohibit or limit

[3] Female sheep one year and older are categorized as "breeding ewes" in U.S. Department of Agriculture (USDA), National Statistics Service surveys which provide the data reported in FRAP 2010; see http://usda.mannlib.cornell.edu/usda/current/SheeGoat/SheeGoat-01-31-2018.pdf.

[4] Cows that have produced calves are categorized as "breeding cows" in USDA National Statistics Service surveys; see http://usda.mannlib.cornell.edu/usda/current/Catt/Catt-07-20-2018.pdf.

grazing, and the transition from forage to higher value perennial tree or grape crops in the state which increases supplemental feed costs for in-state cattle producers. FRASC 2014; FRAP 2010; Anderson 2002.

As shown in Figure 4-2, dairy operations in California have substantially expanded, mainly through the growth of larger dairy operations in the San Joaquin Valley, including Kern County. Most dairies manage milk-producing cows on feedlots, and few forage on rangelands in the state. Since milk cows must give birth to produce milk, however, in-state dairies produce calves that are sold for beef production, including calves that may forage on local rangelands to gain weight prior to market. Female dairy calves also may be grazed on state rangelands to maintain a local supply of heifers for milk cow replacements. Due the intermingling of dairy (particularly Holstein) cattle with beef cattle specifically bred for meat production, some observers indicate that California beef tends to be leaner than in other states. Stull 2007.

4.2.3 Rangeland/Grazing Land in Kern County

FMMP data for Kern County show that, in contrast with the state as a whole, the acreage of land that meets the program's definition of "grazing land" has increased in the County since the mid 1980s. The FMMP provides Kern County grazing land acreage estimates for the periods 1988-2004 and 2004-2016. As shown in Table 4-1, the data indicate that grazing land in the County increased by about 59,000 acres from 1988 to 2004, and by about 58,000 acres from 2004 to 2016.

Table 4-1
Kern County Acreage Mapped as Grazing Land in FMMP Biennial Surveys
1988-2004 and 2004-2016

1988	2004	Net change
1,729,857	1,789,054	59,197
2004	**2016**	**Net change**
1,791,467	1,849,266	57,799

Source: FMMP 2018b.
Since data is separately reported by the FMMP for 1988-2004 and 2004-2016, reported amounts for 2004 differ slightly in each data series. Both series are based on 100% County survey coverage and indicate that from 1988-2016 FMMP mapped grazing land in the County increased by over 100,000 acres (e.g., 119,000 acres).

Table 4-2 summarizes the 1987 and 2012 cattle inventory estimates published by the United States Department of Agriculture, National Agricultural Statistics Service (NASS) for Kern County in conjunction with the 5-year national agricultural census conducted in each of these years. The census data are based on surveys completed and returned to NASS during each census period. For reference, Table 4-2 also includes the cattle inventory estimates for California in the 1987 census and the 2012 census. As discussed in the Project EIR, 2012 is the baseline year for the Project's CEQA analysis, as it was the last year for which complete data on oil and gas activities were available from relevant regulatory agencies at the time that the environmental analysis for this EIR commenced. Project EIR, pp. 2-21 – 2-23. 1987 is 25 years prior to the 2012 baseline year.

Table 4-2
Kern County and California Cattle Inventory, First of January
1987 and 2012 NASS Census of Agriculture
Number of Head[5]

	2012 Census	1987 Census
Kern County		
Beef Cows	30,427	50,020
Milk cows	130,828	20,392
Other cattle (steers, heifers, bulls and calves)	181,128	141,891
Total Cattle	342,383	212,303
California		
Beef Cows	583,594	906,006
Milk cows	1,815,655	1,070,366
Other cattle (steers, heifers, bulls and calves)	2,971,282	2,594,295
Total Cattle	5,370,531	4,570,667
Kern County, percent of State		
Beef Cows	5.2%	5.5%
Milk cows	7.2%	1.9%
Other cattle (steers, heifers, bulls and calves)	6.1%	5.5%
Total Cattle	6.4%	4.6%

Sources: NASS 1987; NASS 2012.

Figure 4-3 shows the total number beef cows, milk cows and other cattle in Kern County in the 1987 and 2012 NASS census reports.

The census data show that, with the exception of beef cows, the number of cattle in Kern County, and the share of total California cattle in the County, increased from 1987 to 2012. The number of milk cows in the County rose by over 110,000 head, and the number of steers, heifers, bulls and calves in the County rose by nearly 40,000 head. The County accounted for 4.6% of the state's total cattle inventory in the 1987 census, and 6.4% of the state's inventory in the 2012 census.

Table 4-3 summarizes the 1987 census and 2012 census sheep inventory estimates published by NASS for Kern County. For reference, Table 4-3 also includes the sheep inventory estimates for California.

[5] Numbers differ from those for breeding cows from FRAP 2010 (shown in Fig. 4-2) because the NASS census is not limited to breeding cows.

Table 4-3
Kern County and California Sheep Inventory, First of January 1987 and 2012 NASS Census of Agriculture

	2012 Census	1987 Census
Kern County		
Sheep	114,571	174,996
California		
Sheep	596,163	979,506
Kern County, percent of State		
Sheep	19.2%	17.9%

Sources: NASS 1987; NASS 2012.

The census data show that, consistent with the trends identified in Figure 4-2, sheep ranching in California and Kern County continued to decline from the peak activity levels in the 1940s. However, the decline in the inventory of sheep was smaller in the County (-54%) than statewide (-64%) between the 1987 census and 2012 census. The percentage of the total California sheep inventory in Kern County increased to over 19% in 2012 from just under 18% in the 1987 census.

Sheep and cattle grazing have historically accounted for almost all of the value of grazing activity in Kern County. In 1987, 92% of the total value, or gross revenue reported for livestock in the County was from sheep and cattle operations, of which 57% was related to cattle. In 2012, as the sheep industry declined nationally, in the state and in Kern County, sheep and cattle operations accounted for 99.8% of livestock revenue in the County, and cattle accounted for 97% of the total. Kern County Crop Report 1987; Kern County Crop Report 2012.

4.2.4 Rangeland/Grazing Land Use and Oil and Gas Operations in Kern County

As shown in Table 4.2-5 of the Project DEIR, approximately 982,166 acres of the Project Area in 2012 consists of grazing land as defined by the mapping criteria used by the FMMP. The FMMP GIS files for the Project EIR base year of 2012 were obtained by Kern County GIS specialists in the Planning and Natural Resources Department and used to tabulate and map FMMP grazing land in the Project Area. Table 4-4 summarizes the mapped grazing land in 2012 acreage by Tier and Project Subarea.

Table 4-4
FMMP Grazing Land Acreage in Project Area by Tier and Subarea
2012

Tier	Western Subarea	Central Subarea	Eastern Subarea	Total
Tier 1	65,846	1,064	16,267	83,177
Tier 2	481,760	44,620	296,838	823,218
Tier 3	544	482	3,211	4,237
Tier 4	3,037	771	5,127	8,935
Tier 5	697	-	378	1,075
Non-jurisdictional and "Other" Land	33,507	11,638	16,379	61,524
TOTAL	585,392	58,576	338,198	982,166

Sources: Compiled from FMMP GIS data for 2012.

Figure 4-4 shows the locations of FMMP grazing land in the Project Area by Tier and Subarea. Approximately 6% (61,524 acres) of the total mapped grazing land is in non-jurisdictional (including "other" land) portions of the Project Area that are not subject to the amended Ordinance. Approximately 91% (831,391 acres) of grazing land is located in Tiers 2-5. As shown in Table 3-3, based on the conservative disturbance factors used in the Project EIR, about 9% of total potential land disturbance related to oil and gas activity subject to the Ordinance will occur in Tiers 2-5 of the Project Area. Approximately 8% (83,177 acres) of the mapped grazing land in the Project Area is located in Tier 1. As shown in Table 3-3, approximately 91% of the total potential land disturbance related to oil and gas activity subject to the Ordinance will occur in Tier 1 of the Project Area.

At the request of the County, WSPA, a Project Proponent, obtained information on acres leased and leasing terms for livestock grazing by oil and gas operators. A memorandum summarizing this information is included as Appendix F of this DSEIR. The memorandum reviews the acres leased for livestock grazing for a total of nine oil and gas operators. Seven of the operators lease a total of 108,090 acres in Kern County for grazing and include the County's three largest oil and gas operators by volume of annual production. Two respondents did not lease land for grazing. The average number of acres leased by the seven operators that lease grazing land is 15,441 acres and the amount of leased land per operator ranges from 640 to 37,000 acres.

Five oil and gas operators provided sample grazing leases to identify typical lease provisions. As summarized by WSPA, the leases typically include the following provisions:

(a) Parties to the lease.
(b) Leased land description.
(c) Lease term.
(d) Lease rent.
(e) Requirements that the grazing lessee will maintain the leased premises, including fences, water tanks and other improvements, in good condition.
(f) Specified improvements that grazing lessees may construct, such as fences, or construct with lessor approval.
(g) Requirements that the grazing lessee will remove improvements at lease termination, unless lessor consents to the improvements remaining.
(h) Requirements that grazing lessee provide water for livestock.

(i) Requirements that grazing lessee will take reasonable steps to control erosion, fire hazards and weeds. Some but not all leases require compliance with U.S. Department of Interior, Bureau of Land Management's Central California Standards for Rangeland Health and Guidelines for Livestock Grazing Management (see Section 4.3 of this DSEIR).
(j) Retention by the lessor of rights of access and rights to explore, drill and produce minerals, construct roads, pipelines and other oil and gas related improvements.
(k) Insurance and indemnity provisions.
(l) Procedural provisions including assignment, notice, governing law, etc.

Livestock grazing is also employed as a land management technique on acreage set aside for habitat conservation purposes. No oil and gas production takes place on acreage where production is excluded by the terms of habitat conservation easements. Certain operators contract with goat herd managers to control invasive weeds on their lands. As discussed above, livestock grazing other than by cattle and sheep represents a statistically negligible share of the total livestock value reported in annual Kern County crop reports.

Table 4-4 shows that about 94% of the grazing land in the Project Area is located in the Eastern Subarea (338,198 acres) and the Western Subarea (585,392 acres), with approximately 6% in the Central Subarea (58,576 acres). Grazing lands in the Eastern and Western Subareas support annual, mainly non-native forage consumed by livestock in the foothills fringing the valley. Table 3-1 shows that 98.5% of all oil and gas Tier 1 areas--which contain the most intensively developed existing oil and gas operations in the Project Area, and comprise the locations where 91% of all future development subject to the Ordinance is expected to occur--are in the Western Subarea (163,227 acres) and the Eastern Subarea (40,518). Figure 4-4 shows the vast majority of Tier 1 areas lie within the Western and Eastern Subareas. Figure 4-5 and Figure 4-6 shows that a similar proportion of grazing land is located in Tier 1 areas within those regions. Consequently, the most intensive livestock grazing and oil and gas activities have occurred in the same portions of the Project Area for decades.

There are published reports of impacts to grazing livestock from exposure to oil well stimulation constituents and related oil and gas activities in other states. DeDonder 2015. A search of publicly available records in July 2018, however, did not identify any lawsuits, legal claims, news reports or studies suggesting that exposure to oil and gas activities has ever caused harm to livestock in Kern County. The record search also did not identify any lawsuits, claims, news reports or studies indicating that livestock operations in the County have been adversely affected by split-estate landholdings. Thus, livestock grazing has not resulted in the kinds of land use conflicts that have occurred between irrigated agriculture and oil and gas operations, which were discussed in the Project EIR and addressed in the Ordinance. For example, as discussed in the Project EIR, lawsuits by orchard growers have been filed against certain oil and gas operators in the past based on assertions that oil and gas operations contaminated irrigation groundwater and harmed their trees. Damages were awarded to an orchard operator in a 2001 case, and a lawsuit filed in 2014 remains pending (see, e.g., DEIR pages 4.9-69 and 4.9-72). The Project DEIR (see, e.g., DEIR pages 3-16 to 3-17) also discussed land use conflicts between farmers and oil and gas operators on lands where the surface owners are different from the mineral rights holders (so-called "split-estates") The amendments and revisions to the Ordinance include a new surface owner signature process in response to this issue (see Kern County Zoning Ordinance Sections 19.98.090 and 19.98.100).

No documentation concerning livestock impacts related to oil and gas operations or split-estate controversies affecting grazing in Kern County were received by the County during the NOP comment period. The County received a single NOP comment letter from a major ranching operator in the Western Subarea. The letter stated that: (a) oil and gas development has almost no impact on

grazing in the area where the ranch operates; (b) oil and gas activity increases available grazing land because the ranch is able to use oil and gas properties that are not under production; (c) forage on most well pads begins to recover within three years of completion; and (d) any loss of grazing land from oil and gas production would be insignificant (see Appendix D).

4.3 Regulatory Setting

Federal, state and local laws and policies applicable to agricultural resources generally in the Project Area are discussed in detail in Chapter 4.2 of the Project DEIR and are incorporated by reference into this DSEIR. The following discussion provides additional regulatory setting information relevant to rangeland/grazing land.

Federal

United States Department of the Interior, Bureau of Land Management (BLM), Central California Standards and Guidelines for Livestock. In 2000, the BLM adopted new standards and guidelines applicable to grazing activities on BLM land in Central California, including BLM lands in non-jurisdictional portions of the Project Area. The guidelines are intended to promote four fundamental aspects of rangeland health potentially affected by livestock grazing practices, including ensuring that: (a) watersheds are properly functioning; (b) ecological processes are in order; (c) water quality complies with state standards; and (d) habitats of protected species are in order. As discussed above, certain oil and gas operator grazing leases incorporate and require lessees to comply with the BLM Central California Standards and Guidelines for Livestock.

State

California Department of Conservation, Division of Land Resource Protection – Farmland Mapping and Monitoring Program

The FMMP produces biennial maps of study area land uses that are contiguous with modern soil surveys developed by the US Department of Agriculture (USDA) in accordance with California Government Code Section 65570. Government Code Section 66570(b) states that "Commencing July 1, 1986, and continuing biennially thereafter, the [Department of Conservation] shall collect or acquire information on the amount of land converted to or from agricultural use, and between agricultural categories, using 1984 baseline information as updated pursuant to this section for every county for which Important Farmland Series maps exist. Commencing on December 31, 2018, and continuing biennially thereafter, the department shall report to the Legislature on the data collected pursuant to this section. In reporting, the department shall specify, by category of agricultural land, the amount of land converted to, or from, agricultural use, by county and on a statewide basis. The department shall also report on the nonagricultural uses to which these agricultural lands were converted or committed." Government Code Section 65560(b) states that: "'Category of agricultural land' means prime farmland, farmland of statewide importance, unique farmland, and farmland of local importance, as defined pursuant to the United States Department of Agriculture's land inventory and monitoring criteria, as modified for California, and grazing land. 'Grazing land' means land on which the existing vegetation, whether grown naturally or through management, is suitable for grazing or browsing of livestock." The remaining categories that are mapped by the FMMP program are used for reporting changes in land use as required for FMMP's biennial farmland conversion report.

Most public land areas, such as National Forests and BLM holdings, are not mapped. The FMMP indicates that mapping resolution for most farmland categories is 10 acres, and for grazing lands is 40 acres. In order to most accurately represent the NRCS digital soil survey, soil units of one acre or larger are depicted in Important Farmland Maps. The FMMP mapping categories state define "Grazing Land (G)" as "Land on which the existing vegetation is suited to the grazing of livestock. This category is used only in California and was developed in cooperation with the California Cattlemen's Association, University of California Cooperative Extension, and other groups interested in the extent of grazing activities." The FMMP convenes a grazing land advisory committee in each project county to help identify grazing lands. The committees consist of members of the local livestock ranching community, livestock ranching organizations, and the U. C. Cooperative Extension livestock advisor. The FMMP works with the president of the local Cattlemen's Association and the U.C. Cooperative Extension livestock advisor in selecting members of these committees. The FMMP indicates that all of Kern County is within the program's current inventory coverage. FMMP 2015.

California Forest and Rangeland Resources Assessment and Policy Act of 1977 (Public Resources Code Sections 4789 - 4789.7)

Section 4789.3 of the Forest and Rangeland Resources Assessment and Policy Act requires that the California Resources Agency prepare and submit to the State Board of Forestry and Fire Protection and the Secretary of the Resources Agency a forest and rangeland resource assessment every five years from January 1, 1987. The most recent assessment was prepared and published in 2010, and no subsequent assessment has been publicly released. FRAP 2010. Section 4789.2 (i) of the Act defines "Rangeland" as "land on which the existing vegetation, whether growing naturally or through management, is suitable for grazing or browsing of domestic livestock for at least a portion of the year. Rangeland includes any natural grasslands, savannas, shrublands (including chaparral), deserts, wetlands, and woodlands (including Eastside ponderosa pine, pinyon, juniper, and oak) which support a vegetative cover of native grasses, grasslike plants, forbs, shrubs, or naturalized species."

California Rangeland, Grazing Land, and Grassland Protection Act (Public Resources Code Sections 10330 – 10344)

The Rangeland, Grazing Land, and Grassland Protection Act was enacted in 2002 to protect California's rangeland, grazing land, and grasslands through the use of conservation easements. The Act designates the Wildlife Conservation Board as the lead agency in the state for acquiring conservation easements to protect rangeland, grazing lands, and grasslands in accordance with the criteria of the Act. The Board defines grazing land to mean "(1) a collective term for rangeland, pastureland, grazing forest land, native and naturalized pasture, hayland, and grazed cropland. Although grazing is generally a predominate use, the term is used independent of any use. (2) Land is used primarily for production of forage plants maintained or manipulated primarily through grazing management. Includes all land having plants harvestable by grazing without reference to land tenure, other land uses or management practices." The Board administers the Act by accepting applications for easements that meet certain program requirements, including the protection of the integrity of rangeland, grazing lands and grasslands.

Local

Kern County General Plan

The Kern County General Plan's Land Use Element establishes a number of land use designations, five of which fall within the "Resource" land use category. The definition of "Resource Reserve" (Map Code 8.2) includes rangeland, and livestock grazing is an allowable use in four of the five designations. The fifth designation, Mineral and Petroleum, includes Extensive and Intensive Agriculture, both categories that include livestock grazing as an allowable use.

Land Use Designation	Map Code	Definition	Uses Allowed
Intensive Agriculture	**8.1**	Areas devoted to the production of irrigated crops or having a potential for such use. Other agricultural uses, while not directly dependent on irrigation for production, may also be consistent with the intensive agriculture designation.	Irrigated cropland; orchards; vineyards; horse ranches; raising of nursery stock ornamental flowers and Christmas trees; fish farms' bee keeping' ranch and farm facilities and related uses; one single-family dwelling unit; cattle feed yards; dairies; dry land farming; **livestock grazing**; water storage; groundwater recharge acres; mineral; aggregate; and petroleum exploration and extraction; hunting clubs; wildlife preserves; farm labor housing; public utility uses; and agricultural industries pursuant to provisions of the Kern County Zoning Ordinance, and land within development areas subject to significant physical constraints.
Resource Reserve	**8.2**	Areas of mixed natural resource characteristics, such as **rangeland,** woodland, and wildlife habitat which occur within an established County water district. Minimum parcel size is 20 acres gross, except lands subject to a Williamson Act Contract/Farmland Security Zone Contract, in which case the minimum parcel size shall be 80 acres gross.	**Livestock grazing**; dry land farming; ranching facilities; wildlife and botanical preserves; and timber harvesting; one single-family dwelling unit; irrigated croplands; water storage or groundwater recharge areas; mineral; aggregate; and petroleum exploration and extraction; recreational activities, such as gun clubs and guest ranches; and land within development areas subject to significant physical constraints.
Extensive Agriculture	**8.3**	Agricultural uses involving large amounts of land with relatively low value-per-acre yields, such **as livestock grazing**, dry land farming, and woodlands. Minimum parcel size is 20 acres gross, except lands subject to a Williamson Act	**Livestock grazing**; dry land farming; ranching facilities; wildlife and botanical preserves; and timber harvesting; one single-family dwelling unit; irrigated croplands; water storage or groundwater recharge areas;

		Contract/ Farmland Security Zone Contract, in which case the minimum parcel size shall be 80 acres gross.	mineral; aggregate; and petroleum exploration and extraction; and recreational activities, such as gun clubs and guest ranches; and land within development areas subject to significant physical constraints.
Mineral and Petroleum	**8.4**	Areas which contain producing or potentially productive petroleum fields, natural gas, and geothermal resources, and mineral deposits of regional and Statewide significance. Uses are limited to activities directly associated with the resource extraction. Minimum parcel size is five acres gross.	Mineral and petroleum exploration and extraction, including aggregate extraction; **extensive and intensive agriculture**; mineral and petroleum processing (excluding petroleum refining); natural gas and geothermal resources; pipelines; power transmission facilities; communication facilities; equipment storage yards; and borrow pits.
Resource Management	**8.5**	Primarily open space lands containing important resource values, such as wildlife habitat, scenic values, or watershed recharge areas. These areas may be characterized by physical constraints, or may constitute an important watershed recharge area or wildlife habitat or may have value as a buffer between resource areas and urban areas. Other lands with this resource attribute are undeveloped, non-urban areas that do not warrant additional planning within the foreseeable future because of current population (or anticipated increase), marginal physical development, or no subdivision activity.	Recreational activities; **livestock grazing**; dry land farming; ranching facilities; wildlife and botanical preserves; and timber harvesting; one single-family dwelling unit; irrigated croplands; water storage or groundwater recharge areas; mineral; aggregate; petroleum exploration and extraction; open space and recreational uses; one single-family dwelling on legal residentially zoned lots on effective date of this General Plan; land within development areas subject to significant physical constraints; State and federal lands which have been converted to private ownership.

Kern County Ordinance Section 7.16 (Estray Ordinance).

The California Food and Agriculture Code allows the Kern County Board of Supervisors to declare certain portions of the county as being devoted chiefly to grazing. Areas so designated are generally referred to as "Open Range." Kern County established an Estray Ordinance in 1942 (Ordinance Code Section 7.16). In such areas, a person may not "take up" any estray (stray) animal found on their property nor will they have a lien against the animal unless their property is surrounded by a good and substantial fence. In areas not designated as "grazing areas," a person finding any estray animal on their property (whether fenced or not) may seize the animal and have a lien on the animal for all expenses involved in seizing, keeping, and caring for the animal. Consequently, in an "Open Range," property owners must fence animals off their property if they do not want them on their

property, while in areas not "Open Range," the animal owners must fence the animals in or run the risk of having those animals "taken up" as estray. The County has implemented a formal process for amending the estray ordinance.

4.4 Impacts and Mitigation Measures

This section analyzes potential Project impacts on rangeland/grazing land in the Project Area. The analysis evaluates the significance of the Project impacts and the need for potential mitigation measures that could be feasibly implemented to address any impact determined to be significant in accordance with CEQA.

Methodology

As discussed in Chapter 1, Introduction and Summary, the April 20, 2018 Judgment and writ of mandate issued by the Court directed the County to complete a Supplemental Analysis to address the Project EIR's deficient analysis of potential impacts to rangeland/grazing land. To fulfill the Court's mandate, this EIR provides an updated analysis incorporating the same potential land disturbance factors used to evaluate biological resources and farmland impacts in the certified EIR. The Judgment upheld analysis of all impacts considered in the certified EIR that are based on the land disturbance methodology.

As shown in Table 3-3, about 91% of the assumed new disturbance in the Project Area from oil and gas activity subject to the amended and revised Ordinance (4,400 of 4,856 acres per year) will occur in existing Tier 1 locations. Within each Project Subarea, the majority of assumed new disturbance would occur in Tier 1 locations, including 94% of all new disturbances in the Western Subarea (3,260 of 3,460 acres), 76% in the Central Subarea (300 of 393 acres), and 84% in the Eastern Subarea (840 of 1,003 acres). Assumed new disturbance within Tier 2 locations would account for 6.1% of total potential disturbance in the Project Area (298 of 4,856 acres), including 4% of all new disturbances in the Western Subarea (148 of 3,460 acres), 15% in the Central Subarea (60 of 393 acres), and 9% in the Eastern Subarea (90 of 1,003 acres). Given existing conditions, it is likely that anticipated new disturbance in the Central Subarea would occur on intensively farmed lands; however, for the purposes of impact assessment, it is conservatively assumed that new disturbance would occur in land that is not undergoing active disturbance. About 71% of all future new disturbance would occur in the Western Subarea (3,460 of 4,856 acres) compared with 21% in the Eastern Subarea (1,003 of 4,856 acres) and 8% in the Central Subarea (393 of 4,856 acres).

As discussed in the Project EIR, the potential annual disturbance levels projected in Table 3-3 are conservatively high because they have been rounded up and increased from the calculated levels of disturbance observed historically in each subarea (see DEIR Appendix F). At least some future oil and gas exploration and production activities in the Project Area are likely to utilize existing actively disturbed areas, such as existing well pads, access roads, or existing facilities, such as pipelines and tanks, As part of the site plan review process under the revised and amended Ordinance, each Applicant is required to submit a site plan to the County that identifies the existing areas of ongoing active disturbance and areas of new land disturbance that would result from proposed Project activities. As discussed above, MMRP MM 4.4-16 requires, for the first time in the history of Kern County, mandatory minimum mitigation for any new land disturbance from oil and gas activities subject to the Ordinance. The actual acreage of land subject to mandatory mitigation requirements would be verified in a completion report to be filed with the County. The primary objective of this new mandatory mitigation requirement is to encourage the avoidance of

new land disturbance, as well as the preservation of land that is not already actively disturbed, throughout the Project Area.

The projected disturbance factors also provide a highly conservative estimate of potential impacts to grazing lands in the Project Area. As discussed in more detail below, livestock are often grazed in close proximity with active oil and gas well fields. In certain well fields that were developed concurrently on land that also functions as active livestock ranching operations, cattle forage throughout the well field. Sheep, which are much more efficient grazers than cattle, graze in locations immediately proximate with operating oil and gas equipment. As reflected in comments received by a major rancher on the NOP, newly developed well pads regain vegetative forage cover within three years of completion that can become available for grazing (see Appendix D). Operators may utilize livestock grazing in proximity to wells as a means of vegetation control for the well site. Oil and gas activities may reduce or, in some densely developed well fields, preclude grazing in those areas for a period of time. However, as local oil and gas reserves are depleted and operations shift location, grazing often returns to those areas. There are numerous locations throughout the Project Area where formerly dense oilfield developments have been decommissioned and grazing lands have reemerged over large landscapes. Consequently, oil and gas areas subject to the assumed disturbance factors may be available for grazing in the short term, and over longer terms have been returned to conditions that facilitate livestock grazing. Appendix G includes photographs of cattle and sheep grazing operations on oil and gas AOFs within the Project Area.

Thresholds of Significance

Neither Appendix G of the CEQA Guidelines nor the Kern County CEQA Implementation Document and Kern County Environmental Checklist include thresholds of significance for evaluating potential impacts to grazing lands. The certified EIR provides a comprehensive discussion and evaluation of potential Project impacts to biological and agricultural resources throughout the Project Area, including all areas mapped as grazing land by the FMMP. The certified EIR also addressed each of the other topics and thresholds included in Appendix G of the CEQA Guidelines. The April 20, 2018 Judgment upheld the analysis of biological and agricultural resources and all other potential impacts in the certified EIR (see Appendix B) except for two issues. One, potential use of road paving as mitigation, is discussed above. The remaining deficiency in the EIR identified in the Judgment and writ of mandate is the evaluation of the significance of potential impacts to rangeland/grazing land.

Accordingly, to complete the Supplemental Analysis in compliance with the Judgment and writ of mandate, for the purposes of this DSEIR the Project will be considered to have a significant impact if it would substantially decrease the productivity of livestock grazing activity in Kern County.

Although the number of acres of grazing land potentially affected by the Project is analyzed and disclosed in the following section, the raw number of acres would be inadequate and misleading as a measure of significance. Grazing of non-native livestock species is an inherently economic activity. CEQA provides that, while economic effects of a project are not significant impacts on the environment, economic effects may be used to determine the significance of physical changes caused by the project. CEQA Guidelines Section 15131(b). In order to determine the significance of a physical change in grazing, data on revenues received from livestock sales and grazing livestock inventories are utilized in this DSEIR. As discussed below, the historic trend demonstrates that grazing productivity has increased in Kern County even as the number of acres utilized for grazing has decreased over time. Moreover, as noted above, the compatibility of livestock grazing in immediate proximity to oil and gas operations demonstrates that Project acres

and grazing land acres can overlap considerably without necessarily causing significant impacts and, over time, areas of densely developed well fields have been returned to conditions that facilitate livestock grazing. In addition, grazing itself may be associated with adverse environmental impacts. For example, the Center for Biological Diversity has asserted that the "ecological costs of livestock grazing exceed that of any other western land use. In the arid West, livestock grazing is the most widespread cause of species endangerment. By destroying vegetation, damaging wildlife habitats and disrupting natural processes, livestock grazing wreaks ecological havoc on riparian areas, rivers, deserts, grasslands and forests alike – causing significant harm to species and the ecosystems on which they depend." CBD 2018. Therefore, choosing a significance methodology and threshold that seeks to conserve the maximum number of grazing land acres would not be environmentally beneficial, especially where the same or greater productivity is being attained on a smaller footprint of grazing land, as demonstrated by the historic data discussed herein.

Project Impacts

Impact 4.4 1: Substantially decrease the productivity of livestock grazing activity within Kern County.

Table 4-5 summarizes the percentage of total acreage in each Tier and Project Subarea that is mapped as grazing land by the FMMP. The table excludes County non-jurisdictional and "other" land that is not subject to the Ordinance.

Table 4-5
Percentage of Total Acreage Mapped as Grazing Land by Tier and Subarea

Percent Grazing Land	Western Subarea	Central Subarea	Eastern Subarea
Tier 1	40.34%	35.44%	40.15%
Tier 2	60.19%	8.53%	63.46%
Tier 3	26.63%	17.21%	28.27%
Tier 4	56.00%	7.40%	27.54%
Tier 5	90.28%	0.00%	21.72%

Sources: DSEIR Table 3-1 and Table 4-4.

Table 4-6 summarizes the annual and 25-year total acres of impacts to grazing land that could occur by Tier and Project Subarea based on the projected disturbed acres by Tier and Subarea shown in DSEIR Table 3-3 and the incidence of mapped grazing land in each Tier and Subarea as shown in Table 4-5.

Table 4-6
Potential Annual and 25-year Grazing Land Impacts by Tier and Project Subarea

Potential Annual Grazing Land Acreage Impacts				
Tier	**Western Subarea**	**Central Subarea**	**Eastern Subarea**	**Total (sum of individual tier and subarea impacts)**
Tier 1	1,315	106	337	1,759
Tier 2	89	5	57	151
Tier 3	8	3	17	28
Tier 4	11	1	3	16
Tier 5	2	-	0	2
Total (sum of individual tier and subarea impacts)	1,425	116	415	1,956
Potential Grazing Land Acreage Impacts Over 25-Years				
Tier	**Western Subarea**	**Central Subarea**	**Eastern Subarea**	**Total (sum of individual tier and subarea impacts)**
Tier 1	32,877	2,659	8,431	43,967
Tier 2	2,227	128	1,428	3,783
Tier 3	200	77	424	701
Tier 4	280	28	83	390
Tier 5	45	-	5.4	51
Total (sum of individual tier and subarea impacts)	35,629	2,892	10,371	48,891

Sources: DSEIR Table 4-4 and Table 4-5.

Table 4-6 indicates that, using the projected disturbed acres in Table 3-3 (which are based on the conservative disturbance factors set forth in the DEIR), the Project could impact up to 1,956 acres of grazing land per year, and 48,891 acres over the 25-year Project planning horizon. About 90% of these impacts would occur in Tier 1 portions of the Project Area and 84.5% would occur in Tier 1 portions of the Western Subarea and the Eastern Subarea. For the reasons discussed above, these estimates are highly conservative, both spatially and temporally. Since livestock may graze in close proximity to oil and gas operations as described above, grazing is likely to occur on a substantial number of acres included in the Project impact totals in Table 4-6. Moreover, the totals in Table 4-6 are based on the conservative assumption that all Project impacts to grazing are permanent although, in fact, over the long term, oil and gas areas have been returned to conditions that facilitate livestock grazing.

The following sections discuss grazing activities in Tier 1 oil and gas areas in more detail.

Sheep grazing in Tier 1 locations

Sheep grazing occurs in Tier 1 locations throughout the Project Area, including the Eastern, Central and Western Subareas. Grazing activity in Tier 1 areas usually peaks from November to April when green vegetation is located at lower elevations in Kern County. Sheep operations subsequently shift to higher elevations, including to the Sierra Nevada range, as upland meadows and grasses become available after the spring thaw.

While there is variability in the size, scope and duration of sheep grazing in Tier 1 areas, a typical flock consists of about 1,800-2,000 sheep. The size of grazing sites for a flock of this size varies considerably depending on available acreage and forage quality, but would be significantly less than required for a comparable number of cattle due to the greater grazing efficiency of sheep. Flocks are transported to each site by the sheepherder and typically remain for several weeks to

two months, depending on the acreage leased. The sheepherder provides water for the flock, usually by means of an onsite water tank transported to the grazing location, and the sheepherder typically remains onsite in a trailer or recreational vehicle until grazing has been completed.

Sheep grazing in Tier 1 areas can occur in and among sites of oil operations, sometimes within 2 feet of operating oil field equipment, though typically avoiding heavily operated areas. The location of grazing flocks, and individual sheep within each flock, is effectively controlled by temporary fencing and herding animals. Once a flock has completed grazing at a specific location, the sheep are removed from the site by the sheepherder and transported to another site, including within other portions of Tier 1 areas depending on the season and whether sufficient forage is available. The sheepherder will also remove and any temporary shelter from the completed grazing site. In a typical year, and subject to annual variability due to rainfall and weather, sheep grazing will largely be completed by June within the lower portions of the Project Area, and by August in Tier 1 lands located at higher elevations.

Cattle grazing in Tier 1 locations

Cattle grazing occurs year-round in Tier 1 locations throughout the Project Area, including the Eastern, Central and Western Subareas. The number of cattle grazed varies with the supply and quality of forage at each location. Cattle are less efficient grazers and require substantially more foraging acreage than sheep. As a result, cattle are not typically moved to and managed to graze within smaller, temporarily delimited portions of Tier 1 areas for short periods of time in the manner of sheep flocks. Cattle grazing in and adjacent to Tier 1 areas typically occurs in larger areas that can be accessed by livestock during most or all of the year.

In certain instances, cattle ranching and oil and gas operations in Tier 1 areas jointly occur within the same landscape. Oil and gas operations, for example, have been developed within previously existing cattle ranches where both uses have persisted over time. As a result, in certain Tier 1 areas, cattle are free to physically graze and move in and among operating oil and gas equipment at all times of the year.

In other Tier 1 locations, cattle grazing occurs in close proximity to some of the most dense oil and gas operations in the project area, but access to the most heavily developed areas is controlled by fencing and cattle guards. Cattle grazing fence lines along the eastern flank of the Temblor Range in the western subarea, for example, extend into several major oil and gas development sites located in Tier 1 areas and come within a few feet of currently operating equipment. Similar proximity to operating oil and gas equipment occurs in other Tier 1 portions of the Project area, including the South Hopkins, Salt Creek, McKittrick, Kern Front, Wheeler Ridge and Mount Poso AOFs.

Existing oil and gas operations in certain Tier 1 locations have moved from adjacent areas that were heavily developed in prior periods. For example, portions of the Tier 1 lands located in the Elk Hills and Mount Poso AOFs were densely covered with oil and gas equipment several decades ago. These areas are currently grasslands that support forage for cattle grazing. As the location of primary oil and gas activities within certain Tier 1 areas gradually shifts over time, cattle grazing can occur in areas once heavily developed for oil and gas operations.

Trends in grazing land use

The Kern County Agricultural Commissioner publishes an annual Crop Report for Kern County based on information provided by agricultural operators, including ranching operations, in the County. As of July, 2018, annual crop reports for each year during the period 1930 to 2016 were

available online at http://www.kernag.com/caap/crop-reports/crop-reports.asp. The annual crop reports include an estimate of the acres of "range/pasture" in use during the reporting year as a line item in the "field crops" summary for Kern County. In 1987, for example, the crop report estimates that 2,083,000 acres of pasture/range were used in the field crop totals. Kern County Crop Report 1987. In 2012, the crop report estimated that 1,479,000 acres of pasture/range were used and reported in the field crop totals for 2012. Figure 4-7 shows the annual acreage of pasture/range reported in use in each Kern County crop report from 1981 to 2016.

The annual amount of rangeland in use reported in the Kern County crop reports significantly decreased in the 25 years prior to 2012. In the 5 years from 1987-1991, for example, an average of approximately 2,197,459 acres of rangeland per year was reported to be in use in Kern County compared with an annual average of 1,462,000 acres during 2012-2016. These data suggest that demand for rangeland in the County has decreased over time, possibly by over 700,000 acres in the last 25 years. By contrast, as shown in Table 4-1, the FMMP has estimated that total County grazing land increased by over 100,000 acres from 1988-2016. Thus, reported rangeland actually in use in the County since 2012 is substantially below the estimated supply of available grazing land in the FMMP data. In 2016, for example, Table 4-1 indicates that Kern County had over 1,849,000 acres meeting the FMMP criteria for grazing land. The pasture/range use reported in the 2016 crop report, was just 1,444,000 acres. Kern County Crop Report 2016.

Trends in livestock grazing productivity

The Kern County annual crop reports include estimates of the gross revenues or value received from livestock sales each year. As discussed above, cattle sales comprise a significant majority of all livestock income in the County, and cattle and sheep sales have collectively generated well over 90% of all livestock income over time. Figure 4-8 shows the annual amount of livestock value reported in each Kern County crop report from 1981 to 2016 in nominal (unadjusted) and inflation-adjusted amounts. The inflation-adjusted figures used constant 2009 dollars based on the California Consumer Price Index (CPI). DOF 2018.

The value of livestock in Kern County rose significantly from 1981 to 2016 in terms of both the nominal amounts reported in the annual crop reports and based on constant 2009 dollars using the CPI. In the 5 years from 1987-1991, the average annual nominal value of livestock sales in Kern County was $43.4 million compared with an annual average of $390.9 million in 2012-2016, a nine-fold increase. Inflation-adjusted livestock value rose about 4.6 times from 76.2 million in 1987-1991 to 356.7 million in 2012-2016. These data show that, although reported rangeland use decreased over the last 25 years, and is currently well below the acreage of grazing land mapped by the FMMP for the County, livestock value generated by sales of cattle and sheep have substantially increased.

Figure 4-9 shows the percentage of total Kern County agricultural value reported in annual crop reports from 1981 to 2012 that is accounted for by the value of livestock sales. Over time, and subject to fluctuation, livestock sales have generally increased as a percentage of total County agricultural value.

In the 5 years from 1987-1991, livestock sales averaged about 2.7% of total Kern County agricultural value. During 2012 to 2016, livestock sales averaged 5.7% of total County agricultural value, more than double the prior rate. As shown in Table 4-7, the value of Kern County livestock also increased much more rapidly than the total value of Kern County agriculture from 1987 to 2012, using both nominal and inflation-adjusted data.

Table 4-7
Kern County Total Agricultural and Livestock Value, 1987 and 2012
Nominal and Constant 2009 (CPI) Dollars

	1987 nominal	2012 nominal	Net Growth	Percent growth
Total County value	1,511,805,000	6,769,855,590	5,258,050,590	348%
Livestock value	40,781,000	395,078,000	354,297,000	869%
	1987 (2009 constant dollars-CPI)	**2012 (constant dollars-CPI)**	**Net Growth**	**Percent growth**
Total County value	2,655,807,379	5,845,982,803	3,190,175,424	120%
Livestock value	78,450,042	371,777,942	293,327,899	374%

Sources: Kern County Crop Report 1987; Kern County Crop Report 2012; DOF 2018.

Significance of potential impacts

The data summarized above indicate that Kern County livestock productivity has substantially increased even as grazing land use significantly decreased, apparently by as much as 700,000 acres as estimated in annual County crop reports during the 25 years prior to 2012. Over approximately the same time (1988-2016), FMMP surveys indicate that mapped grazing land has increased by over 100,000 acres and is currently available in amounts that significantly exceed the reported annual rangeland actually in use for grazing in the County. Unlike the conversion of active farmland, which physically displaces productive agriculture on the affected land, grazing productivity data in Kern County over the last three decades indicate that grazing productivity does not decrease as the availability or use of grazing land decreases. The best available data, in fact, show that livestock value substantially increased even as grazing land use decreased in the County over the last 25 years. Furthermore, it is reasonable to expect that available grazing land will continue to increase during the next 25 years as it has in the previous 25 years. In addition, DOGGR data for 1985 through 2012 demonstrate substantial oil and gas activities in those years. DEIR pages 2-22, 3-16. The net increase of over 100,000 acres of grazing land acres in Kern County as documented by the FMMP, which occurred during a period of active oil and gas development, suggests that grazing land acres can be expected to continue increasing together with continued oil and gas development over the next 25 years.

These data indicate that the productivity of Kern County grazing land would not be significantly affected by the potential impact to about 1,900 acres of grazing land per year--and a total 25-year impact to about 48,000 acres—that could occur from the implementation of the Project. A potential impact on 48,000 acres over 25 years, for example, would be approximately 7% of the total reduction in reported rangeland use in the County over the 25 years from 1987 to 2012. During this period, livestock value generated by sheep and cattle sales rose faster than for County agriculture as a whole, and by nearly 900% in nominal value and 400% in inflation-adjusted value.

In addition, there is substantial evidence that sheep and cattle grazing has and will continue to occur even in highly-developed Tier 1 areas. Consequently, a substantial portion of the area that could be subject to potential impacts, using the projected ground disturbance levels summarized in Table 3-3, will in fact be available for grazing during most of the projected 25-year analysis period. Both sheep and cattle currently graze in Tier 1 locations in close proximity with oil and gas operating equipment. Sheep can be managed to graze on forage immediately adjacent to oil and gas equipment, and in some locations cattle range freely throughout operating oilfields (see Appendix

G). A major ranching operator with land near some of the largest oil and gas well fields in the Western Subarea has stated that oil and gas development helps preserve grazing lands and allows for the return of forage on newly completed well sites within three years from well completion (see Appendix D). There is also substantial evidence that heavily-developed oil and gas locations have been decommissioned and returned to grazing uses in the Project Area over time. There is no evidence that any livestock operations have been physically harmed by oil and gas operations or adversely affected by split-estate landholdings in Kern County.

In summary, the estimates of impacts to grazing land using the projected ground disturbance levels in Table 3-3 provide an extremely conservative projection of potential future Project impacts. Heavily developed Tier 1 areas are currently, and will in the future continue to be, used for grazing and net impacts will likely be significantly lower than projected using the ground disturbance factors.

In addition, the maximum potential grazing land impacts are much smaller than the changes exhibited by long-term trends in grazing activity. Over the last 25 years, the reported livestock use of County rangeland has apparently decreased by several hundred thousand acres, even as the supply of available rangeland has increased. The number of cattle in the County inventoried at the start of 2012 was significantly greater than in 1987, and the County's share of total state cattle and sheep has increased. The value of livestock, almost all generated by cattle and sheep, substantially increased in nominal and inflation-adjusted terms, and more rapidly than the County's value of agriculture as a whole. Based on these considerations, the potential loss of grazing acreage due to Project implementation would not be expected to significantly affect the productivity of grazing activity in the County.

Mitigation Measures

No mitigation measures are required.

While Project implementation is not expected to cause a significant impact on grazing in the County, the implementation of MM 4.4-16 in the MMRP, which was adopted to mitigate Project impacts to biological resources, also will benefit grazing lands. MM 4.4-16 requires, for the first time in Kern County history, that all ground disturbance associated with oil and gas activities subject to the amended and revised Ordinance be mitigated. This new mandatory mitigation requirement generally requires mitigation at a 1.0 to 1.0 ratio (one-acre of new disturbance requires one-acre of mitigation). Only in locations where existing oil and gas activity has already disturbed more than 70% of the land in a proposed site plan is the minimum mandatory mitigation reduced, and even in those areas mitigation at a 1.0 to 0.5 ratio (one-acre of new disturbance requires one-half acre of mitigation) is required. The MMRP contemplates that other forms of mitigation, such as through agreements with state or federal wildlife agencies, or by means of regional habitat conservation plans or similar programs, will fulfill a significant portion of the required mitigation. However, all new ground disturbance for future oil and gas activities subject to the Ordinance must, at a minimum, meet the mandatory land disturbance mitigation standards set forth in the MMRP. As discussed above, non-native annual grasslands predominate in the rangeland/grazing land portions of the Project Area, and their growth creates fire risks and adverse impacts to native plants and species. Grazing has been recognized as a valuable means for controlling non-native annual grasslands in the Project Area.

Lands currently mitigated under MM 4.4-16 include habitat defined as "rangeland" in California Public Resources Code Section 4789.2(i): "natural grasslands, savannas, shrublands (including chaparral), deserts, wetlands, and woodlands (including Eastside ponderosa pine, pinyon, juniper,

and oak) which support a vegetative cover of native grasses, grasslike plants, forbs, shrubs, or naturalized species." Thus, it is reasonable to assume that certain of the mitigation lands used to meet MMRP or other qualifying land disturbance mitigation obligations will permit livestock grazing in some form. Taking the effects of MM 4.4-16 into account, together with the increased availability and decreased use of rangeland/grazing land discussed that have occurred since 1987, total grazing land acres can be expected to continue increase together with continued oil and gas development over the next 25 years.

Thus, even if the most conservative projections of impacts did occur, the required mandatory ground disturbance mitigation requirements in the amended and revised Ordinance would be expected to substantially offset the relatively small amount of grazing land potentially impacted by the Project.

Level of Significance after Mitigation

Impacts would be less than significant.

Cumulative Setting Impacts and Mitigation Measures

As discussed in the certified EIR (see, e.g., the discussion in the Project DEIR, page 4.2-15), the environmental impact report for the Kern County General Plan, which was adopted in 2004, estimated that General Plan implementation could result in the conversion of approximately 55,000 acres of grazing land. Kern County 2004. The Kern County General Plan used a conservative estimate for the potential conversion of grazing land by using the Map Code 4.3 (Specific Plan Required) General Plan land use designations which have an adopted sheet for each named area (Specific Plan Required Maximum Allowed Land Uses) that contains an allocation for all map code uses and a not to exceed total of recommended residential units. These areas have an interim designation of primarily Resource Management and are zoned A (Exclusive Ag) and A -1 (Limited Agriculture), both of which permit grazing. The Map Code 4.3 lands totaled approximately 64,129 acres. The 2004 General Plan FEIR calculated the number of Map Code 4.3 areas that occur in the mountain and desert areas where the lands are used for grazing and not cultivated crops and determined that 55,000 acres of grazing land could be converted if the Map Code 4.3 areas were developed based on their adopted allocation for all map code uses and the applicable not to exceed total of recommended residential units. Kern County 2004. Since that time, 12,692 acres of Map Code 4.3 areas have been rescinded and included in the Greater Tehachapi Specific Plan and the Tejon Mountain Village Specific Plan. Based on the new land uses in both of these plans, 3,048 acres were removed from grazing uses in the plan areas formerly subject to the Map Code 4.3 designation.

Consequently, using the maximum potential impact related to oil and gas activity over 25 years as shown in Table 4-6, plus the maximum potential General Plan impact to grazing land of 55,000 acres (see Kern County 2004) the maximum potential cumulative impacts to grazing land would be approximately 103,891 acres (55,000 acres from General Plan implementation plus 48,891 acres from Project implementation). Since 2004, however, the level of potential grazing land impacts from General Plan implementation projected in 2004 has not occurred, and only 3,048 acres have been redesignated from resource zoning and have had grazing removed in former Map Code Section 4.3 areas. Accounting for the actual impacts since 2004, the maximum potential grazing land conversion from General Plan implementation in remaining Map Code 4.3 designations is at most 51,952 acres (55,000 acres minus the 3,048 acres that were redesignated from resource zoning and have had grazing removed since 2004). Based on the total amount of grazing land impacts from

General Plan implementation since 2004 (3,048 acres), and the lack of infrastructure for developing the remaining areas subject to the General Plan Map Code 4.3 (Specific Plan Required) designation, substantial evidence indicates that much less than 51,952 acres will actually be impacted by General Plan implementation over the next 20 years. If future grazing land impacts are comparable to the level of impacts that occurred since 2004, General Plan implementation over the next 20 years could potentially impact approximately 3,904 acres. This would result in a total grazing land impact from General Plan implementation of just 6,952 acres. Hence, the potential cumulative grazing land impacts attributable to the implementation of the current County General Plan and the Project would be about 55,843 acres accounting for the actual rate of grazing land conversion due to General Plan implementation since 2004.

As discussed above, impacts attributable to oil and gas development using the ground disturbance factors are extremely conservative as even reasonably intensive oil and gas operations allow for livestock grazing. In addition, General Plan impacts since 2004 have been significantly lower than projected, and substantial evidence indicates that the total of these impacts would much lower than the 55,000 acres considered in 2004. Kern County 2004. Consequently, the maximum potential cumulative impacts to grazing land, 103,891 acres, includes highly conservative estimates of both actual Project impacts and actual and reasonably foreseeable General Plan implementation impacts. The potential cumulative impacts to grazing land are larger than for the Project alone, but long-term trends in grazing activity (e.g. increasing total rangeland acreage in County, decreasing use of rangeland acres in County, and higher livestock productivity despite fewer acres in use) exhibit much larger changes over time. The potential maximum cumulative grazing land impact, for example, is lower than the total amount of new grazing land that has been added in the County since 1988, according to the FMMP. The maximum cumulative impact acreage is also many times less than the reported reduction in rangeland use from 1987-2012. Notwithstanding the reduction in rangeland used since 1987, grazing productivity has significantly increased in Kern County over time, and at a rate faster than for the County's agricultural economy as a whole. Based on these considerations, the level of potential cumulative impacts to rangeland that could occur from Project and General Plan implementation would be unlikely to significantly reduce the productivity of grazing activity in the County.

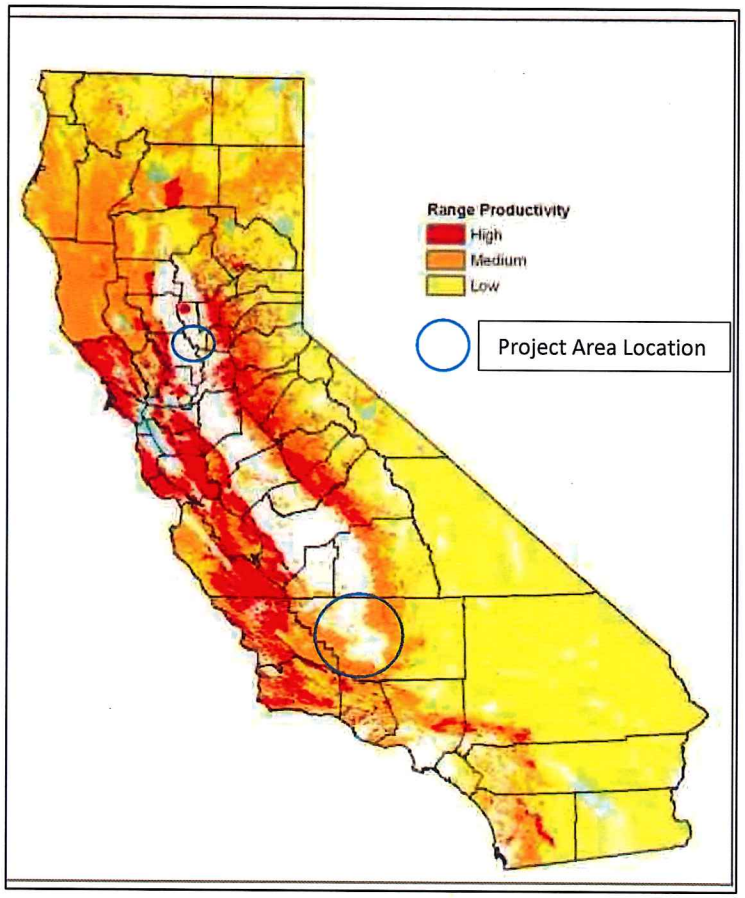
Mitigation Measures

No mitigation measures are required.

Level of Significance after Mitigation

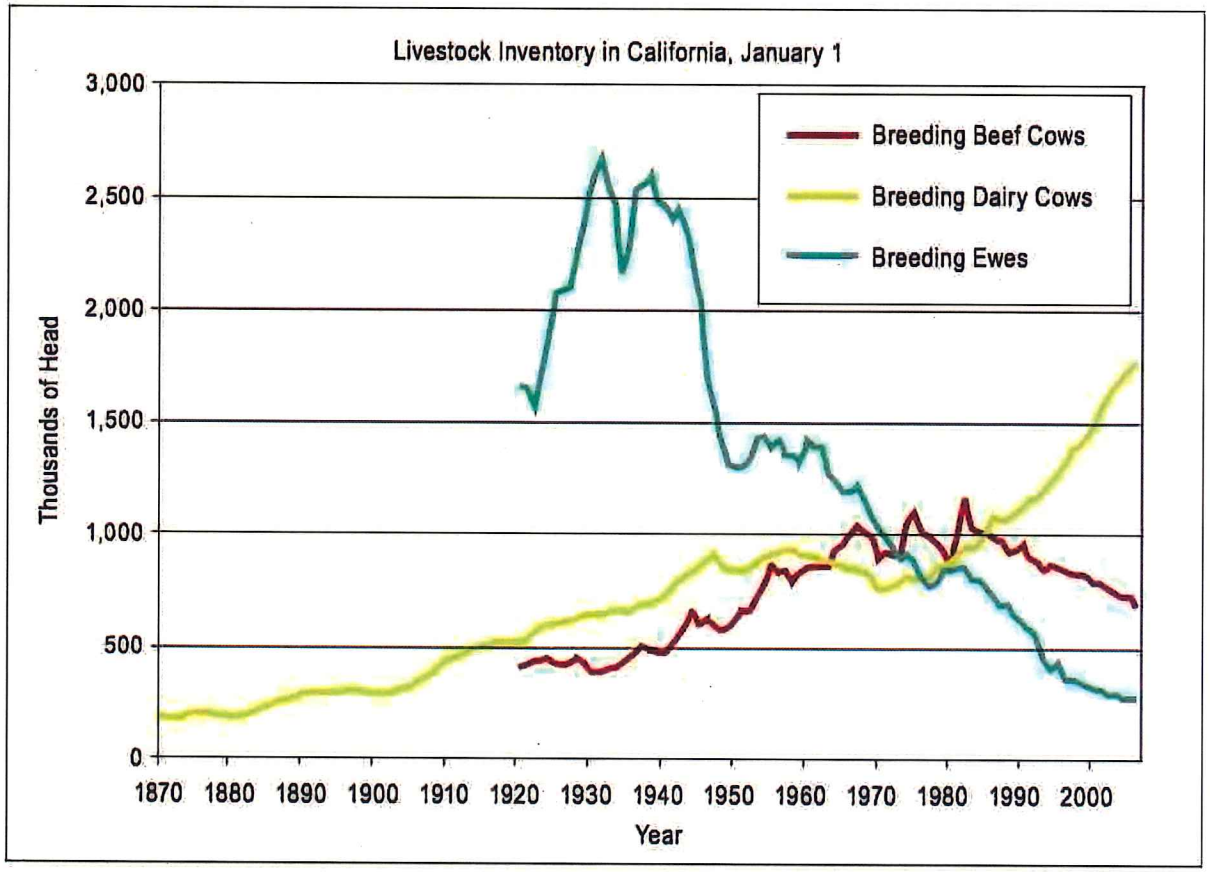
Impacts would be less than significant

Figure 4-1
Rangeland Forage Quality



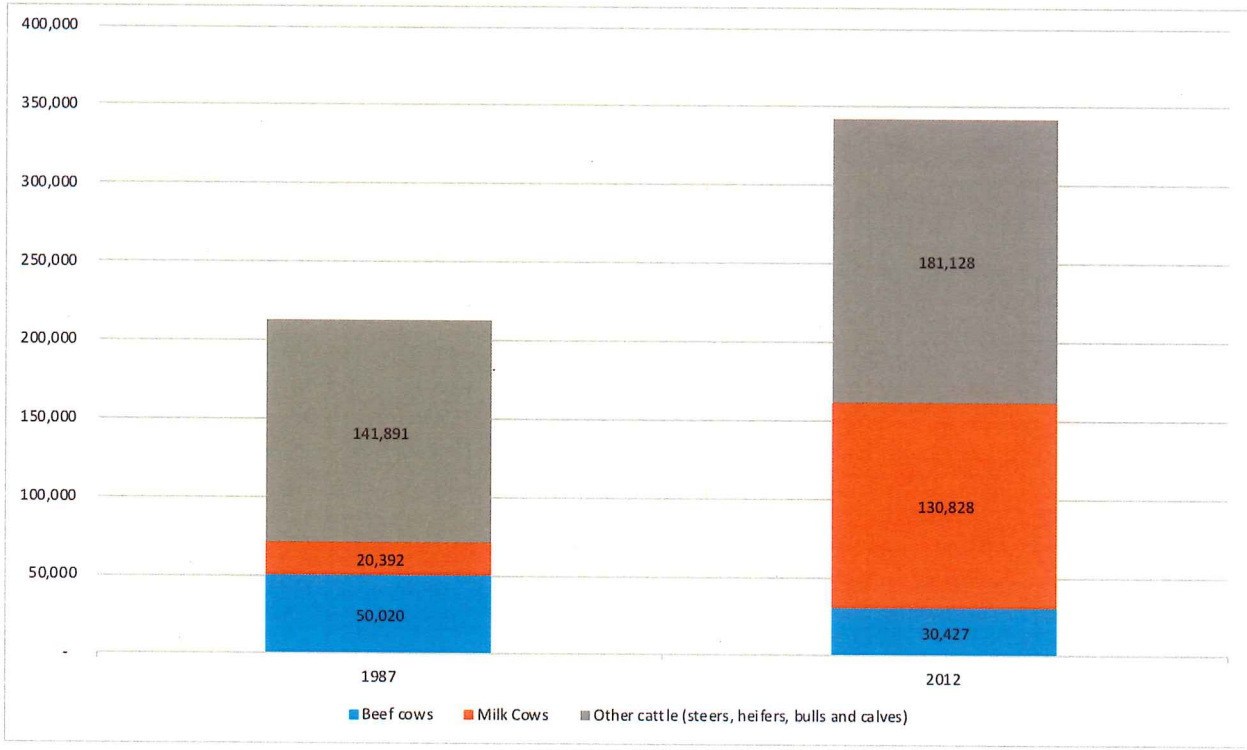
Source: FRAP 2010, Figure 1.2.1

Figure 4-2
Inventory of Breeding Beef Cows, Dairy Cows and Ewes in California
January 1 of Each Year



Source: FRAP 2010, Figure 1.2.7, reporting data from USDA National Agricultural Statistics Service, 2009

Figure 4-3
Number of Beef Cows, Milk Cows and Other Cattle in Kern County, 1987 and 2012



Sources: NASS 1987; NASS 2012.

Figure 4-4
Location of Grazing Land in Project Area by Tier and Subarea

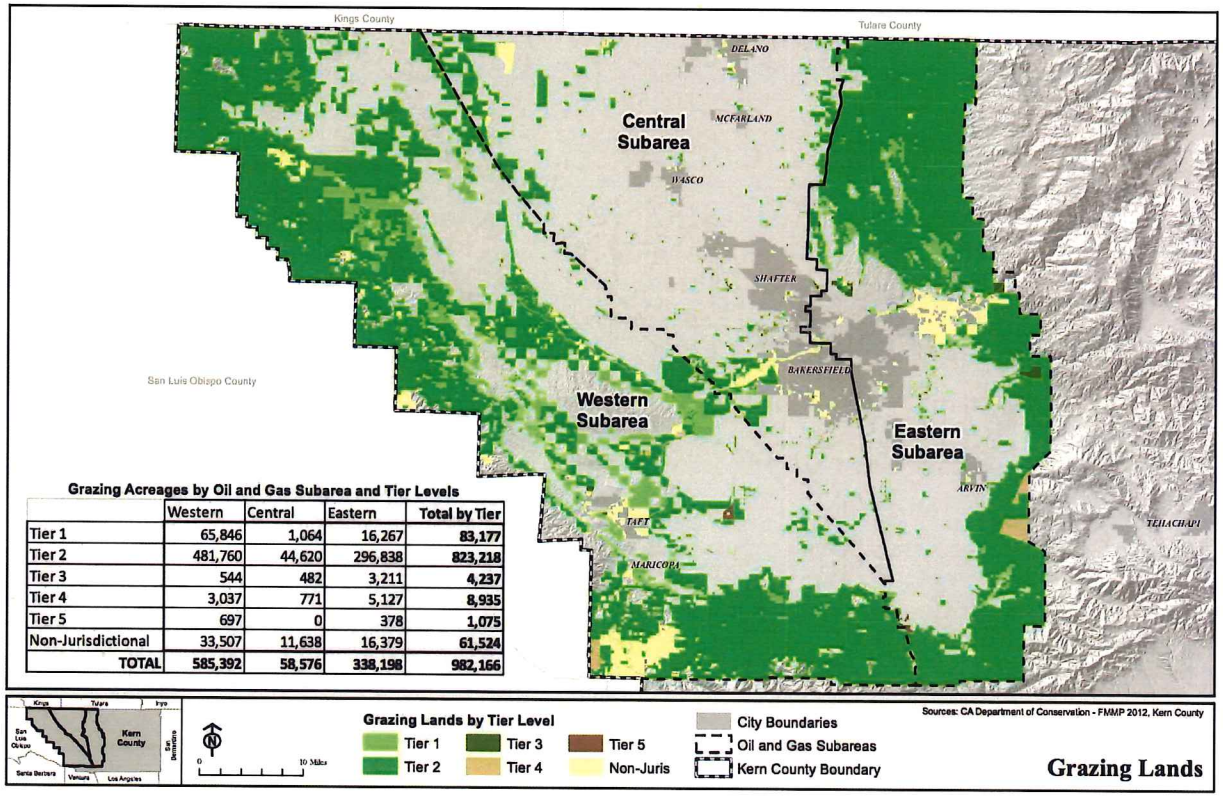
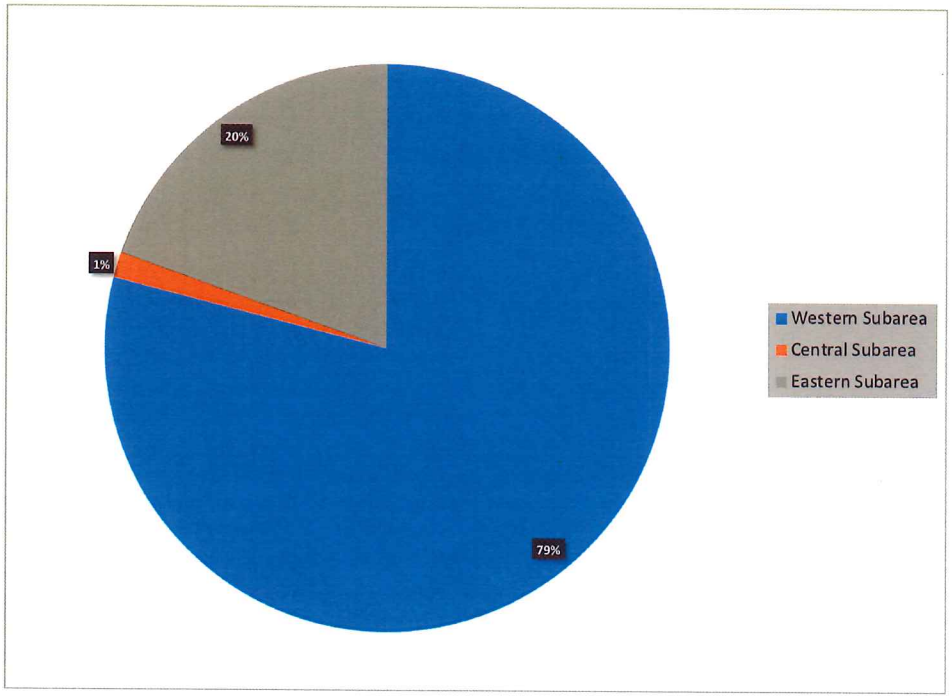
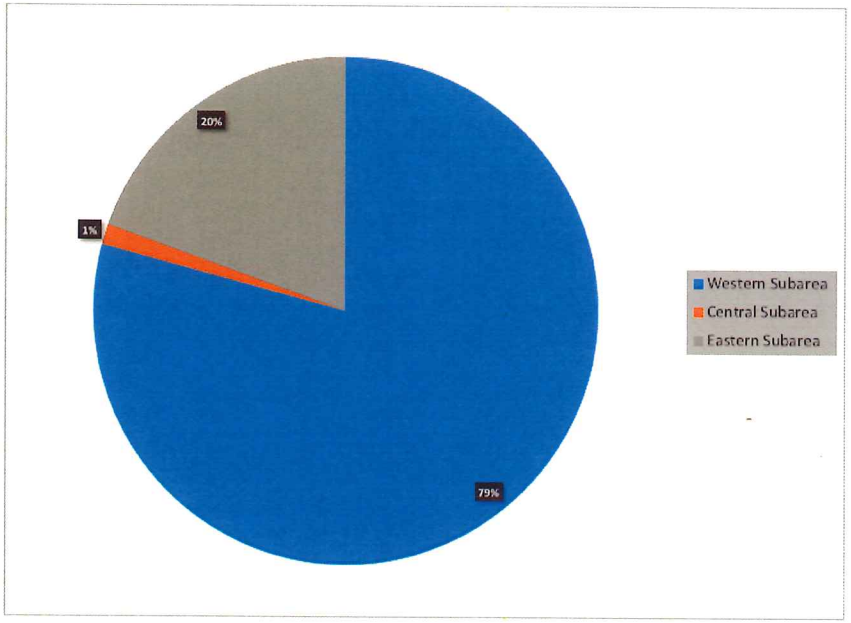


Figure 4-5
Proportion of Tier 1 Acreage in Project Area by Subarea



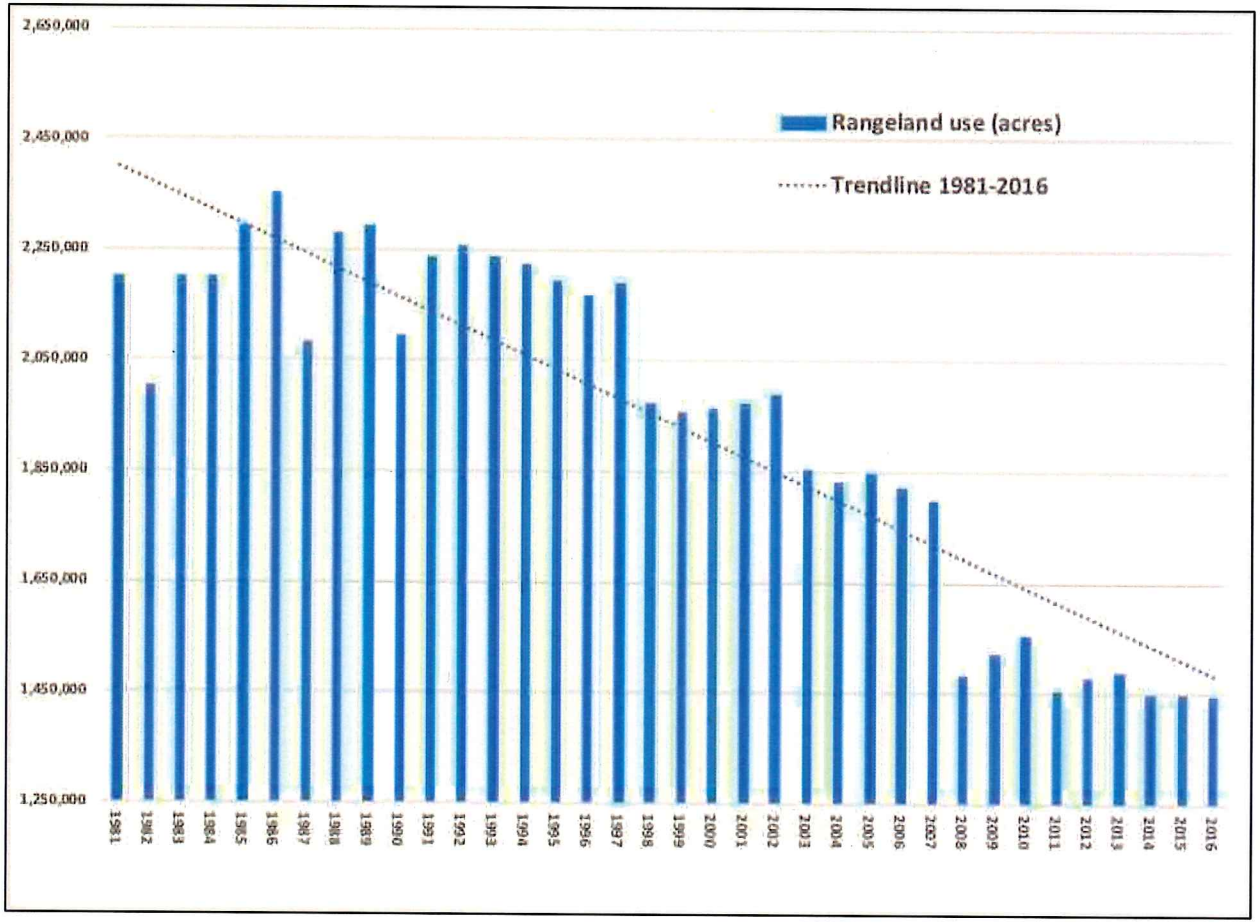
Source: See Table 3-1

Figure 4-6
Proportion of Grazing Land Acreage in Tier 1 Portions of the Project Area by Subarea



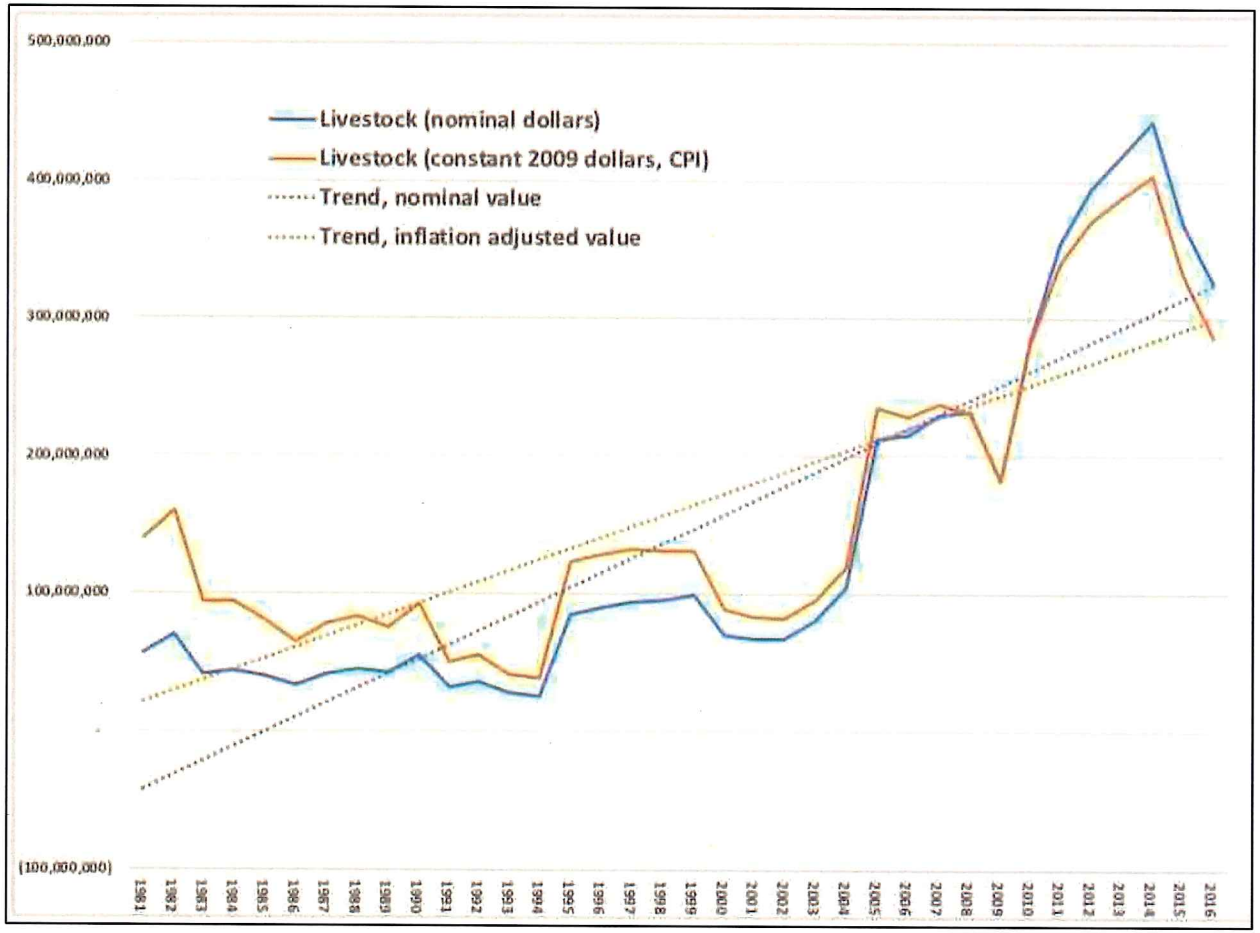
Source: See Table 4-4.

Figure 4-7
Acreage of Pasture/Range Reported in Use
Annual Kern County Crop Reports 1981-2016



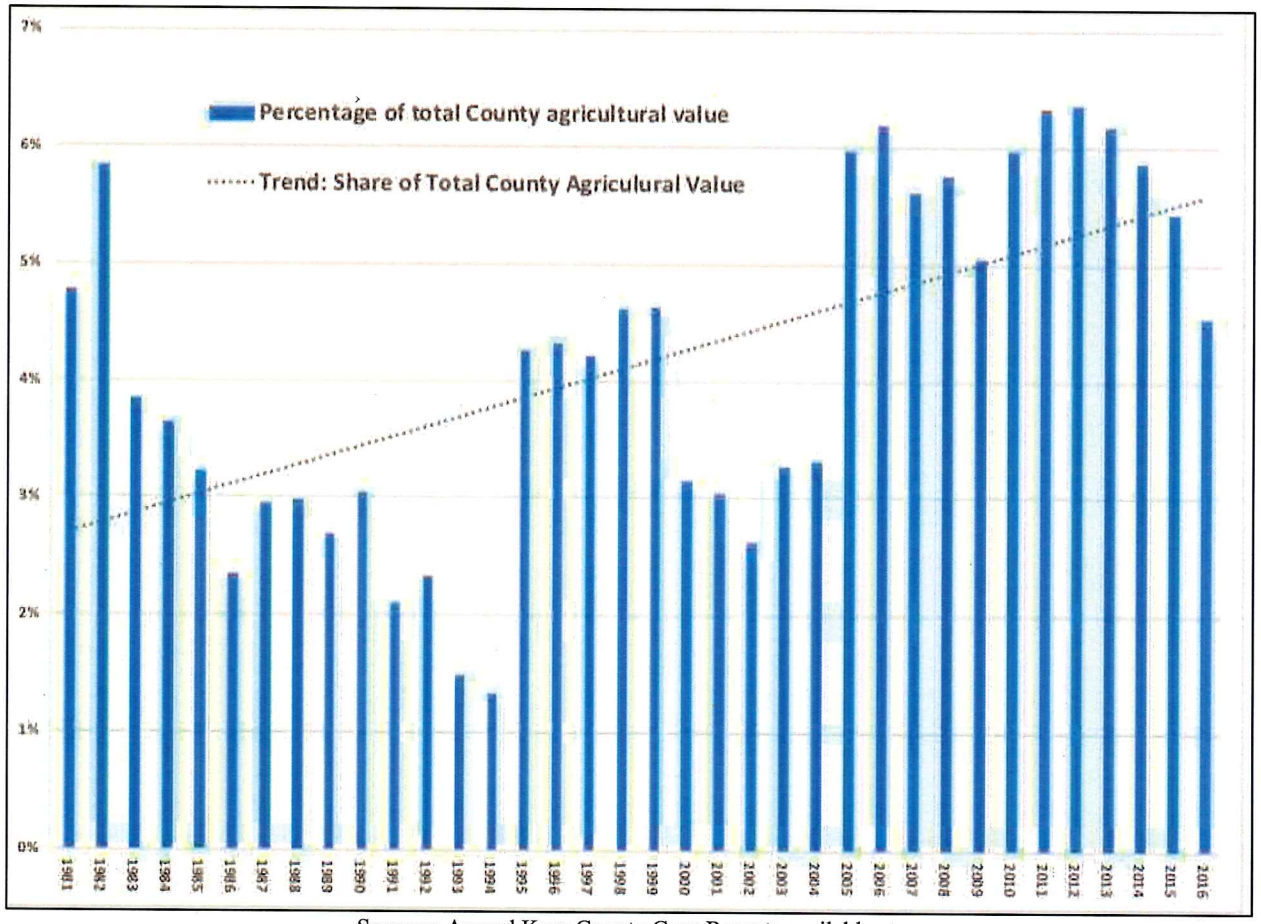
Sources: Annual Kern County Crop Reports available at:
http://www.kernag.com/caap/crop-reports/crop-reports.asp, accessed July 2018.

Figure 4-8
Livestock Value Per Year, Nominal Dollars and
2009 Inflation-Adjusted Dollars (CPI)
1981-2016



Sources: Annual Kern County Crop Reports available at:
http://www.kernag.com/caap/crop-reports/crop-reports.asp, accessed July 2018. DOF 2018.

Figure 4-9
Livestock Value as Percentage of Total County Agricultural Value
1981-2016



Sources: Annual Kern County Crop Reports available at:
http://www.kernag.com/caap/crop-reports/crop-reports.asp, accessed July 2018.

Chapter 5
Consequences of Project Implementation

5.1 Environmental Effects Found to Be Less than Significant

Chapter 5 of the certified EIR is incorporated by reference. As discussed in Chapter 4 of this DSEIR, Project and cumulative impacts to rangeland/grazing land have also been determined to be less than significant.

5.2 Significant Environmental Effects that Cannot Be Avoided

Chapter 5 of the certified EIR is incorporated by reference. As discussed in Chapter 4 of this DSEIR, Project and cumulative impacts to rangeland/grazing land are less than significant and these findings do not change the certified EIR analysis and conclusions concerning significant environmental effects that cannot be avoided.

5.3 Significant Irreversible Impacts

Chapter 5 of the certified EIR is incorporated by reference. As discussed in Chapter 4 of this DSEIR, Project and cumulative impacts to rangeland/grazing land are less than significant and these findings do not change the certified EIR analysis and conclusions concerning significant irreversible effects.

5.4 Significant Cumulative Impacts

Chapter 5 of the certified EIR is incorporated by reference. As discussed in Chapter 4 of this DSEIR, Project and cumulative impacts to rangeland/grazing land are less than significant and these findings do not change the certified EIR analysis and conclusions concerning significant cumulative effects.

5.5 Growth Inducement

Chapter 5 of the certified EIR is incorporated by reference. As discussed in Chapter 4 of this DSEIR, Project and cumulative impacts to rangeland/grazing land are less than significant and these findings do not change the certified EIR analysis and conclusions concerning growth inducement.

Chapter 6
Alternatives

6.1 Introduction

Chapter 6 of the certified EIR is incorporated by reference. As required by the CEQA Guidelines (e.g., Guidelines Section 15126.6), the Project EIR describes a range of reasonable alternatives to the project or to the location of the project site that could feasibly avoid or lessen any significant environmental impacts of the project while attaining most of the project's basic objectives. The Project EIR also compares and evaluates the environmental effects and comparative merits of the alternatives, describes alternatives considered but eliminated from further consideration, including the reasons for elimination, and compares the environmental impacts of several alternatives retained for consideration with those of the Project. The analysis of Project alternatives in the certified EIR was upheld in the April 20, 2018 Judgment (see Appendix B).

Based on the considerations discussed in Chapter 4 of this DSEIR, the Project would not have a significant impact or a cumulatively significant impact to rangeland/grazing land. As a result, the analysis of potential Project alternatives discussed in the Project EIR is not significantly affected by the analysis in this DSEIR. To foster meaningful public participation and informed decision making in accordance with CEQA, however, this section describes an additional potential Project alternative—a ban on grazing in Tier 1 areas—that was eliminated from further consideration, and an alternative that would ban oil and gas drilling on rangeland/grazing land in the Project Area. Among the factors taken into account when addressing the feasibility of these alternatives, as described in Section 15126.6(f)(1) of the CEQA Guidelines, are environmental impacts, site suitability, and economic viability. The Project purposes identified by the CEQA lead agency and the Project Proponents are summarized in Section 3.4 of this DSEIR.

6.2 Alternatives Eliminated from Further Consideration

Livestock Grazing Ban on Tier 1 Lands: As discussed in Chapter 4 of this DSEIR, 90% of the potential impacts to grazing from oil and gas activities subject to the Ordinance would occur in Tier 1 portions of the Project Area. About 84.5% of these impact would occur in Tier 1 portions of the Eastern Subarea and Western Subarea. Tier 1 areas include the most heavily developed oil and gas activities in the Project Area, and 91% of all future Project ground disturbance would be confined to these locations. Potential conflicts between grazing and oil and gas activities could be reduced by prohibiting livestock grazing within all Tier 1 portions of the Project Area. This alternative was eliminated from further consideration in this DSEIR for several reasons, primarily because it would have counterproductive impacts to livestock operations by removing existing areas, including those in close proximity with oil and gas operations, that have historically been available and used for grazing. Additional counterproductive adverse impacts to County livestock operations would result from the relocation of grazing activity to other locations that may be less accessible, have lower foraging value, lack other amenities, and require additional facility development, such as roads, that may be unaffordable for many livestock operations and/or have additional environmental impacts. Moreover, this alternative would have the potential for increased fire risk and harm to native plant and animal species due to non-native annual vegetative accumulation in areas previously subject to control by grazing. The elimination of livestock grazing within Tier 1 lands could encourage alternative land uses, such as urban or industrial development, and would require

other means of annual non-native vegetation control for fire risks, that could have significantly greater environmental impacts than the long-term livestock grazing activities that currently occur in these locations. Finally, a grazing ban in Tier 1 areas would not achieve certain of the Project purposes, including the CEQA lead agency's objective of containing new development within an area large enough to meet generous projections of foreseeable need but in locations that will not impair the economic strength derived from residential developments, agriculture, rangeland, mineral resources, or diminish the other amenities that exist in Kern County. For these reasons, the grazing ban alternative was eliminated from further consideration in this DSEIR.

6.3 Alternatives Analyzed in this DSEIR

Drilling Ban on Grazing Land: A drilling ban on grazing land alternative would be identical to the Project, except that it would further amend Chapter 19.98 of the Kern County Zoning Ordinance to prohibit all new oil and gas exploration on grazing land mapped by the FMMP, defined as "[l]and on which the existing vegetation is suited to the grazing of livestock." FMMP 2015. Under this alternative, it is more likely that oil and gas activities currently taking place on grazing land would be displaced to non- grazing land with potentially greater habitat and wildlife resource values, especially as contrasted with previously grazed and disturbed Tier 1 locations, potentially causing greater overall environmental harm. Moreover, this alternative would result in more horizontal and directional subsurface drilling activities needed to recover subsurface oil and gas resources underlying grazing land from wells located outside of the excluded grazing areas. This additional horizontal and directional subsurface drilling activity would generate greater air quality, greenhouse gas, and toxic air contaminant emissions than would the Project. Horizontal and directional drilling activities generally require more time to complete than does the vertical drilling activity typically associated with Kern County oil and gas well development, and longer drilling periods require the additional combustion of fossil fuels that cause polluting emissions. In addition, since a significant proportion of the Project Area would be off-limits to oil and gas activities under this alternative, this alternative is legally infeasible due to legal restrictions on the County's authority to prohibit access to subsurface mineral interests without liability.

Moreover, a drilling ban on grazing land is likely to counterproductively result in a substantial decrease in grazing. Unlike certain split-estate landholdings where farming occurs on the surface, a substantial amount of the Project Area grazing lands, including Tier 1 lands, are owned in fee by oil and gas operators. Adoption of this alternative could cause oil and gas operators to cease leasing their property for grazing. Since operators can be expected to maintain access to the minerals for which they purchased the property in the first place, it is reasonable to anticipate that many grazing leases in Tier 1 could be terminated, resulting in a major disruption of grazing and the historic pattern of coexisting of oil and gas operations and grazing activity, similar to the grazing ban discussed and eliminated from further consideration in Section 6.2 of this DSEIR.

The comparative environmental impacts and relationship to the Project objectives from a ban on drilling on grazing land would be similar to those associated with Alternative 3, the Reduced Ground Disturbance Alternative, discussed in the certified EIR. Since grazing land would be unavailable for oil and gas development, including in Tier 1 locations, new well development would be more clustered and intensively developed in outside grazing land. This could result in less overall ground disturbance than the Project, which allows for new well development subject to Ordinance requirements in grazing land and non-grazing land portions of the Project Area. Thus, this alternative could have somewhat reduced impacts to biological resources, aesthetic resources, and hydrologic resources as compared to the Project. These potential environmental benefits would be offset by certain environmental impacts greater than those caused by the Project. Some of

activities relocated from grazing land may be moved closer to residential development or sensitive habitat. Moreover, since the alternative would prohibit new wells in active grazing portions of the Project Area, more horizontal and directional subsurface drilling activities would be needed to recover subsurface oil and gas resources located within the precluded areas. This additional horizontal and directional subsurface drilling activity would generate greater air quality, greenhouse gas, and toxic air contaminant emissions than would the proposed Project because such activities generally require more time to complete than does the vertical drilling activity typically associated with Kern County oil and gas well development. Longer drilling periods require the additional combustion of fossil fuels that cause polluting emissions. The extended drilling times associated with this alternative would also generate more noise impacts within more densely developed portions of the Project Area than would the Project, and would result in a comparative increase in traffic within and around excluded grazing areas due to the additional trips needed to move drilling equipment to and from new well sites developed under this alternative. Otherwise, the environmental effects of this alternative are comparable to the Project.

A drilling ban on grazing land would achieve some of the Project objectives. The County's Zoning Code update would be similar to the Project, though it would reduce the overall Project surface footprint to exclude grazing land. The drilling ban on grazing land would streamline the County's oil and gas regulations and environmental review processes. The alternative would also ensure the protection of environmental resources by emphasizing the conservation of productive grazing lands and through the development and implementation of industry-wide best practices, performance standards, and mitigation measures. However, this alternative would have greater overall environmental effects in some impact categories than would the Project, as discussed above (e.g. because otherwise prohibited oil and gas activities on grazing lands would be displaced to non-grazing lands with potentially greater habitat and wildlife resource values). Moreover, given the extent of grazing land in Tier 1 areas, it is likely that less oil and gas would be produced if operators could no longer access resources underlying grazing land in Tier 1 areas except by increased horizontal and directional drilling from non-grazing land. As a result, this alternative would not achieve certain of the Project purposes, including the County's objective of containing new development within an area large enough to meet generous projections of foreseeable need but in locations that will not impair the economic strength derived from residential developments, agriculture, rangeland, mineral resources, or diminish the other amenities that exist in Kern County and helping to reduce California's dependence upon foreign sources of energy. In particular, the alternative would conflict with the County's objective of avoiding impairment of the economic strength derived from rangeland, by counterproductively encouraging oil and gas operators to terminate many grazing leases as discussed above.

6.4 Environmentally Superior Alternative

Chapter 6 of the certified EIR is incorporated by reference. All numbered alternatives discussed below refer to alternatives considered in the certified EIR. Identification of an environmentally superior alternative is required under CEQA (Cal. Code Regs. Section 15126.6(e)(2)).

As compared to the Project, Alternative 1, the No Project Alternative would have greater impacts than the Project in most categories. Alternative 2, the CUP Alternative, would slightly reduce the Project's aesthetic impacts, but would also generate greater environmental effects than the Project in multiple impact categories. As compared to the Project, Alternative 3, the Reduced Ground Disturbance Alternative, would have less impacts to aesthetic resources, agricultural resources, cultural resources, and biological resources, but these environmental benefits would be offset by greater environmental impacts related to air quality, greenhouse gas emissions, noise, and traffic.

Alternative 4, the No Hydraulic Fracturing Alternative, would have less water quality and hazards impacts than the Project, but would have greater impacts related to air quality and greenhouse gas emissions than would the Project. As compared to the Project, Alternative 6, the Recycled Water Alternative, would have less hydrology and water quality impacts, and less utilities and service system impacts, than the Project, but would have greater impacts related to aesthetics, air quality, biological resources, cultural resources, greenhouse gas emissions, and noise. The alternative of a drilling ban on grazing land, discussed in Section 6.3 of this DSEIR, would have less impacts to aesthetic resources, cultural resources, and biological resources, but these environmental benefits would be offset by greater environmental impacts related to air quality, greenhouse gas emissions, noise, and traffic and the counterproductive effect on grazing if oil and gas operators terminate many grazing leases.

As identified in the certified EIR, the environmentally superior alternative is Alternative 5, the Low-Emission EOR Technology Alternative. Compared to the Project, Alternative 5 would have less environmental effects related to air quality, greenhouse gases, and transportation and traffic. Moreover, Alternative 5 would not result in any environmental impacts that are greater than those of the Project.

Chapter 7
Response to Comments

This section is reserved for response to comments to be received on this Supplemental EIR.

Chapter 8
Organizations and Persons Consulted

No organizations or persons were consulted by either the Lead Agency or the Lead Agency's consultant during preparation of the DSEIR.

Chapter 9
Preparers

Lead Agency

Kern County Natural Resources and Planning Department

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Chapter 10
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Appendices

Appendix A:	Mitigation Monitoring and Reporting Plan
Appendix B:	April 20, 2018 Judgment and Writ of Mandate
Appendix C:	Kern County transmittal letter to the San Joaquin Valley Unified Air Pollution Control District
Appendix D:	Notice of Preparation and Comments
Appendix E:	Memorandum re: Current Condition of Grazing Lands in the Southern San Joaquin Valley, Kern County CA
Appendix F:	Memorandum re: Oil and Gas Grazing Lease Summary
Appendix G:	Photographs of cattle and sheep grazing in Project Area Administrative Oil Fields

Appendix A

Impact		Mitigation Measure	Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
4.1	**Aesthetics**					
4.1-3	**MM 4.1-1**	The Applicant shall use existing roads to access oil production areas, or shall construct new roads (or extend existing roads) to minimize the amount of disturbance without impeding existing surface use.	Delineated on Site Plan; During construction and operation	Kern County Planning and Community Development Department (KC PCDD)		
			Steps to Compliance: A. The Applicant shall implement measures related to use of access roads as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			
	MM 4.1-2	All derricks, boilers, and other drilling equipment used to drill, repair, clean out, deepen or redrill any well with oil, gas, or other hydrocarbon shall be removed from the drill site within 90 days after completion of production tests or after abandonment of any well. Earthen sumps used in drilling shall be filled within 90 days after any well has been placed in production (unless such sumps are to be used within six months for the drilling of another well), and any sump used in productions shall be filled after its abandonment and restored to a uniform grade within ninety days.	During construction and operation	KC PCDD		
			Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			
	MM 4.1-3	Sumps and ponds shall be permitted only to the extent authorized by the Central Valley Regional Water Quality Control Board (via waiver, Waste Discharge Requirements, or other form of authorized written documentation) and shall comply with all applicable legal requirements and mitigation measures for sumps serving as storage, percolation or evaporation ponds for produced water.	Delineated on Site Plan; During construction and operation	KC PCDD		
			Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			
	MM 4.1-4	Except where located within agricultural land, new oil or gas tanks located within 200 feet of any sensitive receptor shall be partially screened from public view by shrubs, trees or solid screen fencing. Similarly, new pump sites (including multiple well pump sites) within 500 feet of any dwelling must be surrounded by a fence, at least 6 feet in height, constructed of dark-colored chain-link with wood or metal slates, dark green or brown fabric material, or other more visually restrictive fencing material. The height of all new pumping units shall not exceed 80 feet, and shall be painted in accordance with the Kern County Zoning Ordinance.	Delineated on Site Plan; During construction and operation	KC PCDD		
			Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			
	MM 4.1-5	Project signage is limited to directional, warning, safety, security and identification signs in connection with oil, gas, or other hydrocarbon drilling and development operations in accordance with Chapter 19.84.135 of the Kern County Zoning Ordinance. For any signage necessary for wayfinding, safety, or security, the Applicant shall use the minimum necessary to adequately	Delineated on Site Plan; During construction and operation	KC PCDD		
			Steps to Compliance: A. The Applicant shall implement measures as specified in the			

Impact	Mitigation Measure		Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
		communicate the required information.	mitigation measures. B. The Kern County Planning and Community Development Department will verify.			
4.1-4	**MM 4.1-6**	Permanent nighttime lighting that will be installed for new facility operations will only be lighting required for safety or security. During operations when the lighting is in use, lighting for safety and security will be shielded and oriented downward, bare bulbs will be fully screened from view from sensitive viewing receptors such as residences, and on-demand lighting and/or timers will be used to minimize visual impacts of lighting. In doing so, the Applicant shall comply with the standards in the amended Chapter 19.81 – Outdoor Lighting "Dark Sky Ordinance."	Delineated on Site Plan; During operation **Steps to Compliance:** A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.	KC PCDD		
4.1-5	Implement MM 4.1.1 through 4.1.6 Steps to Compliance					
Agricultural Resources						
4.2-1	**MM 4.2-1**	For new oil and gas exploration and extraction activities that are: 1) on land designated Prime, Farmland of Statewide Importance or Unique Farmland; and 2) that have been actively farmed 5 years or more out of the last 10 years, agricultural land mitigation is required at a ratio of 1:1. The 1:1 ratio is applied to actual ground disturbance area for oil and gas activities (inclusive of temporary construction and permanent operational impact areas), but excludes non-farmed existing areas such as roads, and tank and maintenance areas, and lands for which agricultural mitigation has previously been provided at a 1:1 ratio. Prior to ground disturbing activity, the Applicant shall submit to the County written evidence of completion of one or more of the following measures to achieve this 1:1 mitigation ratio: a. Funding and/or purchasing agricultural conservation easements or similar instrument acceptable to the County (to be managed and maintained by an appropriate entity). b. Purchasing of credits for conservation of agricultural lands from an established agricultural farmland mitigation bank or an equivalent agricultural farmland preservation program managed by the County. c. Restoring agricultural lands to productive use through the removal of legacy oil and gas production equipment, including well abandonment and removal of surface equipment. d. Participating in any agricultural land mitigation program adopted by Kern County that provides equal or more effective mitigation than the measures listed above. Mitigation lands shall meet the definition of Prime Farmland, Farmland of Statewide Importance, and/or Unique Farmland, and be of similar or higher agricultural quality as the lands, as established by the California Department of Conservation. Completion of the selected measure or, with the Kern County Planning and Community Development Director's approval, a combination of measures, are to occur on qualifying land in Kern County. If qualifying lands	Delineated on Site Plan; Prior to Issuance of Oil and Gas Conformity or Minor Activity Review Permit **Steps to Compliance:** A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.	KC PCDD		

Impact	Mitigation Measure	Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
	cannot be found in Kern County, upon written application to the County, the mitigation lands may be located within the San Joaquin Valley (San Joaquin, Stanislaus, Merced, Fresno, Madera, Kings, Tulare, or Kern County) or outside the San Joaquin Valley with written evidence that the same or equivalent crops can be produced on the mitigation land. Mitigation consisting of removal of legacy equipment within active agricultural fields shall not require recordation of an agricultural conservation easement or conservation easement. Available mitigation funding shall be prioritized for acquisition of large blocks of agricultural land for preservation, and removal of legacy equipment, to minimize and mitigate fragmentation and edge impacts.				
4.2-5	**MM 4.2-2** To protect crops and structures adjacent to oil and gas activities on active agricultural lands, each Applicant/operator shall comply with the following mitigation measures set forth in other chapters of this Environmental Impact Report: a. Surface water runoff and drainage on the well pads shall be mitigated as described in mitigation measures for Hydrology and Water Quality. b. A Spill Prevention Countermeasure and Contingency Plan or Division of Oil Gas and Geothermal Resources Assembly Bill 1960 spill plan, as applicable, shall be prepared for the site and oil and chemical spills treated in accordance with the Division of Oil Gas and Geothermal Resources Senate Bill 4 Regulations for the site to protect adjacent farmland, as described in mitigation measures for Hazards. c. Speed limits for oil and gas trucks shall be posted on unpaved roads to reduce dust generation; in the absence of signage, speed limits shall be limited to 25 miles per hour (or an alternate, more stringent dust suppression standard as adopted by the San Joaquin Valley Air Pollution Control District), and Applicants shall attest that employees have been trained in the appropriate speed limits. d. Unpaved roads shall be watered or otherwise treated for dust suppression and control as described in Mitigation Measure for Air Quality, unless speeds are restricted to 15 mph. e. Vehicle tracking control shall be installed where unpaved roads intersect with public paved roads, to prevent tracking of mud, dust, and weed seeds off site, unless speeds are restricted to 15 mph. This shall consist of a 50-foot length of a 3 inch-thick layer of gravel one inch or larger in diameter (or an alternate, more stringent dust suppression technique as approved by the San Joaquin Valley Air Pollution Control District). f. Stormwater control shall be required at construction sites during well drilling, reworking, and/or decommissioning as described in mitigation measures for Hydrology. g. Hazardous materials shall be stored within secondary containment as	Delineated on Site Plan; Prior to Issuance of Oil and Gas Conformity or Minor Activity Review Permit	KC PCDD		
		Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			

Impact	Mitigation Measure	Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
	described in mitigation measures for Hazards. h. Overhead electrical or communication lines shall be shown on the Site Plan, and shall be aligned to the greatest extent feasible with existing access roads and the minimum distance between the access road and the well installation or other oil and gas facility, parallel to tree or row crops, described further in mitigation measures for Public Utilities. If the use of existing roads is not feasible, lines shall be routed to minimize surface disturbance and minimize the impacts to surface activity. i. Underground pipelines serving the Project shall be shown on the Site Plan with locations marked and recorded with USAA, and periodically inspected and maintained as described in mitigation measures for Hazards.				
4.2-7	Implement mitigation measure MM 4.2-1 and MM 4.2-2 Steps to Compliance.				
Air Quality					
4.3-1	**MM 4.3-1** Consistent with the requirements of the San Joaquin Valley Air Pollution Control District Regulation II-Permits, the Applicant shall obtain an Authority to Construct permit and a Permit to Operate for any facility or equipment requiring a permit from the San Joaquin Valley Air Pollution Control District, such as stationary sources required to obtain permits pursuant to District Rule 2010. All emissions increases from permitted equipment shall comply with District Rule 2201.	Prior to Issuance of Oil and Gas Conformity or Minor Activity Review Permit	San Joaquin Valley Air Pollution Control District; KC PCDD		
		Steps to Compliance: A. The Project Proponent shall submit an application to obtain Authority to Construct permit and Permit to Operate; B. The San Joaquin Valley Air Pollution Control District will review and approve prior to issuance of the permits.			
	MM 4.3-2 The Applicant shall develop and implement a Fugitive Dust Control Plan in compliance with San Joaquin Valley Air Pollution Control District fugitive dust suppression regulations to further reduce emissions, during construction, of particulate matter that is 10 microns or less and 2.5 microns or less in diameter. The Fugitive Dust Control Plan shall include: a. Name(s), address(es), and phone number(s) of person(s) responsible for the preparation, submission, and implementation of the plan. b. Description and location of operation(s). c. Listing of all fugitive dust emissions sources included in the operation. d. The following dust control measures shall be implemented: 1. All on-site unpaved roads shall be effectively stabilized using water or chemical soil stabilizers that can be determined to be as efficient as or more efficient for fugitive dust control than California Air Resources Board approved soil stabilizers, and that shall not increase any other environmental impacts including loss of vegetation. 2. All material excavated or graded will be sufficiently watered to prevent excessive dust. Watering will occur as needed with	Prior to Issuance of Oil and Gas Conformity or Minor Activity Review Permit	KC PCDD		
		Steps to Compliance: A. The Project Proponent shall prepare a Fugitive Dust Control Plan and submit it to the Kern County Planning and Community Development Department prior to construction. B. The Kern County Planning and Community Development Department will approve the Plan prior to issuing grading or building permits.			

Impact	Mitigation Measure	Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
	complete coverage of disturbed areas. The excavated soil piles will be watered as needed to limit dust emissions to less than 20% opacity or covered with temporary coverings. 3. Construction activities that occur on unpaved surfaces will be discontinued during windy conditions when winds exceed 25 miles per hour and those activities cause visible dust plumes. Construction activities may continue if dust suppression measures are used to minimize visible dust plumes. 4. Track-out debris onto public paved roads shall not extend 50 feet or more from an active operation and track-out shall be removed or isolated such as behind a locked gate at the conclusion of each workday, except on agricultural fields where speeds are limited to 15 mph. 5. All hauling materials should be moist while being loaded into dump trucks. 6. All haul trucks hauling soil, sand, and other loose materials on public roads shall be covered (e.g., with tarps or other enclosures that would reduce fugitive dust emissions). 7. Soil loads should be kept below 6 inches or the freeboard of the truck. 8. Drop heights should be minimized when loaders dump soil into trucks. 9. Gate seals should be tight on dump trucks. 10. Traffic speeds on unpaved roads shall be limited to 25 miles per hour. 11. All grading activities shall be suspended when visible dust emissions exceed 20%. 12. Other fugitive dust control measures as necessary to comply with San Joaquin Valley Air Pollution Control District Rules and Regulations. 13. Disturbed areas should be minimized. 14. Disturbed areas should be re-vegetated as soon as possible after disturbance if area is no longer needed for oil and gas activities.				
	MM 4.3-3 All off-road construction diesel engines not registered under California Air Resources Board's Statewide Portable Equipment Registration Program, which have a rating of 50 horsepower or more, shall meet, at a minimum, the Tier 3 California Emission Standards for Off-road Compression-Ignition Engines as specified in California Code of Regulations, Title 13, section 2423(b)(1) unless that such engine is not available for a particular item of equipment. In the event a Tier 3 engine is not available for any off-road engine larger than 100 horsepower, that engine shall be equipped with retrofit controls that would provide nitrogen oxides and particulate matter emissions that are equivalent to	Delineated on Site Plan; During construction and operation	KC PCDD		
		Steps to Compliance: A. The Project Proponent shall take the specified steps to reduce exhaust emissions during construction. B. The Kern County Building Inspection Department will verify in the field during construction.			

<table>
<tr><th>Impact</th><th>Mitigation Measure</th><th>Time Frame for Implementation</th><th>Responsible Monitoring Agency</th><th>Date</th><th>Initials</th></tr>
<tr><td></td><td>Tier 3 engine.
a. All equipment shall be turned off when not in use. Engine idling of all equipment shall be limited to five minutes, except under exemptions specified in California Code of Regulations Title 13 Section 2449(d)(2)(A).
b. All equipment engines shall be maintained in good operating condition and in proper tune per manufacturers' specifications.</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>MM 4.3-4 To further reduce emissions of oxides of nitrogen from on-road heavy-duty diesel haul vehicles:
a. 2007 engines or pre-2007 engines shall comply with California Air Resources Board retrofit requirements set forth in California Code of Regulations Title 13 Section 2025.
b. All on-road construction vehicles, except those meeting the 2007/California Air Resources Board-certified Level 3 diesel emissions controls, shall meet all applicable California on-road emission standards and shall be licensed in the State of California. This does not apply to worker personal vehicles.
c. All on-road construction vehicles shall be properly tuned and maintained in accordance with the manufacturers' specifications.</td><td>Delineated on Site Plan; During construction and operation
Steps to Compliance:
A. The Project Proponent shall take the specified steps to reduce exhaust emissions during construction.
B. The Kern County Building Inspection Department will verify in the field during construction.</td><td>KC PCDD</td><td></td><td></td></tr>
<tr><td>4.3-2</td><td colspan="5">Implement MM 4.3-1 through MM 4.3-4 Steps to Compliance.</td></tr>
<tr><td>4.3-3</td><td>MM 4.3-5 Construction:
The Site Plan Application shall include a Site Vicinity Figure showing the location of any sensitive receptor(s) within 3,000 feet of the construction site (potential impact area) for the proposed new well or other ancillary facility or equipment (excluding pipelines).
a. If there are no sensitive receptors within this potential impact area, then no construction mitigation measures shall be required.
b. If there are sensitive receptors within the potential impact area, then additional information must be provided showing the setback from the closest edge of the well pad to the property line of the nearest sensitive receptor. The minimum distances shall be as follows:
<table>
<tr><th>Well Depth (Feet)</th><th>Minimum Setback Distance from Well Site to Adjacent Property Line of an Existing Sensitive Receptor (Feet)</th></tr>
<tr><td colspan="2">Western Subarea</td></tr>
<tr><td>10,000</td><td>367</td></tr>
<tr><td>5,000</td><td>116</td></tr>
</table></td><td>Delineated on Site Plan; During construction and operation
Steps to Compliance:
A. Submit a Site Plan Application including a Site Vicinity Figure
B. Submit additional information as applicable
C. Implement risk minimization measures as applicable</td><td>KC PCDD</td><td></td><td></td></tr>
</table>

Impact	Mitigation Measure	Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials

2,000	NA
Central Subarea	
10,000	367
5,000	116
2,000	NA
Eastern Subarea	
10,000	296
5,000	NA
2,000	NA

c. If the above setbacks cannot be met, and for existing wells, the Applicant shall provide a site-specific or other risk assessment to the San Joaquin Valley Air Pollution Control District, which may include implementation of one or more of the following risk minimization measures, or other such measures that are demonstrated by the Applicant to the San Joaquin Valley Air Pollution Control District, to achieve a level of risk less than the threshold risk level, and shall provide confirmation from the San Joaquin Valley Air Pollution Control District that the activity that is the subject of the application will not exceed the risk threshold:
   1. Placement of engines in the potential impact area away from the sensitive receptors.
   2. Utilize directional drilling to locate rig away further from the sensitive receptor(s).
   3. Use of late-model engines, low-emission diesel products, alternative cleaner fuels (e.g., natural gas or liquefied petroleum gas), engine retrofit technology, add-on devices such as diesel particulate filters or oxidation catalyst, and/or other options as such become available to reduce emissions from off-road and other equipment.
   4. Utilize electricity line power if available.
   5. Shutdown all equipment when not in use, and otherwise minimize engine idling by limiting idling to 15 minutes.
   6. Use of automatic rigs.
   7. Assist and pay to relocate residents to temporary lodging during well construction, drilling, and completion activities, if such

Impact	Mitigation Measure	Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
	residents voluntarily agree to such relocation.				
	MM 4.3-6 Applicants shall include in their Worker Environmental Awareness Program information on how to recognize the symptoms of Valley Fever and to promptly report suspected symptoms of work-related Valley Fever to a supervisor. Workers exposed to fugitive dust shall be provided with the option of using a filter fitted over their nose and mouth, secured by a strap, including training for appropriate mask practices as part of the Worker Environmental Awareness Training Program.	Provide with Application Package; During construction and operation	KC PCDD		
		Steps to Compliance: A. The Project Proponent shall include the required information into the Worker Environmental Awareness Program and the required options and training. B. The Kern County Planning and Community Development Department will verify in the field during construction and operation.			
4.3-4	**MM 4.3-7** Applicant shall submit an Odor Complaint Management Plan to the County prior to receiving its first Site Plan conformity review approval. The Plan shall include a designated contact for odor complaints, creation of a log for odor complaints, and protocol for handling odor complaints. The Odor log and report files shall be available for public review upon request.	Provide with Application Package; During construction and operation	KC PCDD		
		Steps to Compliance: A. Submit an Odor Complaint Management Plan to the Kern County Planning and Community Development Department; B. The Kern County Planning and Community Development Department will approve the Plan prior to issuing the oil and gas conformity review approval.			
4.3.5	Implement MM 4.3-1 through MM 4.3-4 Steps to Compliance.				
4.3-6	**MM 4.3-8** For criteria emissions, not required to be offset under a District rule as described in MM 4.3-1, and for Project vehicle and other mobile source emissions, the County will enter into an emission reduction agreement with the San Joaquin Valley Air Pollution Control District, pursuant to which the Applicant shall pay fees to fully offset Project emissions of oxides of nitrogen, reactive organic gases, and particulate matter of 10 microns or less in diameter (including as applicable mitigating for reactive organic gases by additive reductions of particulate matter of 10 microns or less in diameter) (collectively, "designated criteria emissions") to avoid any net increase in these pollutants. The air quality mitigation fee shall be paid to the County as part of the Site Plan review and approval process, and shall be used to reduce designated criteria emissions to fully offset Project emissions that are not otherwise required to be fully offset by District permit rules and regulations. As an alternative to paying the fee, an Applicant may reduce emissions for one or more designated criteria emissions through actual reductions in air emissions from other Applicant sources, as submitted to the County and validated by the District. This Project offset requirement alternative shall be enforced by the County and verified by San Joaquin Valley Air Pollution Control District, and	Provide with Application Package; During construction and operation	San Joaquin Valley Air Pollution Control District; KC PCDD		
		Steps to Compliance: A. The Project Proponent shall take the specified steps to reduce emissions according to the emission reduction agreement between the County and the San Joaquin Valley Air Pollution Control District. B. The San Joaquin Valley Air Pollution Control District will verify compliance with the offset requirements			

Impact	Mitigation Measure	Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
	must be approved in advance by the San Joaquin Valley Air Pollution Control District. If a voluntary emission reduction agreement is not executed by the County and San Joaquin Valley Air Pollution Control District, then each Applicant must mitigate for the full amount of designated criteria pollutants as verified by the San Joaquin Valley Air Pollution Control District, with evidence of such District-verified offsets presented as part of the Site Plan Conformity Review application documentation. Examples of feasible air emission reduction activities that may be funded by air quality fees paid by Applicant or proposed and implemented by the Applicant under the emission reduction agreement include, but are not limited to, the following: a. Replacing or retrofitting diesel-powered stationary equipment such as motors on generators, pumps and wells with electric or other lower-emission engines that are not subject to Title V reductions. b. Replacing or retrofitting diesel-powered school, transit, municipal and other community mobile sources such as buses, car fleets, and maintenance equipment, with electric or other lower-emission engines. c. Reducing emissions from public infrastructure sources such as water and wastewater treatment and conveyance facilities, and reducing water-related emissions through water conservation and reclamation. d. Funding lower-emission equipment and processes for local businesses, schools, non-profit and religious institutions, hospitals, city and county facilities.				
Biological Resources					
4.4.1	**MM 4.4-1** A qualified biologist shall conduct a biological reconnaissance survey in potential special-status species habitat to advise the project proponent of potential project impacts, potential surveying needs, and advise on the need for focused special status surveys. Early consultation with United States Fish and Wildlife Service and California Department of Fish and Wildlife would confirm the biologist's advice and/or inform project proponents of additional recommendations. Based on the information gathered from the biological reconnaissance survey and any informal consultation with United States Fish and Wildlife Service and California Department of Fish and Wildlife, focused/protocol surveys shall be conducted by a qualified or permitted biologist (whichever is applicable) well in advance of ground disturbing activities to determine the presence/absence of sensitive species protected by state and federal Endangered Species Acts and potential project impacts to those species. The survey shall be conducted in accordance with the most current standard protocol of United States Fish and Wildlife Service and California Department of Fish and Wildlife. The purpose of focused/protocol surveys is to confirm the presence or absence of any species listed as threatened or endangered under the federal Endangered Species Act, threatened or	Provide with Application Package; During construction and operation	California Department of Fish and Wildlife; U.S. Fish and Wildlife Service; KC PCDD		
		Steps to Compliance: A. A qualified biologist must conduct the surveys. B. A survey plan must be submitted to USFWS and the CDFW for approval prior to surveys. C. Results from the surveys must be submitted to the USFWS, CDFW and Kern County Planning and Community Development Department. D. The survey report must contain avoidance and minimization measures if sensitive species were documented within the survey area.			

Impact	Mitigation Measure		Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
		endangered under the California Endangered Species Act, rare or endangered in the California Native Plant Protection Act, or designated as fully-protected in the California Fish and Game Code (collectively, "Protected Species"), and to confirm the presence or absence of any other species considered "sensitive" under California Environmental Quality Act ("Sensitive Species"), and to identify and implement feasible avoidance and minimization measures for such species. The surveys shall be conducted in accordance with all currently-applicable presence and absence survey and/or species protocols established by the United States Fish and Wildlife Service and the California Department of Fish and Wildlife ("Species Protocols"). In the absence of any approved protocols, the survey shall extend for a minimum of 250 feet from all areas where any ground disturbance activities would occur, provided that permission to access has been obtained. As an alternative to individual pre-disturbance surveys for each application, and after consultation with and concurrence by the California Department of Fish and Wildlife and the United States Fish and Wildlife Service, multiple parcels or areas of oil and gas production lands (including lands which may have multiple surface or mineral ownership) may be consolidated for the purpose of more efficiently managing pre-disturbance surveys and determinations regarding the absence of protected species in areas of proposed new ground disturbance activities. A biological monitor shall be present during ground-disturbing activities in project locations that have special-status species habitat or are adjacent to potential special-status species habitat. Within 30 days before any ground disturbing activities in special-status species habitat, a qualified biologist shall conduct a pre-disturbance survey to record existing conditions of the site, determine if conditions have changed since the reconnaissance or focused/protocol surveys were conducted, and to determine where sensitive species avoidance buffers will be established.				
	MM 4.4-2	No incidental take of any species listed as threatened or endangered under the federal Endangered Species Act, threatened or endangered under the California Endangered Species Act, rare or endangered in the California Native Plant Protection Act, or designated as fully-protected in the California Fish and Game Code (Protected Species) may occur unless the incidental take is authorized by applicable state and federal wildlife agencies in the form of a permit or other written authorization, an approved state or federal conservation plan, or in accordance with an approved regional plan such as the Draft Valley Floor Habitat Conservation Plan and/or Natural Community Conservation Plan.	Provide with Application Package; During construction and operation	U.S. Fish and Wildlife Service; California Department of Fish and Wildlife; KC PCDD		
			Steps to Compliance: A. Obtain permits and/or written authorization from USFWS and CDFW. B. The Kern County Planning and Community Development Department will verify documents and consistence with the Draft Valley Floor Habitat Conservation Plan and/or Natural Community Conservation Plan.			
	MM 4.4-3	Protective buffers shall be used, where effective and feasible in the opinion and guidance of the qualified biologist, to avoid any unauthorized incidental take of	Provide with Application Package;	U.S. Fish and Wildlife Service;		

<table>
<tr><th>Impact</th><th>Mitigation Measure</th><th>Time Frame for Implementation</th><th>Responsible Monitoring Agency</th><th>Date</th><th>Initials</th></tr>
<tr><td></td><td>Protected Species, and to minimize any incidental take of Sensitive Species, by separating the planned disturbance area from any locations where biological reconnaissance surveys, previously conducted focused/protocol surveys, or pre-disturbance surveys have detected the presence of Protected Species or Sensitive Species. Protective buffers shall be delineated using brightly colored stakes and/or flagging or similar materials and remain until construction activities are complete, at which time of completion the buffers must be removed. If special-status plant or animal species are found adjacent to the project during biological surveys, protective buffers shall be established around active dens and/or burrows of special-status animal species, or populations of special-status plant species to avoid unauthorized take of protected species as listed in the table below. The protective buffer distance shall be increased if required to avoid unauthorized incidental take of any Protected Species as determined by a qualified biologist. Protective buffer distances and other avoidance measures that may be implemented to avoid impacts to Protected Species or Sensitive Species must be consistent with the United States Fish and Wildlife Service and/or the California Department of Fish and Wildlife, and shall be implemented and overseen by a qualified biologist.

Table: Disturbance Buffers for Sensitive Resources
<table><tr><th>Sensitive Resource</th><th>Buffer Zone from Disturbance (feet)</th></tr><tr><td>Potential San Joaquin kit fox den</td><td>50</td></tr><tr><td>Known San Joaquin kit fox den</td><td>100</td></tr><tr><td>Natal San Joaquin kit fox den</td><td>Contact California Department o Fish & Wildlife, United States Fish & Wildlife Service</td></tr><tr><td>Atypical San Joaquin kit fox den</td><td>50</td></tr><tr><td>Rodent burrows</td><td>50</td></tr><tr><td>Listed bird species active nests</td><td>0.5 mile</td></tr></table></td><td>During construction and operation</td><td>California Department of Fish and Wildlife; KC PCDD</td><td></td><td></td></tr>
<tr><td colspan="6">Steps to Compliance:
A. The Applicant shall implement measures related to exclusion barriers or buffers as specified in the mitigation measures.
B. The Kern County Planning and Community Development Department will verify.</td></tr>
</table>

Impact	Mitigation Measure		Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
	Burrowing owl burrow (breeding and non-breeding season)	Pursuant to California Department of Fish & Wildlife guidelines (see Table 4.4-85)				
	San Joaquin coachwhip, silvery legless lizard, coast horned lizard	30				
	American badger: Non-maternity dens Maternity dens	 50 200				
	Special-status plants	50				
MM 4.4-4	Occupied burrowing owl burrows shall not be disturbed during the species nesting season (February 1 through August 31). The following distances shall be maintained between all disturbance areas and burrowing owl nesting sites (Table 4.4-85).		Provide with Application Package; During construction and operation	U.S. Fish and Wildlife Service; California Department of Fish and Wildlife; KC PCDD		

Table 4.4-85: Setback Distances for Burrowing Owl Nesting Sites by Level of Proposed Project Impacts

Location		
Nesting sites	Nesting sites	Nesting sites
Time of Year		
April 1–Aug 15	Aug 16–Oct 15	Oct 16–Mar 31
Project Impact Level		
Low		
656 feet (200 meters)	656 feet (200 meters)	164 feet (50 meters)
Medium		
1,640 feet (500 meters)	656 feet (200 meters)	328 feet (100 meters)
High		
1,640 feet (500 meters)	1,640 feet (500 meters)	1,640 feet (500 meters)

Steps to Compliance:

A. The Applicant shall implement measures related to nesting windows and buffer set-backs from nest sites as specified in the mitigation measures.

B. The Kern County Planning and Community Development Department will verify.

C. If passive relocation techniques are implement ted the Applicant must follow the *Staff Report on Burrowing Owl Mitigation Guidelines*.

D. If passive relocation or an alternative is implemented a burrowing owl management plan must be prepared and approved by the California Department of Fish and Wildlife.

E. The Kern County Planning and Community Development Department will verify.

Impact	Mitigation Measure	Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
	Burrowing owls present in proposed disturbance areas or within 500 feet or as specified under an approved Habitat Conservation Plan (as identified during pre-disturbance surveys) outside of the breeding season (between September 1 and January 31) may be moved away from the disturbance area using passive relocation techniques approved by the California Department of Fish and Wildlife. Passive relocation techniques in the California Department of Fish and Wildlife *Staff Report on Burrowing Owl Mitigation Guidelines* (California Department of Fish and Game 2012) include installing one-way doors in burrow entrances for 48 hours, to ensure the owl(s) have left the burrow, daily monitoring during the passive relocation period, and collapsing existing burrows to prevent reoccupation. A minimum of one or more weeks will be required to relocate the owl(s) and allow for acclimatization to alternate off-site burrows. Prior to burrow exclusion or eviction, a burrowing owl management plan shall be prepared and approved by the California Department of Fish and Wildlife. Destruction of burrows shall occur only pursuant to a management plan for the species approved by the California Department of Fish and Wildlife; burrow excavation shall be conducted by hand whenever possible. As an alternative to passive relocation, occupied burrows identified off-site within 500 feet of construction activities may be buffered with hay bales, fencing (e.g. sheltering in place), or as directed by the qualified biologist and the California Department of Fish and Wildlife, to avoid disturbance of burrows.				
	MM 4.4-5 The pre-disturbance surveys shall determine whether active bat maternity roosts are located in or within 250 feet of any disturbance area. All active bat maternity roosts shall be avoided during breeding periods, including postponing disturbance activities if required, and to the maximum extent feasible at other times. If an active bat maternity roost location cannot feasibly be avoided by disturbance, the United States Fish and Wildlife Service and California Department of Fish and Wildlife must be contacted to identify appropriate impact minimization measures prior to initiating any disturbance that would affect the roost.	Provide with Application Package; During construction and operation	U.S. Fish and Wildlife Service; California Department of Fish and Wildlife; KC PCDD		
		Steps to Compliance: A. Conduct pre-disturbance surveys as specified in the mitigation measure. B. If avoidance of bat maternity roosts is not feasibly contact the USFWS and CDFW for appropriate minimization measures and approval prior to ground disturbing activities. C. The Kern County Planning and Community Development Department will verify.			
	MM 4.4-6 Any potential San Joaquin kit fox dens (as defined in United States Fish and Wildlife Service 2011) detected during reconnaissance or focused/protocol surveys shall be reevaluated for species activity no more than 30 days prior to the commencement of ground disturbance. Potential kit fox dens shall be marked and a 50-foot avoidance buffer shall be delineated using brightly	Provide with Application Package; During construction and operation	U.S. Fish and Wildlife Service; California Department of Fish and Wildlife;		

Impact	Mitigation Measure		Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
		colored stakes and flagging or similar materials to prevent inadvertent damage to the potential den. If a potential den cannot feasibly be avoided, the den may be hand excavated in accordance with the United States Fish and Wildlife Service *Standardized Recommendations for Protection of the Endangered San Joaquin Kit Fox Prior to or During Ground Disturbance* (United States Fish and Wildlife Service 2011). If species activity is detected, the location shall be identified as a "known" kit fox den in accordance with the U.S. Fish and Wildlife Service species guidelines (United States Fish and Wildlife Service 2011). A minimum 100-foot buffer from any disturbance area shall be maintained for known dens and a minimum 500-foot buffer from any disturbance area shall be maintained for natal dens. No excavation of a known or natal den shall occur without prior authorization from the United States Fish and Wildlife Service and the California Department of Fish and Wildlife. For activities occurring on land covered under an approved federal and/or State incidental take authorization, the requirements set forth in those documents shall be implemented. Other standard measures to protect San Joaquin kit fox, including capping pipes, covering trenches, adding exit ramps to excavated areas, shall be implemented in accordance with MM 4.4-15.		KC PCDD		
			Steps to Compliance: A. The Applicant shall conduct pre-disturbance surveys as specified in the mitigation measure. B. If den buffers or avoidance is not feasible; the Applicant must consult and obtain approval from the USFWS and CDFW. C. The Applicant shall implement the USFWS *Standardized Recommendation for Protection of the Endangered San Joaquin Kit Fox Prior to or During Ground Disturbance* if a den cannot feasibly be avoided. D. Implement Habitat Conservation Plan measures if activity occurs on covered lands. E. The Kern County Planning and Community Development Department will verify.			
	MM 4.4-7	Occupied American badger dens detected during pre-disturbance surveys shall be flagged and ground-disturbing activities avoided within 50 feet of the den. Maternity dens shall be avoided and a minimum 200-foot buffer from disturbance shall be maintained during pup-rearing season (February 15 through July 1). Maternity dens must be avoided to the maximum extent feasible. If a maternity den cannot feasibly be avoided, the California Department of Fish and Wildlife must be contacted to identify appropriate impact minimization measures prior to initiating any disturbance that would affect the den, including potential passive relocation by excavation before or after the rearing season.	Provide with Application Package; Provide with Application Package; During construction and operation	U.S. Fish and Wildlife Service; California Department of Fish and Wildlife; KC PCDD		
			Steps to Compliance: A. The Applicant shall conduct pre-disturbance surveys as specified in the mitigation measure. B. Implement avoidance measures as specified in the mitigation measure. C. Consult with CDFW if maternity dens cannot be feasibly avoided. D. The Kern County Planning and Community Development Department will verify.			
	MM 4.4-8	Pre-disturbance surveys for all sites located above 2,000 feet in elevation, or within 200 feet down gradient from the 2,000-foot elevation contour line, shall specifically survey for any golden eagle nests located within 2 miles of the site. If golden eagle nests are detected by the surveys, the qualified biologist shall conduct a nest-specific viewshed analysis. No disturbance may occur within 0.25 mile, or within 0.5 mile of the viewshed of an active golden eagle nest unless otherwise authorized by State and federal wildlife agencies. The United States Fish and Wildlife Service and California Department of Fish and Wildlife must be notified prior to the commencement of any disturbance activities within 1 mile of an active golden eagle nest to avoid golden eagle take.	Provide with Application Package; During construction and operation	U.S. Fish and Wildlife Service; California Department of Fish and Wildlife; KC PCDD		
			Steps to Compliance: A. The Applicant shall conduct pre-disturbance surveys as specified in the mitigation measure. B. Implement avoidance measures as specified in the mitigation			

Impact	Mitigation Measure	Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
		measure. C. Consult with USFWS and CDFW if nest buffers cannot be feasibly avoided. D. The Applicant must provide documentation in writing that consultation with USFWS and CDFW was conduct for project activities within a nest buffer. E. The Kern County Planning and Community Development Department will verify.			
	MM 4.4-9 All sites located above 2,000 feet in elevation, or within 200 feet down gradient from the 2,000-foot elevation contour line, shall implement the following measures to avoid and minimize potential adverse impacts to the California condor: a. The site shall, at all times, be maintained to avoid any trash, debris, food sources and microtrash, such as bottle caps, that could be ingested by or attract California condor. Trash shall be disposed in animal-proof containers as required in BIO 4.4-19. b. The Worker Environmental Awareness Program described in BIO MM 4.4-18 shall include information about microtrash and potential effects to California condor, and shall prohibit the disposal of trash (and microtrash) on the site of oil and gas activities. c. If a condor is observed in a proposed construction site, all disturbance activities must immediately cease within 500 feet of the condor until the animal has moved from the site. If condor occurrence persists, the United States Fish and Wildlife Service and the California Department of Fish and Wildlife must be contacted to identify appropriate avoidance measures prior to initiating or resuming any disturbance activity. d. All condor observations shall be reported within 24 hours to the United States Fish and Wildlife Service and the California Department of Fish and Wildlife. e. All tanks, liquid storage facilities, and any open area containing water or other liquid materials, including drilling sumps, must be covered or otherwise shielded in a manner that prevents condor intrusion and potential entrapment. f. No overhead transmission lines may be used at the site without the prior approval of the United States Fish and Wildlife Service and the California Department of Fish and Wildlife.	Provide with Application Package; During construction and operation	U.S. Fish and Wildlife Service; California Department of Fish and Wildlife; KC PCDD		
		Steps to Compliance: A. A qualified biologist shall monitor all construction activities for impacts to the California condor. B. The Applicant shall train workers on the issue of trash, debris, food sources and microtrash – what it is, and its potential effects to the California condors. C. The Applicant shall implement the Workers Environmental Awareness Program prior to the start of construction. D. The Applicant shall report all California condor sightings during construction to the USFWS and CDFW, and Kern County Planning and Community Development Department. E. The Applicant shall provide written documentation the Kern County Planning and Community Development Department showing implementation of additional measures specified in the mitigation measures.			
	MM 4.4-10 Pre-disturbance surveys for active bird nests must be conducted no more than 10 days prior to the commencement of disturbance. Surveys shall follow United States Fish and Wildlife and California Department of Fish and Wildlife guidance and/or protocols, as applicable. If no active nests or nesting birds are identified, then Project construction activities may proceed and no further	Provide with Application Package; During construction and operation	U.S. Fish and Wildlife Service; California Department of Fish and Wildlife;		

Impact	Mitigation Measure	Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
	mitigation measures for nesting birds are required. If active nest(s) are identified, the active nest(s) should be continuously surveyed for the first 24 hours after detection, to establish a behavioral baseline prior to any construction-related activities. Once construction commences, all nests shall be continuously monitored to detect any behavioral changes as a result of the Project (i.e., nest avoidance or abandonment). If behavioral changes are observed, the work causing that change should cease and the California Department of Fish and Wildlife and the United States Fish and Wildlife should be consulted for additional avoidance and minimization measures. If continuous monitoring of identified nests by a qualified wildlife biologist is not feasible, a minimum no-disturbance buffer of 250 feet will be established around active nests and a 500-foot no-disturbance buffer around the nests of raptors until the breeding season has ended, or until a qualified biologist has determined that the birds have fledged and are no longer reliant upon the nest or parental care for survival, and any adult birds are no longer occupying the nest. Variance from these no-disturbance buffers may be implemented a qualified biologist concludes that work within the buffer area would not cause nest avoidance or abandonment (e.g., when the disturbance area would be concealed from a nest site by topography). The California Department of Fish and Wildlife and the United States Fish and Wildlife must be notified in advance of implementing of a variance in the no-disturbance buffer.		KC PCDD		
		Steps to Compliance: A. The Applicant shall conduct pre-disturbance surveys as specified in the mitigation measure. B. Implement avoidance measures as specified in the mitigation measure C. A qualified biologist shall monitor all construction activities for impacts to active bird nests if nest buffers cannot be implemented. D. The Applicant shall provide written documentation and approval of variance from the no-disturbance areas to Kern County Planning and Community Development Department. E. The Kern County Planning and Community Development Department will verify prior to issuing NTP or permits.			
	MM 4.4-11 The following measures will be implemented to avoid take of blunt-nosed leopard lizard and to ensure protection of these animals during Project activities: a. Project activities will avoid all potential burrows that may be occupied by blunt-nosed leopard lizards. Suitable burrows within and adjacent to potential habitat for the species should be avoided by a minimum distance of 50-feet in all areas where ground-disturbing Project activities will occur. b. No more than one year prior to ground disturbing activities, focused surveys following current California Department of Fish and Wildlife and United States Fish and Wildlife protocols for detection of this species or other methods approved by both agencies shall be conducted in all potential blunt-nosed leopard lizard habitat within the work site and a 250-foot buffer area. If no individual blunt-nosed leopard lizards are observed during focused surveys, and surveys are current (e.g., completed in the same calendar year), then Project activities may proceed. c. If blunt-nosed leopard lizards are detected during focused surveys, a blunt-nosed leopard lizard avoidance plan shall be prepared for the Project that will result in avoidance of incidental take of this species unless take is separately authorized under a Natural Communities	Provide with Application Package; During construction and operation	U.S. Fish and Wildlife Service; California Department of Fish and Wildlife; KC PCDD		
		Steps to Compliance: A. The Applicant shall conduct focused surveys as specified in the mitigation measure. B. Implement avoidance measures as specified in the mitigation measure C. A qualified biologist shall monitor all construction activities except during periods of inactivity (the winter season). D. The Applicant shall provide avoidance plan if blunt-nosed leopard lizards were detected during focused surveys. E. Implement the Worker Environmental Awareness Program. F. Implement additional measures as described in the mitigation measure. G. The Kern County Planning and Community Development Department will verify prior to issuing NTP or permits.			

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	Conservation Plan and appropriate federal authorization is obtained. At a minimum, the blunt-nosed leopard lizard avoidance plan shall be provided to the California Department of Fish and Wildlife and the County, and shall contain the following elements: 1. A Worker Environmental Awareness Program shall be implemented for all construction personnel before construction begins (see MM 4.4-18). 2. During periods that are optimal for blunt-nosed leopard lizard activity (early spring through late fall), a qualified biologist will be present during all ground disturbing activities. The qualified biologist will check the Project site(s) and access route(s) daily during the blunt-nosed leopard lizard active season to determine presence or absence of lizards in or near the work areas. Monitoring by a qualified biologist is not required during periods of inactivity (the winter season). 3. All open trenches or excavations shall be covered at the end of each workday or protected with the use of exclusion fencing to prevent wildlife entrapment. If an excavation is too large to cover, escape ramps shall be installed at an incline ratio of no greater than 2:1. All trenches and pipes shall be inspected for the presence of wildlife each day prior to the commencement of work. If blunt-nosed leopard lizards are observed at the work site during construction, construction shall cease within a 250-foot radius and the United States Fish and Wildlife Service and the California Department of Fish and Wildlife shall be consulted to determine what additional measures would be necessary to prevent take of this species. 4. Offsite locations where blunt-nosed leopard lizards have been observed or are likely to occur shall be clearly marked to prevent workers from driving off the road and to prevent inadvertent destruction of burrows. Barriers, such as exclusionary fencing may be installed. All construction equipment and construction personnel vehicles will be checked prior to moving to ensure no blunt-nosed leopard lizard are under equipment/vehicles. 5. A speed limit of 10 miles per hour shall be posted and observed within 0.25 miles of any reported blunt-nosed leopard lizard observation. 6. Construction activities shall avoid burrows that may be used by blunt-nosed leopard lizards. Any location of proposed construction activity with potential to collapse or block burrows (i.e., stockpile storage, parking areas, staging areas, trenches) will be identified prior to construction in the blunt-nosed leopard lizard avoidance				

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	plan and approved by the qualified biologist. The qualified biologist may allow certain activities in burrow areas if the combination of soil hardness and activity impact is not expected to collapse burrows and no blunt-nosed leopard lizards have been found during pre-Project surveys in the impact area. 7. All individual blunt-nosed leopard lizards observed above-ground will be avoided. Any individual blunt-nosed leopard lizard that may enter the Project site(s) would be allowed to leave unobstructed, and on its own accord. If a blunt-nosed leopard lizard is detected during biological monitoring or observed at any other point, the California Department of Fish and Wildlife and the United States Fish and Wildlife Service shall be notified to determine what additional measures would be necessary to prevent take of the species.				
	MM 4.4-12 The Applicant shall comply with the following: a. Plant surveys for Protected Species and Sensitive Species must be completed by a qualified biologist during the appropriate blooming periods for species identification and detection. Plant surveys shall be conducted in accordance with all applicable protocols established by the United States Fish and Wildlife Service and the California Department of Fish and Wildlife for particular plant species ("Plant Survey Protocol"), and shall extend 50 feet from areas where any new disturbance would occur unless a greater survey distance is specified in the Plant Survey Protocol. All detected plant populations of Protected Species and Sensitive Species shall be identified in the field during the surveys with temporary flags or other appropriate materials to avoid and minimize impacts to the plant populations from any disturbance activities. b. No incidental take or relocation of any plant listed under the federal Endangered Species Act, the California Endangered Species Act, or the California Native Plant Protection Act may occur unless the incidental take is authorized by the United States Fish and Wildlife Service and/or the California Department of Fish and Wildlife in a permit or other authorization, or in an approved Habitat Conservation Plan or Natural Communities Conservation Plan. If focused plan surveys detect the presence of any listed plant, the plant populations shall be buffered from disturbance activities by implementing applicable impact avoidance protocols established by the United States Fish and Wildlife Service and/or the California Department of Fish and Wildlife unless incidental take authority is obtained. Projects covered under incidental take authority shall conduct activities in accordance with the take authorization. The California Department of Fish and	Provide with Application Package; During construction and operation	U.S. Fish and Wildlife Service; California Department of Fish and Wildlife; KC PCDD		
		Steps to Compliance: A. The Applicant shall conduct botanical surveys as specified in the mitigation measure. B. Implement avoidance measures as specified in the mitigation measure. C. Implement additional measures as identified in the mitigation measure. D. The Kern County Planning and Community Development Department will verify prior to issuing NTP or permits.			
		Prior to ground-disturbing activities	U.S. Fish and Wildlife Service; California Department of Fish and Wildlife; KC PCDD		
		Steps to Compliance: A. The Applicant shall implement measures related to rare plants as specified in the mitigation measure. B. The Kern County Planning and Community Development Department will verify.			

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	Wildlife may be contacted to determine the appropriate buffer required to prevent incidental take of a listed plant if avoidance protocols have not been established for the species. The qualified biologist shall confirm that all applicable listed plant buffers have been implemented prior to the commencement of any disturbance activity. c. If any non-listed sensitive plant species are identified that may be impacted by new ground disturbing activities, populations must be avoided by a 50-foot buffer.				
	MM 4.4-14 A Worker Environmental Awareness Program shall be developed and implemented for all personnel that could access the site prior to commencing any disturbance activities. The program shall consist of an on-site or center presentation that will describe the locations and types of sensitive plant, wildlife, and sensitive natural communities (collectively, "Biological Resources") on and near the site, an overview of the laws and regulations governing the protection of Biological Resources, the reasons for protecting the Biological Resources, the specific protection and avoidance measures that are applicable to the site, and the identity of designated points of contact should questions or issues arise, including the qualified biologist. The program shall provide training to recognize, avoid and report to applicable qualified biologists any Biological Resources on the site. a. The Worker Environmental Awareness Program shall emphasize the need to avoid contact with onsite wildlife, and avoid entry into areas where Biological Resources have been identified based on pre-disturbance field surveys and to implement the buffer avoidance or other protection measures established by the United States Fish and Wildlife Service shall be identified California Department of Fish and Wildlife or required by the Biological Resource mitigation measures. The training shall emphasize the importance of not feeding or domesticating wildlife and the need to avoid any trash, microtrash, or potential food disposal onsite except in animal-proof containers emptied daily to avoid attracting, or causing adverse impacts to special status wildlife. b. All onsite personnel must sign a statement verifying that they have completed the Worker Environmental Awareness Program, and that they understand and agree to implement the biological requirements for the worksite. If signed employee statements are not available, documentation may be provided by Worker Environmental Awareness Program training records, which shall be kept by the Applicant for a minimum of 5 years. Each Applicant shall maintain a list of all persons who have completed the training program, and shall provide the list to the County or to state and federal wildlife agency representatives upon request.	Provide with Application Package; During construction and operation	KC PCDD		
		Steps to Compliance: A. The Applicant shall implement measures related to Worker Environmental Awareness Program as specified in the mitigation measure. B. The Kern County Planning and Community Development Department will verify.			

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	MM 4.4-15 The following additional measures shall be implemented to avoid and minimize potential significant adverse impacts to Protected and Sensitive Species: a. All vehicles shall observe a 20-mile-per-hour speed limit in all areas of disturbance and on unpaved roads unless otherwise posted. Off-road traffic outside of designated access routes is prohibited. Speed limit signs shall be posted in visible locations at the point of site entry and at regular intervals on all unpaved access roads. b. All disturbance activities, except emergency situations or drilling that may require continuous operations, shall only occur during daylight hours. Night time disturbance activity for drilling purposes shall use directed lighting, shielding methods, or reduced lumen intensity to avoid unnecessary visual disturbance to wildlife and to comply with applicable lighting mitigation measures. c. All food-related trash items and all forms of microtrash, such as wrappers, cans, bottles, bottle tops, and food scraps shall be disposed of in closed, animal proof containers and removed daily from the site. d. Excavations, spoils piles, access roadways, and parking and staging areas shall subject to dust control as set forth in the dust control mitigation measures. e. The use of herbicides for vegetation control shall be restricted to those approved by the United States Fish and Wildlife Service and the California Department of Fish and Wildlife. No rodenticides shall be used on any site unless approved by the United States Fish and Wildlife Service, and the California Department of Fish and Wildlife, and shall observe label and other restrictions mandated by the United States Environmental Protection Agency, California Department of Food and Agriculture, and state and federal laws and regulations. For split estates, no herbicides for vegetation control may occur in Tier 2 areas without surface owner approval. f. No plants or wildlife shall be collected, taken, or removed from the site or any adjacent locations except as necessary for Project-related vegetation removal or wildlife relocation by a qualified biologist and subject to all applicable permits and authorizations. g. All open trenches or excavations shall be covered at the end of each workday to prevent wildlife entrapment. If an excavation is too large to cover, escape ramps shall be installed at an incline ratio of no greater than 2:1. All trenches and pipes shall be inspected for the presence of wildlife each day prior to the commencement of work. h. To enable San Joaquin kit foxes and other wildlife to pass through the Project site, any perimeter fencing shall include a 4- to 8-inch opening between the fence mesh and the ground or the fence shall be raised 4 inches above the ground except blunt-nosed leopard lizard exclusion	Provide with Application Package; During construction and operation	KC PCDD		
	Steps to Compliance: A. The Applicant shall implement measures related to protected and sensitive species as specified in the mitigation measure. B. The Kern County Planning and Community Development Department will verify.				

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	fencing. The bottom of the fence fabric shall be knuckled (wrapped back to form a smooth edge) to protect wildlife. i. All vertical tubes used in Project construction and chain link fencing poles, shall be temporarily or permanently capped to avoid the entrapment and death of special-status wildlife and birds. All pipes 1.5 inches or greater in diameter stored overnight on a project location must have end caps or other physical barriers that prevent wildlife from entering the pipe. j. All dead or injured special status wildlife shall be left in place and reported to the United States Fish and Wildlife Service and the California Department of Fish and Wildlife within 48 hours of discovery for rescue or salvage. Discovery of state or federal listed species that are injured or dead shall also be managed consistent with regulatory requirements, including being reported immediately via telephone and within 24 hours in writing, and with a copy to Kern County Planning and Community Development. k. All drilling installations and operations will comply at all times with the applicable federal, State, county, and local law ordinances and regulations. l. All activity shall use previously disturbed areas to the maximum extent feasible to minimize the amount of new disturbance. m. All concrete and asphalt debris should be removed from the site for recycling or proper disposal. n. No vehicles or construction equipment shall be parked within a wetland or waterbody/dry wash. o. Tracked vehicles and other construction equipment must be washed or maintained to be weed-free prior to entering and working within areas of new disturbance. p. All washing of trucks, paint, equipment, or similar activities should occur in areas where runoff is fully contained for collection and offsite disposal. Wash water may not be discharged from the site and shall be located at least 100 feet from any water body, or sensitive Biological Resources. q. Locate all extra work areas (such as staging areas and additional spoil storage areas) at least 50 feet away from wetland boundaries or waterbody, except where the adjacent upland consists of cultivated or rotated cropland or other disturbed land. r. All areas that must be avoided as result of the pre-disturbance surveys, and areas where new disturbance will occur, shall be clearly delineated by fencing or staking and flagging and/or rope or cord. s. No firearms shall be allowed on any site. t. No pets shall be allowed on any site.				

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	u. No smoking may occur except in designated areas. v. If ground disturbance is intended to be temporary and does not occur on cultivated and crop lands, perform topsoil segregation during construction activities to preserve the seed bank for restoration efforts. Store the segregated topsoil separate from the subsoil and restore segregated topsoil to its original location.				
	MM 4.4-16 Ground disturbance shall be mitigated at a 1.0 to 1.0 ratio (one-acre of new disturbance shall require one-acre of mitigation) except in Tier 1 areas that contain existing disturbance of 70% or greater which shall be mitigated at a 1.0 to 0.5 ratio (one-acre of new disturbance shall require one-half acre of mitigation), for the land included in the Site Plan. This compensatory mitigation requirement does not apply to construction on ground for which compensatory mitigation has already been provided, or on ground that has been previously disturbed (e.g., cleared of vegetation for other oil and gas extraction uses, existing unpaved roads, and existing unvegetated well pads). Ground disturbance activities that are authorized by permits or other written authorizations approved by the United States Fish and Wildlife Service and the California Department of Fish and Wildlife, which include avoidance and compensatory mitigation acreage requirements, may be used to satisfy this County compensatory mitigation ratio. Compensatory mitigation shall be required for the actual acreage of ground disturbance documented during the site plan review and completion process. New disturbance mitigation may be satisfied by one or a combination of the following measures: a. The recordation of a conservation easement or similar permanent, long-term conservation management agreement in a form acceptable to the County for land within the Project Area on land that has mitigation value. The easement lands may be owned by an Applicant or a third party under contract with an Applicant. Larger land areas may be placed under a conservation easement or similar agreement, and an Applicant may "draw down" the conserved land as needed to satisfy the acreage mitigation requirements for multiple site plan review conformity permits or other authorizations from the County for oil and gas activities. b. Acquisition of land preservation credits from a mitigation bank located within the Project Area which is owned by the County, on other lands approved by the County, or on lands approved for mitigation or conservation purposes by the United States Fish and Wildlife Service or the California Department of Fish and Wildlife. c. Removal of legacy oil and gas equipment, inclusive of compliance with applicable legal requirements (e.g., well plugging and abandonment requirements under state or federal regulations), restoration of the surface grade to be consistent with surrounding	Provide with Application Package; During construction and operation **Steps to Compliance:** A. The Applicant shall implement measures related to mitigation ratios as specified in the mitigation measure. B. The Applicant shall implement the additional measures specified in the mitigation measure. C. The Kern County Planning and Community Development Department will verify.	U.S. Fish and Wildlife Service; California Department of Fish and Wildlife; KC PCDD		

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	lands, complete a reseeding effort using native species, and notification of the site owner (if not the Applicant) of the completion of the removal and grading restoration work. d. Enhancement or restoration of existing habitat on lands already subject to a conservation easement or similar agreement, or which become subject to a conservation easement or similar agreement subsequent to the certification of this Environmental Impact Report, provided that such activities are covered in a permit or authorization, conservation plan, Habitat Conservation Plan, or Natural Community Conservation Plan, approved by the United States Fish and Wildlife Service or the California Department of Fish and Wildlife. e. Payment of a biological resources mitigation fee for the acquisition and management of mitigation lands, legacy equipment removal, and/or land enhancement already subject to conservation easements or a similar agreements under the terms of any biological resource mitigation program that is adopted by Kern County and approved by the United States Fish and Wildlife Service or the California Department of Fish and Wildlife. The County shall coordinate with the United States Fish and Wildlife Service or the California Department of Fish and Wildlife to identify priority conservation areas and potential conservation partners and funding sources to increase the efficiency and effectiveness of mitigation fee expenditures.				
4.4.2	Implement MM 4.4-1 through 4.4.18, described above, and dust control, spill and hazardous material avoidance and containment, and surface and subsurface water quality and hydrology mitigation measures.				
	MM 4.4-17 Pre-disturbance surveys shall be conducted by a qualified biologist during the appropriate periods for detecting Sensitive Natural Communities that could occur within the Project Area. The surveys shall be completed consistent with applicable protocols approved by the United States Fish and Wildlife Service and/or the California Department of Fish and Game, including the Protocols for Surveying and Evaluating Impacts to Special Status Native Plant Populations and Natural Communities (California Department of Fish and Wildlife 2009). The qualified person shall map and identify all sensitive natural communities, including riparian communities that occur in or within 100 feet of any new disturbance area. The site plan for the proposed activity shall identify waters, wetlands, resources subject to section 1600 of the CFGC, and other riparian habitats that occur in and within 100 feet of the disturbance area.	Provide with Application Package; During construction and operation	U.S. Fish and Wildlife Service; California Department of Fish and Wildlife; KC PCDD		
		Steps to Compliance: A. The Applicant shall conduct pre-disturbance surveys as specified in the mitigation measure. B. The Applicant shall submit a site plan identifying all waters, wetlands and other riparian habitats as specified in the mitigation measure. C. The Kern County Planning and Community Development Department will verify.			
	MM 4.4-18 No land disturbance activity in any Sensitive Natural Community that requires a state or federal permit, including state or federally regulated wetlands and waters, shall occur unless the activity is specifically authorized by the issuance	Provide with Application Package; During construction and	U.S. Fish and Wildlife Service; California		

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	of permits or approvals as required by state and federal law. This provision is not intended to restrict survey activities or restrict permit approvals for such disturbance activities. However, no new wells, tanks, sumps or ponds shall be constructed within 50 feet of federal or state waters or wetlands.	operation	Department of Fish and Wildlife; KC PCDD		
4.4-3	Implementation of the Biological Resources mitigation measures would ensure that oil and gas activities would not disturb state or federally regulated wetlands and waters unless the activity is specifically authorized by the issuance of permits or approvals as required by state and federal laws and that activities in the vicinity of wetlands and water bodies would not adversely disturb them. Other mitigation measures identified in this Environmental Impact Report would further reduce potential state or federally jurisdictional wetland and waters, including dust control, spill and hazardous material avoidance and containment, surface and subsurface water quality and hydrology, mitigation measures.	**Steps to Compliance:** A. The Applicant shall implement the measures specified in the mitigation measure. B. The Kern County Planning and Community Development Department will verify.			
4.4-4	Implementation of the Biological Resources mitigation measures would reduce wildlife movement impacts. Other mitigation measures identified in this Environmental Impact Report to further reduce wildlife movement impacts, include dust control, nighttime lighting, noise controls, spill and hazardous material avoidance and containment,, and surface and subsurface water quality and hydrology (including but not limited to Kern River and Poso Creek channels), measures.				
4.4-5	**MM 4.4-19** In the event that new disturbance would occur at a site within an oak woodland area as defined in Section 1.10.10 of the Kern County General Plan Land Use, Open Space and Conservation Element (10% or greater oak tree cover), the Applicant shall comply with the minimum 30% canopy retention standard in Section 1.10.10 KK (a). Impacts to oak trees in other locations, and in locations that meet the criteria for an oak woodland area, shall be avoided to the maximum extent practicable, including modification of the disturbance area, if feasible, to avoid existing oak trees within a site.	Provide with Application Package; During construction and operation	KC PCDD		
		Steps to Compliance: A. The Applicant shall implement the measures specified in the mitigation measure. B. The Kern County Planning and Community Development Department will verify.			
4.4-6	**MM 4.4-20** Applicants shall fund through the Site Conformity Review administrative fee, preparation by Kern County of, an annual report describing the Project's ground disturbance acreage, and the acreage of compensatory mitigation lands, in each sub-area. For Covered Activities within areas included in proposed HCPs, the requirements of MM 4.4-1 – 4.4-19 may be superseded by specific requirements imposed by USFWS as part of approval of a federal incidental take permit (e.g., under Section 10 or Section 7 of the Endangered Species Act), or by CDFW as part of approval of a state incidental take permit (e.g., under the Fish and Game Code), provided that USFWS (in the case of a federal incidental take permit) or CDFW (in the case of a state incidental take permit) concludes in writing that such requirements provide equivalent or greater protection than MM 4.4-1 – 4.4-19 (or any subset thereof).	Provide with Application Package; During construction and operation	KC PCDD		
		Steps to Compliance: A. The Applicant shall implement the measures specified in the mitigation measure. B. The Kern County Planning and Community Development Department will verify.			
4.4-7	Implement MM 4.4-1 through MM 4.4-20 Steps to Compliance.				

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Cultural Resources					
4.5-1	**MM 4.5-1** Prior to initiating ground disturbance activities for an activity for which a conformity review is required, the Applicant shall: a. Provide an archival records search completed by a qualified archaeologist. This shall include an examination of the California Historical Resources Information Files at the Southern San Joaquin Valley Information Center, California State University, Bakersfield, and a search of the Native American Heritage Commission Sacred Lands Files, Sacramento. The Applicant may rely on a previously performed records search for subsequent ground disturbing activities. b. If an application location has been previously surveyed and no cultural resources have been recorded on it, no further cultural resources studies shall be required. c. Implement either: 1. If a site plan includes land that has experienced 100% previous ground-surface disturbance, or is within a section with 300 or more existing oil wells or other agricultural, industrial or urban uses, and the records searches indicate that no cultural or Native American resources are known on it, no further cultural resources studies shall be required. All other application locations shall be subject to intensive (100%) pedestrian ground-surface survey (Phase I survey/Class III inventory) by qualified archaeologists. The Applicant may rely on a previously performed ground surface survey for subsequent ground disturbing activities; or 2. If an application location has not been previously surveyed based on the records search information, an intensive (100%) pedestrian ground-surface survey (Phase I survey/Class III inventory) by qualified archaeologists shall be required. d. All prehistoric/Native American archaeological sites, whether identified during the records searches or during the intensive survey, shall be demarcated by a qualified archaeologist, fenced by the Applicant, and preserved in place. e. Historical (Euro-American) archaeological sites that are potentially eligible for listing in the National Register of Historic Places shall be evaluated by a qualified archaeologist and must meet the requirements of the National Historic Preservation Act of 1966 in order to qualify. Qualifying sites, structures and equipment that are identified during the records search or field survey shall be fenced and preserved in open-space, removed and curated, or treated using appropriate data recovery	Provide with Application Package; During construction and operation	KC PCDD; State Historic Preservation Office		
		Steps to Compliance: A. The Applicant shall implement the measures specified in the mitigation measure. B. The Kern County Planning and Community Development Department will verify.			

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	procedures. f. Historical (Euro-American) archaeological site types relating to oil and gas activities that have been determined Not Significant/Unique shall require no archaeological study or treatment. g. All oil and gas industry employees conducting work in the area identified on the Conformity Site Plan shall complete Worker Environmental Awareness Program training including training dedicated to cultural resources protection.				
4.5-2	Implement MM 4.5-1 Steps to Compliance.				
4.5-3	**MM 4.5-2** As part of any Worker Environmental Awareness Program training, all construction personnel shall be trained regarding the recognition of possible buried paleontological resources and protection of paleontological resources during construction, prior to the initiation of construction or ground-disturbing activities. Training shall inform construction personnel of the procedures to be followed upon the discovery of paleontological materials. All personnel shall be instructed that unauthorized collection or disturbance of fossils is unlawful.	Provide with Application Package; During construction and operation	KC PCDD		
		Steps to Compliance: A. The Applicant shall implement the Worker Environmental Awareness Program measures specified in the mitigation measure. B. The Kern County Planning and Community Development Department will verify.			
	MM 4.5-3 All permits for new wells that use Enhanced Oil Recovery or Well Stimulation methods shall pay a mitigation fee of $50 per well shall be paid to the Buena Vista Museum to fund the continued education and curation of paleontological resources and provide educational support regarding the paleontological history of the region.	Provide with Application Package; During construction and operation	KC PCDD; Buena Vista Museum		
		Steps to Compliance: A. The Applicant shall pay a mitigation fee as specified in the mitigation measure. B. The Kern County Planning and Community Development Department will verify.			
4.5-4	**MM 4.5-4** In the event archaeological materials are encountered during the course of ground disturbance or construction, the Project operator/contractor shall cease any ground disturbing activities within 50 feet of the find. The qualified archaeologist shall evaluate the significance of the resources and recommend appropriate treatment measures. Per California Environmental Quality Act Guidelines Section 15126.4(b)(3), Project redesign and preservation in place shall be the preferred means to avoid impacts to significant historical resources. Consistent with California Environmental Quality Act Guidelines Section 15126.4(b)(3)(C), if it is demonstrated that resources cannot be avoided, the qualified archaeologist shall develop additional treatment measures in consultation with the County, which may include data recovery or other appropriate measures. The Planning and Community Development Department shall consult with appropriate Native American representatives in determining	During construction	KC PCDD		
		Steps to Compliance: A. The Applicant shall submit an unanticipated discovery plan as part of the oil and gas conformity review. B. A qualified archaeologist shall evaluate any unanticipated site for significance and recommend appropriate treatment measures. C. The Applicant qualified archaeologist shall outline the recommendations for data recovery and curation in a report for submittal to the Kern County Planning and Community Development Department. D. The Kern County Planning and Community Development Department shall deem if or when ground disturbing activities within 50 feet of the find can or cannot resume.			

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		appropriate treatment for unearthed cultural resources if the resources are prehistoric or Native American in nature. If after consultation it is deemed appropriate, archaeological materials recovered during any investigation shall be curated at an accredited curation facility. The qualified archaeologist shall prepare a report documenting evaluation and/or additional treatment of the resource. A copy of the report shall be provided to the Kern County Planning and Community Development Department and to the Southern San Joaquin Valley Information Center. In the event archaeological materials are encountered, in Tier 2 the surface owner shall be notified immediately.				
	MM 4.5-5	If human remains are uncovered during Project construction, the Applicant shall immediately halt all work, contact the Kern County Coroner to evaluate the remains, and follow the procedures and protocols set forth in Section 15064.4 (e)(1) of the California Environmental Quality Act Guidelines. The Kern County Planning and Community Development Department shall be notified concurrently. If the County Coroner determines that the remains are Native American, the Project proponent shall contact the Native American Heritage Commission, in accordance with Health and Safety Code Section 7050.5, subdivision (c), and Public Resources Code 5097.98 (as amended by Assembly Bill 2641). The Native American Heritage Commission shall designate a Most Likely Descendant for the remains per Public Resources Code 5097.98. Per Public Resources Code 5097.98, the applicant, in coordination with the landowner, shall ensure that the immediate vicinity, according to generally accepted cultural or archaeological standards or practices, where the Native American human remains are located, is not damaged or disturbed by further development activity until the discussion and conference with the Most Likely Descendant has occurred, if applicable, taking into account the possibility of multiple human remains. If the remains are determined to be neither of forensic value to the Coroner, nor of Native American origin, provisions of the California Health and Safety Code (7100 et. seq.) directing identification of the next-of-kin will apply. In the event human remains are uncovered, in Tier 2 the surface owner shall be notified immediately.	During construction	KC PCDD		
			Steps to Compliance: A. The Applicant shall implement the measures specified in the mitigation measure. B. The Kern County Planning and Community Development Department will verify.			
4.5-5	Implement MM 4.5-1 through MM 4.5-5 Steps to Compliance.					
Geology and Soils						
4.6-1	**MM 4.6-1**	Prior to beginning a ground disturbance activity, the Applicant shall comply with the following regulations (as applicable) and confirm compliance in its Site Plan Conformity Review application documentation: a. Alquist-Priolo Earthquake Fault Zoning Act. b. California Building Code. c. Division of Oil Gas and Geothermal Resources regulations, as identified in the California Code of Regulations, Title 14, Division 2, Chapter 4, including regulations implementing Senate Bill 4 as applicable. If hydraulic fracturing is conducted for any well associated	Prior to ground disturbance activity	KC PCDD		
			Steps to Compliance: A. The Applicant shall implement the measures specified in the mitigation measure. B. The Kern County Building Department will verify during the oil and gas conformity review process.			

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	with the Site Plan Conformity Review, the Applicant shall comply with requirements to monitor the California Integrated Seismic Network for indication of an earthquake of magnitude 2.7 or greater for the period of 10 days following the end of hydraulic fracturing. The earthquake search radius shall be consistent with Division of Oil Gas and Geothermal Resources Senate Bill 4 regulations. The data will be submitted to Division of Oil Gas and Geothermal Resources for an evaluation of the risks and actions consistent with the Division of Oil Gas and Geothermal Resources Senate Bill 4 regulations. In approving a well stimulation treatment permit that would authorize, within an urban area (i.e., an area with a population over 50,000, as defined by the U.S. Census Bureau), the emplacement of well stimulation fluids into an oil or gas formation that has not been previously been subject to well stimulation activity, and/or into an oil or gas formation for which Division of Oil Gas and Geothermal Resources does not yet possess adequate information about formation fracture geometries, Division of Oil Gas and Geothermal Resources shall impose a permit condition requiring that the applicant conduct ground monitoring to characterize as-built fracture geometries prior to, during, and post-hydraulic fracturing. Monitoring shall also be conducted during fracturing treatments by use of applicable microseismic fracture mapping, tilt measurements, tracers, or proppant tagging. Copies of ground monitoring records shall be provided to the County and Division of Oil Gas and Geothermal Resources for review and approval within 30 days of well stimulation treatment. d. Additionally, the Applicant shall: 1. Avoid placement of structures intended for human occupancy on or within 50 feet of any active faults designated and mapped pursuant to the Alquist-Priolo Earthquake Fault Zoning Act where the fault breaks the surface. 2. Have a professional geologist prepare a fault rupture hazard evaluation according to guidelines in California Geological Survey Special Publication 42, 2007 for new developments with structures that are intended for human occupancy. 3. All Class II injection wells shall be authorized, and shall comply with all applicable legal requirements, Underground Injection Control Program Approval permit conditions, and be operated according to the California Code of Regulations Title 14 requirements, as described in the mitigation measures for Hydrology and Water Quality. 4. Ensure that active fault trace placement restrictions are in place for all permanent tanks and storage reservoirs used to store, treat, or				

Impact	Mitigation Measure	Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
	transport hazardous materials or materials that are considered pollutants to surface water and groundwater, located in an Earthquake Fault Zone. Ensure that all newly installed pipelines subject to 49 Code of Federal Regulations (CFR) Parts 192 and 195, are engineered and constructed in compliance with the requirements of the pipeline safety regulations, as set forth by the Pipeline Hazardous Materials Safety Administration (PHMSA). All other newly installed pipelines that transport gas or hazardous liquids are to be constructed, tested operated and maintained in accordance with good oilfield practice and applicable standards set forth and approved by the State Oil and Gas Supervisor. Ensure that all new pipelines designated for or water used for fire suppression are engineered and constructed in compliance with the requirements of California Building Code Chapter 9, Fire Protection Systems, and the California Fire Code to address potential fault rupture displacements.				
	MM 4.6-2 All structures designed for human occupancy shall be designed to withstand substantial ground shaking in accordance with applicable California Building Code seismic design standards and Kern County Building Code.	During construction and operation	Kern County Public Works Department		
		Steps to Compliance: A. The Applicant shall implement the measures specified in the mitigation measure. B. The Kern County Building Department will verify during the oil and gas conformity review process.			
4.6-2 4.6-3	Implement MM 4.6-1 and MM 4.6-2 Steps to Compliance.				
4.6-4	**MM 4.6-3** Operators shall avoid siting wells or accessory equipment and facilities on slopes greater than 30% unless the Applicant determines that mineral recovery is infeasible from a different location, and site-specific Professional Engineering certification is submitted concluding that the new equipment will not cause landslides.	Provide with Application Package; During construction and operation	Kern County Public Works Department		
		Steps to Compliance: A. The Applicant shall implement the measures specified in the mitigation measure. B. The Kern County Building Department will verify during the oil and gas conformity review process.			
4.6-5	Implement stormwater mitigation measures, as described in Section 4.9, Hydrology and Water Quality.				
	Implement MM 4.6-3and MM 4.6-4, as described:				
4.6-6	**MM 4.6-4** The Applicant shall confirm compliance with, and shall implement, a Division of Oil Gas and Geothermal Resources approved re-pressuring plan as required by Division 3, Chapter 1, Article 5.5 of the Public Resources Code, commencing with Section 3315. In developed areas where subsidence is confirmed or suspected, subsidence monitoring shall be required using Synthetic Aperture Radar studies and/or other methods as approved by the	Provide with Application Package; During construction and operation	KC PCDD; Division of Oil Gas and Geothermal Resources		
		Steps to Compliance: A. The Applicant shall implement the measures specified in the			

Impact	Mitigation Measure		Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
		Division of Oil Gas and Geothermal Resources to quantify and evaluate the potential effect on the area.	mitigation measure. B. The Kern County Planning and Community Development Department will verify during the oil and gas conformity review process.			
4.6-7	**MM 4.6-5**	The Applicant shall avoid building infrastructure on expansive soils unless the Applicant determines that mineral recovery is infeasible from a different location, and site-specific Professional Engineering certification is submitted concluding that the new equipment will not cause substantial risks to life or property.	Prior to issuing the NTP or permits **Steps to Compliance:** A. The Applicant shall implement the measures specified in the mitigation measure. B. The Kern County Planning and Community Development Department will verify during the oil and gas conformity review process.	KC PCDD		
4.6-8	Implement MM 4.6-1 Steps to Compliance.					
4.6-9	Implement MM 4.6-1 through MM 4.6-5 Steps to Compliance.					
Green House Gas Emissions						
4.7-1	**MM 4.7-1**	An Applicant covered by the Cap-and-Trade Program with permitted stationary sources shall comply with the Cap-and-Trade regulation (especially by surrendering greenhouse gas allowances or offset credits to satisfy their compliance obligation under the Program), and implement Best Performance Standards applicable to greenhouse gas reduction for Components at Light Crude Oil and Natural Gas Production, Natural Gas Processing Facilities, Petroleum Refineries, Gas Liquids Processing Facilities, and Chemical Plants (San Joaquin Valley Air Pollution Control District 2010), Thermally Enhanced Oil Recovery Wells (San Joaquin Valley Air Pollution Control District 2010a), Steam Generators (San Joaquin Valley Air Pollution Control District 2010b), and Front-line Organic Liquid Storage Tanks (San Joaquin Valley Air Pollution Control District 2011).	Provide with Application Package; During construction and operation **Steps to Compliance:** C. The Applicant shall implement the measures specified in the mitigation measure. D. The Kern County Planning and Community Development Department will verify during the oil and gas conformity review process.	KC PCDD; San Joaquin Valley Air Pollution Control District		
	MM 4.7-2	Each Applicant covered by the Cap-and-trade Program shall comply with applicable Cap and Trade regulations, and other applicable greenhouse gas emission control and reduction regulations as these may be adopted or amended over time, to reduce, avoid, mitigate and/or sequester greenhouse gas emissions from Project-related air emissions.	Provide with Application Package; During construction and operation **Steps to Compliance:** E. The Applicant shall implement the measures specified in the mitigation measure. F. The Kern County Planning and Community Development Department will verify during the oil and gas conformity review process.	KC PCDD; San Joaquin Valley Air Pollution Control District		
	MM 4.7-3	Each Applicant shall implement methods to recover for reuse or destroy methane existing in associated gas and casinghead gas, as follows: a. Recover all associated gas produced from the reservoir via new wells,	Provide with Application Package; During construction and	KC PCDD; San Joaquin Valley Air Pollution		

Impact	Mitigation Measure	Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
	regardless of the well type, except for gas produced from wildcat and delineation wells or as a result of start-up, shutdown and maintenance activities (whether planned or unplanned), system failures, and emergencies in accordance with San Joaquin Valley Air Pollution Control District regulations (Rule 4401 and 4409), as this may be amended over time. b. Compliance with the expected California Air Resources Board methane regulation.	operation	Control District		
		Steps to Compliance: G. The Applicant shall implement the measures specified in the mitigation measure. H. The Kern County Planning and Community Development Department will verify during the oil and gas conformity review process.			
	MM 4.7-4 Each Applicant shall offset all greenhouse gas emissions not covered by the Cap-and-Trade program or other mandatory greenhouse gas emission reduction measures through Applicant reductions of greenhouse gas emissions as verified by Kern County, through acquisition of offset credits from the California Air Pollution Control Officers Association Exchange Register or other third party greenhouse gas reductions, with consultation to the validity of methodology for calculating reductions verified by the San Joaquin Valley Air Pollution Control District and accepted by Kern County, or through inclusion in an Emission Reduction Agreement, to offset Project-related greenhouse gas emissions that are not included in the Cap and Trade program to assure that no net increase in greenhouse gas emissions from the Project.	Provide with Application Package; During construction and operation	KC PCDD; San Joaquin Valley Air Pollution Control District		
		Steps to Compliance: I. The Applicant shall implement the measures specified in the mitigation measure. J. The Kern County Planning and Community Development Department will verify during the oil and gas conformity review process.			
4.7-2	Implement MM 4.7-3 Steps to Compliance.				
4.7-3	Implement MM 4.7-4 Steps to Compliance.				
Hazards and Hazardous Materials					
4.8-1	**MM 4.8-1** The Applicant shall provide a comprehensive Worker Environmental Awareness Program to the County with its first Site Plan Conformity Review permit application in each calendar year. The program shall include all training requirements identified in Applicant Best Management Practices and mitigation measures, and include training for all field personnel (including Applicant employees, agents and contractors). The Worker Environmental Awareness Program shall include protocols and training for responding to and handling of hazardous materials and hazardous waste management, and emergency preparedness, release reporting, and response requirements. In Tier 2, the Worker Environmental Awareness Program shall be provided to the surface owner at the time of the application pathway process so the surface owner may educate employees as well.	Provide with Application Package; During construction and operation	KC PCDD		
		Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			
	MM 4.8-2 The Applicant shall arrange for transportation, storage and disposal of all hazardous materials in compliance with the Hazardous Materials Transportation Act. Drivers transporting hazardous materials or wastes should follow the measures recommended by the Federal Motor Carrier Safety Administration for avoiding roll-over accidents. To avoid roll-over accidents involving cargo tank trucks:	Provide with Application Package; During construction and operation construction	KC PCDD; Environmental Protection Agency; California Department of Transportation		

Impact	Mitigation Measure	Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
	a. Avoid sudden movements that may lead to roll-overs. b. Control your load in turns and on straight roadways. c. Identify high risk areas on roads. d. Remain alert and attentive behind the wheel. e. Control speed and maintain proper "speed cushions."	**Steps to Compliance:** A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			
	MM 4.8-3 The Applicant shall implement the following practices: a. Construction activities shall be conducted to allow for easy clean-up of spills. Construction crews shall have sufficient tools, supplies, and absorbent and barrier materials to contain and recover spilled materials. b. Fuels and lubricants shall be stored only at designated staging areas. Fuel and lubricant tanks shall have appropriate secondary spill containment (e.g., curbs). Compliance with laws and regulations is required, including compliance with hazardous materials and hazardous waste storage laws, as applicable. c. Storage of fuel and lubricants in the staging area shall be at least 100 feet away from the edge of water bodies. Refueling and lubrication of equipment shall be restricted to upland areas at least 100 feet away from stream channels and wetlands. d. Any fuel truck shall carry an oil spill response kit and spill response equipment at all times. e. Applicants shall be required to perform all routine equipment maintenance at the well pad or other suitable locations (i.e., maintenance yards), and promptly collect and lawfully dispose of wastes in compliance with existing regulatory requirements. f. Berms and/or dikes (secondary containment) shall be constructed around the permanent above-ground bulk tanks and the foundations shall be installed with a passive leak detection system, so that potential spill materials shall be contained and collected in specified areas isolated from any water bodies. Tanks shall not be placed in areas subject to periodic flooding or washout. Compliance with laws and regulations is required, including compliance with hazardous materials and hazardous waste storage laws as applicable, including for secondary containment, such as Division of Oil Gas and Geothermal Resources regulation (Title 14, C,C.R. § 1773.1), which requires secondary containment in "an engineered impoundment such as a catch basin, which can include natural topographic features, that is designed to capture fluid released from a production facility." g. A sufficient supply of sorbent and barrier materials shall be maintained on construction sites consistent with the type and level of construction activities. Sorbent and barrier materials shall also be utilized to contain runoff from contaminated areas where appropriate.	Provide with Application Package; During construction and operation **Steps to Compliance:** A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.	KC PCDD		

Impact	Mitigation Measure	Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
	1. Shovels and drums shall be stored at each well pad or be readily available. If small quantities of soil become contaminated, hand tools such as shovels or other appropriate tools, shall be used to collect the soil and the material shall be stored in storage drums. Large quantities of contaminated soil may be bio-remediated on-site or at a designated remediation facility, subject to government approval, or collected utilizing heavy equipment, and stored in drums or other suitable containers prior to disposal. Should contamination occur adjacent to staging areas as a result of runoff, shovels and/or heavy equipment shall be utilized to collect the contaminated material. Contaminated soil shall be disposed of in accordance with state and federal regulations. 2. Above-ground tanks, valves and other equipment shall be visually inspected monthly and when the tank is refilled. Inspection records shall be maintained. Applicants shall periodically check tanks for leaks or spills. 3. Drain valves on all tanks shall be locked to prevent accidental or unauthorized discharges from the tank. 4. Equipment maintenance shall be conducted in staging areas or other suitable locations (i.e., maintenance shops or yards) to the extent practical. 5. The Applicant shall maintain equipment in operating condition to reduce the likelihood of fuel or oil line breaks and leakage. Any vehicles with chronic or continuous leaks shall be removed from the site and repaired before being returned to operation. h. Applicants are encouraged, but not required, to use an alternate to silica sand as a proppant, after Division of Oil Gas and Geothermal Resources has determined that such an alternative does not introduce new hazards.				
	MM 4.8-4 The Applicant shall implement the following measures to prevent, repair, and remediate accidental leaks and spills from oil and gas operations. a. The Applicant shall identify gas, oil and produced water pipelines to be used for each new or reworked well site in its Site Plan, and shall show the location of any sensitive receptor located within 300 feet of any such pipeline. For any pipeline located within 300 feet of a sensitive receptor, the Applicant shall present evidence that each such pipeline has been integrity tested using pressure testing or other accepted test methods by a qualified professional within a two-year period prior to submittal of the Site Plan, and shall provide a copy of the test result to	Provide with Application Package; During construction and operation	KC PCDD; Division of Oil Gas and Geothermal Resources		

Impact	Mitigation Measure	Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
	the County. For all waste gas lines less than or equal to 4 inches in diameter, a Pipeline Management Plan shall be developed and implemented in accordance with Division of Oil Gas and Geothermal Resources regulations Title 14, Division 2, Chapter 4, Section 1774.2. The Pipeline Management Plan shall include: 1. A listing of information on each pipeline including, but not limited to: i. Pipeline type. ii. Grade. iii. Installation date of pipeline. iv. Design and operational pressure. v. Any leak, repair, inspection and testing history. 2. A description of the testing method and schedule for all pipelines. b. The Applicant shall notify the Kern County Environmental Health Division, Certified Union Program Agency (CUPA), surface landowner, and sensitive receptors located within 300 feet, of any hazardous materials/waste release immediately upon discovery, and to other applicable agencies as required by other laws. The Applicant shall immediately contain the leak (e.g., by isolating or shutting down the leaking equipment), clean up contaminated media (e.g., soils), and repair the leak prior to recommencing operations. The Applicant shall report the status and progress of the leak repair and remediation work to the County and the CUPA on monthly intervals or predetermined intervals until the repair has been completed. Contaminated media shall be analyzed according to 22 C.C.R. §§ 66261.21-66261.24 for determination of appropriate hazardous waste disposal. Hazardous Waste Determination procedures are provided in 22 C.C.R. § 66262.11. c. As part of the Site Plan, the Applicant shall identify the location and right of way for all pipelines to be used for the transport of oil, gas, and produced water, including pipelines that intersect the main transport line, based on existing data and using commercially available technology, and, based on the results of this analysis, shall identify any sensitive receptors within 300 feet of the pipeline for purposes of complying with Mitigation Measure 4.8-4. Mechanical integrity testing of all such pipeline lengths within 300 feet of a sensitive receptor shall be required pursuant to Mitigation Measure 4.8.4-a. d. If a release, identified pursuant to subsection (b), cannot be repaired or remediated within 48 hours, and has potential impact to sensitive	**Steps to Compliance:** A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			

Impact	Mitigation Measure	Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
	receptors, the Applicant shall incur costs to sample and analyze the potentially affected area, which may include soil, groundwater, outdoor or indoor air of sensitive receptors within 300 feet of the leak. Applicant shall pay all temporary relocation costs (e.g., housing, food, and transportation) for any exposed sensitive receptor until such time as the leak has been repaired and post-indoor air testing has been completed, as confirmed by identified agency having oversight of the remediation.				
	MM 4.8-5 If, during grading or excavation work, the Applicant observes evidence of contamination or if soil contamination is suspected, work near the excavation site shall be terminated, the work area cordoned off and appropriate health and safety procedures implemented for the location by the contractor's Health and Safety Officer. Samples shall be collected by a trained and qualified individual. Analytical data from suspected contaminated material shall be reviewed by the contractor's Health and Safety Officer. If the sample testing determines that contamination is not present, work may proceed at the site; however, if contamination is detected above regulatory limits, the Kern County Public Health Services Department shall be notified. All actions related to encountering unanticipated hazardous materials at the site shall be documented and submitted to the Kern County Public Health Services Department.	Provide with Application Package; During construction and operation	Kern County Public Health Services; Kern County Environmental Health;		
		Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Public Health Services and Environmental Health will verify.			
	MM 4.8-6 The Applicant shall implement measures to prevent the release or accidental spillage of solid waste, garbage, construction debris, sanitary waste, industrial waste, naturally occurring radioactive materials, oil and other petroleum products, and other wastes into water bodies or water sources, including all applicable practices included in the most up-to-date versions of the following documents: Exemption of Oil and Gas Exploration and Production Wastes From Federal Hazardous Waste Regulations (EPA 2002). Equivalent industry standards such as Environmental Protection for Onshore Oil and Gas Productions and Leases (American Petroleum Institute 2009) and related standards may also be utilized, provided that a professional engineer, certified industrial hygienist or certified safety professional certifies to the County that such alternative standards are as or more protective of human health and the environment, as compared to the standards in the referenced Environmental Protection Agency manual. The determination of when and the extent to which a measure is "practical" is to be made by the Applicant; however, all of the below activities must comply with all applicable legal requirements, including federal and state laws and regulations, County ordinances, and the mitigation measures included in this Final EIR. a. Classify the various oil and gas exploration and production wastes for proper disposal as described in United States Environmental Protection Agency 2002, and in accordance with applicable California laws and regulations.	Provide with Application Package; During construction and operation	KC PCDD		
		Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			

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	b. Size reserve pits properly to avoid overflows. c. Use closed loop mud systems when practical, particularly with oil-based muds. d. Review safety data sheets of materials used, and select less toxic alternatives when possible. e. Minimize waste generation, such as by designing systems with the smallest volumes possible (e.g., drilling mud systems). f. Reduce the amount of excess fluids entering reserve and production pits. g. Keep non-exempt wastes out of reserve or production pits. h. Design the drilling pad to contain stormwater and rigwash. i. Recycle and reuse oil-based muds and high density brines, when practical, and when such recycling and reuse complies with hazardous waste laws and recycling laws. j. Perform routine equipment inspections and maintenance to prevent leaks or emissions. k. Reclaim oily debris and tank bottoms when practical, and when such reclamation complies with hazardous waste laws and recycling laws. l. Minimize the volume of materials stored at facilities. m. Construct adequate berms around materials and waste storage areas to contain spills. n. Perform routine inspections of materials and waste storage areas to locate damaged or leaking containers. o. Train personnel to use sensible waste management practices.				
	MM 4.8-7 Conduct exploration and development activities as described in *Surface Operating Standards and Guidelines for Oil and Gas Exploration and Development The Gold Book* (Bureau of Land Management 2007) or equivalent industry standard such as Environmental Protection for Onshore Oil and Gas Production Operations and Leases (American Petroleum Institute 2009) and related standards. The following specific measures should be undertaken at a minimum: a. Sufficient impervious secondary containment, such as containment dikes, containment walls, and drip pans, should be constructed and maintained around all qualifying petroleum facilities, including tank batteries and separation and treating areas consistent with the Environmental Protection Agency's Spill Prevention, Control, and Countermeasures regulation (40 Code of Federal Regulations 112). The containment structure must have sufficient volume to contain, at a minimum, the content of the largest storage tank containing liquid hydrocarbons within the facility/battery and sufficient freeboard to contain precipitation, unless more stringent protective requirements are deemed necessary by the authorized officer. Drip pans should be routinely checked and cleaned of petroleum or chemical discharges	Provide with Application Package; During construction and operation	KC PCDD; Environmental Protection Agency; Kern County Fire Department		
		Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			

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	and designed to prevent access by wildlife and livestock. b. Chemical containers should not be stored on bare ground, and should be maintained in good condition and placed within secondary containment in case of a spill or high velocity puncture. c. Containment dikes are not to be constructed with topsoil or coarse, insufficiently impervious spoil material. Containment is strongly suggested for produced water tanks. Chemicals should be placed within secondary containment and stored so that the containers are not in contact with soil or standing water and product and hazard labels are not exposed to weathering. d. Maintain a clean well location. Remove trash, junk, and other materials not in current use. e. In approving a well stimulation treatment permit, the applicant shall include in the spill contingency plan required by Section 1722.9 of Title 14 of the California Code of Regulations a protocol for measuring and reporting earthquake and earth consequences that occur during the well stimulation process, for however many well stimulation treatments are proposed to occur simultaneously at any given time. The Spill Contingency Plan shall include requirements for adequate personnel and equipment that may be necessary to conduct post-earthquake inspection and repair plans to evaluate any damage that has occurred. The Spill Contingency Plan shall include spill prevention, control and countermeasure plans to address the hazardous substances associated with well stimulation activities. The post-earthquake inspection procedures shall ensure the integrity of the mechanical systems and well integrity of wells used for stimulation or wastewater injection and idle wells that might have become conduits for escaping fluids or gases. The plan shall include procedures describing the necessary steps to be taken after service is disrupted in order to make the facilities secure, operational and safe as soon as possible.				
	MM 4.8-8 Applicants shall use the appropriate American Petroleum Institute Standards, or other recognized sources imposing the same or equivalent standards, for their facility, such as the following: a. Use cements and well materials in well completions as described in Specifications for Cements and Materials for Well Cementing (American Petroleum Institute 2011). b. Prior to start-up of all new facilities, verify and prove the construction, installation, integration, testing, and preparation of systems have been completed as designed following the practices described in Facilities Systems Completion Planning and Execution (American Petroleum Institute 2013a). c. When the use of centralizers and stop-collars are required during well	Provide with Application Package; During construction and operation	KC PCDD; Division of Oil Gas and Geothermal Resources		
		Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			

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	completion activities, follow the installation and testing requirements described in Recommended Practice for Centralizer Placement and Stop-collar Testing (American Petroleum Institute 2010a). d. Limit the environmental footprint of oil and gas exploration and production and reduce the incidence of releases of hazardous substances following the practices described in Environmental Protection for Onshore Oil and Gas Production Operations and Leases (American Petroleum Institute 2009). e. Minimize improper disposal by following the practices described in American Petroleum Institute Order No. G00004, Guidelines for Commercial Exploration and Production Waste Management Facilities (American Petroleum Institute 2001) or other recognized methods. These guidelines discuss the relevant regulations and permitting requirements; siting, construction, and technical consideration for various waste disposal options; as well as mitigation options. f. Minimize the environmental footprint of exploration and production activities following the practices described in Land Drilling Practices for Protection of the Environment (American Petroleum Institute 2010b) or other recognized sources. g. When pressure testing is required by State or federal law, prior to pressurizing or re-pressurizing petroleum product pipelines, ensure the integrity of pipelines following the practices described in Recommended Practice for the Pressure Testing of Steel Pipelines for the Transportation of Gas, Petroleum Gas, Hazardous Liquids, Highly Volatile Liquids, or Carbon Dioxide (American Petroleum Institute 2013b) or other recognized sources. h. To minimize releases of hazardous substances during oilfield construction, pit and sump operations shall be conducted in accordance with State Water Resources Control Board General Orders or appropriate Regional Water Quality Control Board waste discharge requirements or general orders.				
	MM 4.8-9 For all operations subject to the Oil and Gas Conformity Review, the Applicant shall comply with the pipeline management plan, including inspection and maintenance requirements, as administered by the Division of Oil Gas and Geothermal Resources pursuant to 14 California Code of Regulations 1774.	Provide with Application Package; During construction and operation	KC PCDD; Division of Oil Gas and Geothermal Resources		
		Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			
4.8-2	**MM 4.8-10** The Applicant shall incorporate annual maintenance checks for leaks and corrosion that cause releases into current operations, maintenance, and	Provide with Application Package;	KC PCDD; Division of Oil Gas		

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	inspection schedules as provided by the Division of Oil Gas and Geothermal Resources pursuant to 14 California Code of Regulations Sections 1774.1 and 1774.2, the Applicant shall visually inspect all above-ground pipelines for leaks and corrosion at least once per year, comply with the pipeline testing requirements included therein, shall maintain records of such inspections and testing; and shall make inspection and testing records available to the County for review upon request.	During construction and operation	and Geothermal Resources		
		Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			
	MM 4.8-11 As part of the Hazardous Materials Business Plan and the spill prevention, control, And countermeasures Plan, the Applicant shall require annual worker training requirements to: increase awareness of the most common types of failures and methods to avoid mistakes, shall maintain records of employee training, and shall make such records available to the County for review upon request.	Provide with Application Package; During construction and operation	KC PCDD; Kern County Fire Department		
		Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			
	MM 4.8-12 An Applicant who plans to perform cyclic steam injection activities above reservoir fracture pressures shall conduct such activities in accordance with the requirements set forth in the Division of Oil Gas and Geothermal Resources site-specific Project Approval Letter for the injection project. The following requirements from a Project Approval Letter for an injection project are examples of the types of conditions that would be triggered if a surface expression were to occur, though such conditions may be modified by the Division of Oil Gas and Geothermal Resources to reflect site-specific conditions and changing regulatory requirements. a. Cease cyclic steaming operations in accordance with the site-specific Project Approval Letter. Streaming can resume following the Division of Oil Gas and Geothermal Resources specifications outlined in the Project Approval Letter. b. All new or reactivated surface expressions that discharge oil in a reportable quantity shall be reported as an oil spill to the California Emergency Management Agency at (800) 852-7550. c. Any measures to address surface expressions from the well and associated Project shall be reviewed by the Division of Oil Gas and Geothermal Resources prior to initiating. d. Immediately control any water, steam, or oil flowing from a surface expression and contained. All discharged material shall be removed and disposed of in a manner approved by all state and local agencies. e. Cordon off and clearly mark all surface expressions to prevent inadvertent access. f. Conduct air sampling of any emissions associated to a recent surface expression in accordance to the local air board requirements to ensure	During construction and operation	KC PCDD; Division of Oil Gas and Geothermal Resources; Kern County Environmental Health		
		Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department and the Division of Oil Gas and Geothermal Resources will verify.			

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	a health hazard condition does not exist. g. Report immediately to the Division of Oil Gas and Geothermal Resources all surface expressions within 300 feet of the Project site. If the surface expression continues to flow after five days, all wells within a 300-foot radius shall cease steaming until the surface expression ceases to flow. If the surface expression continues to flow, the damage will be evaluated at the Supervisor's discretion, as assigned by Section 3106 of the Public Resources Code and existing laws and regulations.				
	MM 4.8-13 The Applicant shall comply with the Division of Oil Gas and Geothermal Resources requirements for assuring safe drilling and drill casing practices, well design, construction and well management requirements, blowout requirements, and all other provisions of 14 California Code of Regulations 1744 and other applicable Division of Oil Gas and Geothermal Resources regulations. The Applicant shall also reduce the incidence of well control loss by following the practices described in Recommended Practice for Well Control Operations (American Petroleum Institute 2012).	During construction and operation	KC PCDD; Division of Oil Gas and Geothermal Resources		
		Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			
	MM 4.8-14 The Applicant shall report contamination caused by oil and gas activities, including previously unknown injection wells, of a reportable quantity of hazardous substances, as specified in the Code of Federal Regulations Title 40 and/or the California Code of Regulations Titles 22 and 23, which is discovered during Project construction activities and operations. Notification must be made to Kern County Environmental Health Division and the appropriate implementing regulatory agency that has responsibility or oversight of the specific contamination conditions. The Applicant shall remediate such contamination outside Tier 1 areas as required by the Kern County Environmental Health Division and the appropriate implementing regulatory agency.	During construction and operation	KC PCDD; Kern County Environmental Health; Environmental Protection Agency		
		Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			
4.8-3	**MM 4.8-15** The Applicant who intends to use acutely hazardous chemicals, including chemicals at or above the specified threshold quantities or a process which involves a Category 1 flammable gas or a flammable liquid with a flashpoint below 100 degrees Fahrenheit (37.8 degrees Celsius) on site in one location, in a quantity of 10,000 pounds (4535.9 kilograms) or more according to 8 California Code of Regulations Section 5189, Appendix A, within 0.25 mile from a school must: a. Evaluate whether other alternative chemicals that are less hazardous could be used. b. Ensure that the smallest quantity of necessary acutely hazardous materials are stored on site. c. Notify the occupants of the buildings when and where acutely hazardous materials would be used.	Provide with Application Package; During construction and operation	KC PCDD; Kern County Fire Department		
		Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department and Kern County Fire Department will verify.			

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	d. Notify Kern County Fire Department about the details of the use of acutely hazardous materials (e.g., when, where, how much). e. Ensure that all employees who would contact the acutely hazardous materials are trained on the handling, transport, storage, and disposal of the materials. f. Ensure that all employees who would contact the acutely hazardous materials are trained and are provided the proper personal protective equipment. g. Ensure that all employees who would contact the acutely hazardous materials are trained and have exercised on the Spill Prevention, Control, and Countermeasures Plan that addresses these chemicals. **MM 4.8-16** The applicant shall not use any well stimulation fluid unless the applicant presents one of the following: 1. Safety Data Sheet that accurately describes the physical and chemical properties of the well stimulation fluid; or 2. Safety Data Sheets that accurately describe the physical and chemical properties of all chemical compounds in the well stimulation fluid; or 3. Toxicological report prepared by a qualified laboratory and/or the fluid vendor confirming the environmental profile of the well stimulation fluid is known; or 4. Results of an aquatic bioassay by a qualified laboratory confirming the environmental profile of the well stimulation fluid is known. For purposes of this mitigation measure, the term "environmental profile" means the physical and chemical properties of a compound that determine its risk to human health and the environment. This mitigation measure shall be superseded by any list of approved well stimulation treatment fluids, chemicals or additives published by the State of California or by any applicable State of California regulation pertaining to chemical use in well stimulation treatment.				
4.8-4	Implement Steps to Compliance as described in MM 4.8-1, MM 4.8-17, MM 4.8-18				
4.8-5	**MM 4.8-17** The Applicant shall determine whether any proposed construction or alteration meets requirements for notification of the Federal Aviation Administration. If a proposed construction or alteration is found to require notification, the Applicant shall notify the Federal Aviation Administration and request that the Federal Aviation Administration issue a Determination of No Hazard to Air Navigation. If the Federal Aviation Administration determines that the	Provide with Application Package; During construction and operation	KC PCDD; Federal Aviation Administration		
		Steps to Compliance: A. The Applicant shall implement measures as specified in the			

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		construction or alteration would result in a potential hazard to air navigation, the Applicant would be required to work with the Federal Aviation Administration to resolve any adverse effects or airport operations. The Applicant shall notify the Federal Aviation Administration and the nearest Airport, by completing and submitting Federal Aviation Administration Form 7460-1 if oil and gas related exploration, production, or associated development activities are planned that meet one or more of the following criteria: a. Any construction or alteration exceeding 200 feet above ground level. b. Any construction or alteration within 20,000 feet of all public use airports except Poso-kern Airport which exceeds a 100:1 surface from any point on the runway. c. Any construction or alteration within 10,000 feet of the Poso-Kern Airport which exceeds a 50:1 surface from any point on the runway. d. Any construction or alteration within 5,000 feet of a public use heliport which exceeds a 25:1 surface. e. When requested by the Federal Aviation Administration. f. Any construction or alteration located on a public use airport or heliport regardless of height or location.	mitigation measures. B. The Kern County Planning and Community Development Department and Federal Aviation Administration will verify.			
	MM 4.8-18	The Applicant shall determine the distance from the proposed operation to the nearest boundary of the Joint Service Restricted R-2508 Complex, using a map of this Complex provided by the County. The Applicant shall notify the Joint Service Restricted R2508 Complex representative identified by the County if oil and gas related exploration, production, or associated development activities are planned that meet one or more of the following criteria: a. Any structure within 75 miles of the R-2508 Complex that is greater than 50 feet tall. b. Any project within 50 miles of the R-2508 Complex that emit radio and communication frequencies. c. Any project that would create environmental impacts such as visibility or elevated obstructions within 25 miles of the R-2508 Complex.	Provide with Application Package; During construction and operation	KC PCDD		
			Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			
	MM 4.8-19	All oil and gas related development activities shall review the Kern County Airport Land Use Compatibility Plan for compliance with all applicable policies.	Provide with Application Package; During construction and operation	KC PCDD; Kern County Airport		
			Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			
4.8-8	**MM 4.8-20**	The Applicant is required to implement the following measures: a. Comply with Kern County Fire Codes. b. Maintain firefighting apparatus and supplies required by the Kern	Provide with Application Package; During construction and	KC PCDD; Kern County Fire Department		

Impact	Mitigation Measure	Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
	County Fire Department. c. Maintain of a list of all relevant fire-fighting authorities for each work site. d. Have available equipment to extinguish incipient fires and or construction of a fire break, such as: chemical fire extinguishers, shovels, axes, chain saws, etc. e. Carry water or fire extinguishers and shovels in non-passenger vehicles in the field. f. Have and maintain an adequate supply of fire extinguishers for welding, grinding, and brushing crews. g. Use available resources to protect individual safety and to contain any fire that occurs and notify local emergency response personnel. h. Remove any flammable wastes generated during oil and gas activities regularly. i. Store all flammable materials used in oil and gas activities away from ignition sources and in approved containers. j. Allow smoking only in designated smoking areas. k. Prohibit smoking where flammable products are present and when the fire hazard is high. Train personnel regarding potential fire hazards and their prevention. l. All internal combustion engines, stationary and mobile, shall be equipped with spark arresters. Spark arresters shall be in good working order. m. Light trucks and cars with factory-installed (type) mufflers shall be used only on roads where the roadway is cleared of vegetation. Said vehicle types shall maintain their factory-installed (type) muffler in good condition. n. Fire rules shall be posted on the Project bulletin board at the contractor's field office and areas visible to employees. o. Equipment parking areas and small stationary engine sites shall be cleared of all extraneous flammable materials. p. Personnel shall be trained in the practices of the Fire Safety Plan relevant to their duties. Construction and maintenance personnel shall be trained and equipped to extinguish small fires in order to prevent them from growing into more serious threats.	operation **Steps to Compliance:** A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department and Kern County Fire Department will verify.			
	MM 4.8-21 The Applicant should restrict the use of chainsaws, chippers, vegetation masticators, grinders, tractors, torches, and explosives at its locations, and ensure the sites where this equipment is used are equipped with portable or fixed fire extinguishers and/or a water tank, with hoses, fire rakes, and other tools to extinguish and or control incipient stage fires. The Worker Environmental Awareness Program shall include fire prevention and response training for workers using these tools.	Provide with Application Package; During construction and operation **Steps to Compliance:** A. The Applicant shall implement measures as specified in the mitigation measures.	KC PCDD		

Impact	Mitigation Measure	Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
		B. The Kern County Planning and Community Development Department will verify.			
4.8-9	**MM 4.8-22** Applicants shall ensure that trash is stored in closed containers and removed from the site at regular intervals. Open containers shall be inverted and construction ditches shall not be allowed to accumulate water. Construction and maintenance operations shall not generate standing water. Naturally occurring depressions, drainages, or pools at the site shall not be drained or filled without consulting with the appropriate resource agency (Kern County, United States Army Corps of Engineers, United States Fish and Wildlife Service, California Department of Fish and Wildlife) as applicable, and obtaining the appropriate permits.	During construction and operation	KC PCDD		
		Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			
4.8-10	Implement MM 4.8-1 through MM 4.8-22, as described above, and dust control and toxic air contaminant setback mitigation measure, as described in Section 4.3, Air Quality, risk reduction measures, as described in Section 4.6, Geology and Soils, and mitigation measures to maintain water quality, as described in Section 4.9, Hydrology and Water Quality.				
Hydrology and Water Quality					
4.9-1	**MM 4.9-1** The Applicant shall comply with all applicable federal, state, regional and local agency water quality protection laws and regulations, and commonly utilized industry standards, including (where applicable) obtaining coverage under the stormwater construction general permit and industrial general permit issued by the State Water Resources Control Board and complying with industry stormwater management standards for construction and operational activities. The applicant shall obtain all required permits from Division of Oil Gas and Geothermal Resources, and such permits shall include measures that will safeguard protected groundwater with appropriate casing, seal and related down-hole technical specifications.	During construction and operation	KC PCDD; State Water Resources Control Board; Environmental Protection Agency		
		Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Applicant shall a Stormwater Management Plan. C. The Applicant shall submit in writing approval from federal and state agencies verifying permit approval. D. The Kern County Planning and Community Development Department will verify.			
	MM 4.9-2 A. Oil and Gas activities in Tier 1 shall comply with the following. 1. In areas subject to National Pollutant Discharge Elimination System stormwater permitting requirements, project applicants shall file a Notice of Intent to the State Water Resources Control Board to comply with the statewide General Permit for Discharges of Stormwater Associated with Construction Activities (Construction General Permit State Water Resources Quality Control Board Order No 2009-009-DWO) prior to undertaking all ground-disturbing activities greater than one acre and shall prepare and implement a Stormwater Pollution Prevention Plan for construction activities on the Project site in accordance with the Construction General Permit. For	Provide with Application Package; During construction and operation	KC PCDD; Kern County Public Works Department		
		Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Applicant shall submit a drainage plan. C. The Applicant shall submit in writing approval from federal and state agencies verifying permit approval. D. The Kern County Engineering, Surveying and Permit Services			

Impact	Mitigation Measure	Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
	facilities requiring coverage under the Construction General Permit, the site specific Stormwater Pollution Prevention Plan shall include measures to achieve the following objectives: (1) all pollutants and their sources, including sources of sediment associated with construction activity are controlled; (2) all non-stormwater discharges are identified and either eliminated, controlled and treated, (3) site Best Management Practices are effective and result in the reduction or elimination of pollutants in stormwater discharges and authorized non-stormwater discharges from construction activity and (4) stabilization Best Management Practices to reduce or eliminate pollutants after construction are completed. The Stormwater Pollution Prevention Plan shall be prepared by a qualified preparer and shall include the minimum Best Management Practices required for the identified risk level. The Stormwater Pollution Prevention Plan shall include a construction site monitoring program that identified requirements for dry weather visual observations of pollutants at all discharge locations and, as appropriate, depending on the project risk level, sampling of site effluent and receiving waters. A qualified Stormwater Pollution Prevention Plan practitioner shall be responsible for implementing and all monitoring for the Best Management Practices as well as all inspection, maintenance and repair activities at the project site. If applicable, each project shall also implement and fully comply with the Industrial Storm Water Permit (Order No 97-03-DWO) and Kern County Municipal Stormwater Permit (Order No 5-01-120). All plans under these requirements shall be submitted to Kern County Public Works for review and approval. 2. Any operator of a facility that meets the following requirements is not required to be covered by the Construction General Permit (State Water Regional Control Board Memorandum dated 5-18-2010): a. discharges of stormwater runoff from oil and gas exploration, production, processing or treatment operations or transmission facilities, including field activities or operations that may be considered construction activity; 1. are not contaminated by contact with, or do not come into contact with, any overburden, raw material, intermediate products, finished product, byproduct or waste products; 2. are only contaminated by or only come into contact with sediment; and 3. pursuant to 40.C.F.R. § 122.26(c)(1) (iii) that do not contribute to a violation of a water quality standard. Any change to this State Water Regional Control Board determination will require full compliance with National Pollutant	Department will verify.			

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	Discharge Elimination System requirements. 3. Any operator not subject to National Pollutant Discharge Elimination System stormwater permitting requirements shall implement Best Management Practices during construction and operation. All selected practices shall be shown on a drainage implementation plan and self-certified as complete and feasible by a licensed professional qualified in drainage and flood control issues. The plan shall be submitted to the Kern County Planning and Community Development department. The following Best Management Practices shall be implemented and shown on the drainage implementation plan : a. Utilizing established facilities design, construction or similar standards as appropriate (e.g., American Society for the Testing and Materials (ASTM) American Petroleum Institute (API)). b. Implementation good housekeeping and maintenance practices: i. Preventing trash, waste materials and equipment from construction storm water. ii. Maintaining wellheads, compressors, tanks and pipelines in good condition without leaks or spills. iii. Designing and maintaining graded pads to not actively erode and discharge sediment iv. Maintaining vehicles in good working order v. Providing secondary containment for all –above –ground storage tanks and maintaining such containment features in good operating condition c. Implementing spill prevention and response measures i. Utilizing preventative operating practices such as tank level monitoring, safe chemical handling and conducting regular inspections. ii. Developing and maintaining a spill response plan iii. Conducting spill response training for employees and have a process to ensure contractors have the necessary training iv. Maintaining spill response equipment on site. d. Implementing material storage and management practices: i. Preventing unauthorized access ii. Utilizing "run-on" and "run-off" control berms and swales iii. Stabilizing exposed slopes through vegetation and other appropriate methods (e.g., hay bales or rolls).				

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	B. Oil and gas activities outside Tier 1 shall comply with all applicable state and federal stormwater management laws. For any oil and gas activity outside Tier 1 that is not subject to state or federal stormwater management laws, regulations or general permits, the Applicant shall prepare a drainage plan that is designed to minimize runoff and minimize the potential for impeding or redirecting 100-year flood flows. The drainage plan shall be prepared in accordance with the Kern County Grading Code, the Green Code and approved by the Kern County Department of Public Works, Floodplain Management Section. The plan shall specify best management practices to prevent all construction pollutants from contacting stormwater, with the intent of keeping sedimentation or any other pollutants from moving offsite and into receiving waters. The requirements of the Plan shall be incorporated into design specifications. Recommended best management practices for the construction phase must be shown on a drainage plan, and shall include the following: a. Erosion Control - 1. Scheduling of construction activities to avoid rain events. 2. Limiting vegetation removal to the minimum required. b. Sediment Control - 1. Secure stockpiling of soil. 2. Installation of a stabilized construction entrance/exit and stabilization of disturbed areas. c. Non-stormwater Control - 1. Proper fueling and maintenance of equipment and vehicles. 2. Proper concrete handling techniques. d. Waste and Material Management - 1. Properly managing construction materials, designating construction staging areas in or around the Project site. 2. Stockpiling and disposing of demolition debris, concrete, and soil properly. 3. Prompt removal and proper disposal of litter. 4. Proper disposal of demolition debris, concrete and soil. 5. Proper protections for fueling and maintenance of equipment and vehicles. 6. Provide and maintain adequate secondary containment to minmize or eliminate pollutants from moving offsite and into receiving waters. e. Post-Construction Stabilization - 1. Ensuring the stabilization of all disturbed soils per revegetation or application of a soil binder. C. If construction activities will alter federal jurisdictional waters, project applicants shall comply with the federal Clean Water Act Section 404 and				

Impact	Mitigation Measure		Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
		Section 401 permitting and certification requirements. If construction activities will alter state waters, project applicants shall comply with California Department of Fish and Wildlife Streambed Alteration requirements.				
	MM 4.9-3	All drilling operations must either use a closed loop system to avoid discharges of drilling muds and fluids, or obtain coverage under the State Water Resources Control Board low threat discharge General Order (Waste Discharge Requirements General Order 2003-0003-DEW), obtain individual Waste Discharge Requirements issued by the Central Valley Regional Water Quality Control Board for the unit, or obtain coverage under a general order issued by the Central Valley Regional Water Quality Control Board applicable to drilling ponds. Any surface ponds or sumps must be cleared of fluids and muds in accordance with the State Water Resources Control Board general order, applicable Water Discharge Requirements and Division of Oil Gas and Geothermal Resources regulations. Compliance with the State Water Resources Control Board or Central Valley Regional Water Quality Control Board low-threat discharge orders or Water Discharge Requirements, if closed-loop systems are not used, and applicable laws, regulations and standards will reduce potential surface water quality impacts from contact with drilling muds or fluids during drilling and construction to less than significant levels. After consultation with and approval by the Regional Water Board with jurisdiction over injection and groundwater, applicant shall provide for a tracer or some other reasonable method to allow well stimulation fluids to be distinguished from other fluids or chemicals for well stimulation permits. This could consist of an added tracer using an inert constituent that could be used to identify the presence of well stimulation fluids. Alternatively, it could be an intrinsic tracer, or some naturally occurring component that makes the well stimulation fluids chemically unique. Potential geochemical changes in the subsurface during injection or migration shall be considered. Use of a tracer shall be required to be disclosed to the public under Section 1788 of the SB 4 regulations. The regulations specifically require that the applicant require the composition and disposition of all well stimulation treatment fluids other than water, including "any radiological components or tracers injected into the well as part of the well stimulation treatment, a description of the recovery method, if any, for those components or tracers, the recovery rate, and specific disposal information for the recovered components or tracers a radiological component or tracer injected" (Section 1788 (15)). For any well stimulation treatment activity, the applicant shall not conduct well stimulation treatment activity until the State Water Resources Control Board, in consultation with the Central Valley Regional Water Quality Control Board, has	During construction and operation	KC PCDD; State Water Resources Control Board; Central Valley Regional Water Quality Control Board		
			Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. Obtain Waste Discharge Permit. C. The Kern County Planning and Community Development Department will verify.			

Impact	Mitigation Measure		Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
		approved either a groundwater monitoring plan or exclusion from groundwater monitoring for a given well, consistent with the State Water Resources Control Board Model Criteria for Groundwater Monitoring in Areas of Oil and Gas Well Stimulation.				
	MM 4.9-4	For any activity for which Chapter 19.98 applies, the Applicant shall not conduct any Class II injection activity regulated by the Underground Injection Control program, including enhanced oil recovery activities that discharge into any underground source of current or future beneficial use groundwater, including drinking water, unless the aquifer has been exempted by the United States Environmental Protection Agency or injection has otherwise been authorized by the U.S. Environmental Protection Agency or by the Division of Oil Gas and Geothermal Resources, in consultation and agreement by the State Water Resources Control Board, consistent with Public Resources Code 3131.	During construction and operation	KC PCDD; Environmental Protection Agency; Division of Oil Gas and Geothermal Resources		
			Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			
	MM 4.9-5	For any activity for which Chapter 19.98 applies, the Applicant shall not discharge produced water into any surface disposal facility unless the facility has received the Waste Discharge Requirements from the Central Valley Regional Water Quality Control Board, or the need for Water Discharge Requirements has been waived by the Central Valley Regional Water Quality Control Board. As required by the SB 4 regulations, well stimulation treatment fluids and produced fluids from wells that have been stimulated cannot be stored, discharged, or disposed into surface ponds or pits.	During construction and operation	KC PCDD; Central Valley Regional Water Quality Control Board		
			Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			
	MM 4.9-6	For any oil and gas activity within a Special Flood Hazard Area, the Applicant shall ensure that all constructed facilities are elevated or floodproofed in compliance with the requirements and standards found in the Kern County Floodplain Management Ordinance and Chapters 19.50 and 19.70 of the Kern County Zoning Code.	Provide with Application Package; During construction and operation	KC PCDD		
			Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			
4.9-2 4.9-3 4.9-4 4.9-6 4.9-8 4.9-9 4.9-11	Implement Steps to Compliance MM 4.9-1 through MM 4.9-6					

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Land Use and Planning					
4.10-1	Implement specified mitigation measures, including those that are applicable from Section 4.1, Aesthetics and Visual Resources, Section 4.3, Air Quality, Section 4.4 Biological Resources, Section 4.12, Noise, Section 4.15, Recreation, and Section 4.17, Utilities and Service Systems.				
Noise					
4.12-1	**MM 4.12-1** **Construction:** The Site Plan Application shall include a Site Vicinity Figure showing the location of any sensitive receptor(s) within the distances listed in the construction noise setbacks table, as shown below, of the construction site (potential impact area) for the proposed new well or other ancillary facility or equipment (excluding pipelines). This Figure need not be prepared for Tier 1 areas unless a sensitive receptor is located within 3,270 feet of a construction site inside the Tier 1 area. a. If there are no sensitive noise receptors within this potential impact area, then no construction mitigation measures shall be required. b. If there are sensitive human noise receptors within the potential impact area, then additional information must be provided showing the type of equipment being used and the noise contours with levels not exceeding 65 dB DNL at the nearest exterior wall of the sensitive receptor or more than 1 dB DNL higher than the ambient noise levels, if in excess of 65 dB DNL. If noise levels are shown to exceed 65 dB DNL or more than 1 dB DNL higher than the ambient noise levels in excess of 65 dB DNL, then one or more of the following mitigation measures shall be taken: 1. Placement of a temporary sound attenuation wall(s) shall be placed at the optimal distance to the sensitive receptor, as determined by an acoustical expert. 2. Construction of a temporary berm shall be placed at the optimal distance to the sensitive receptor, as determined by an acoustical expert. 3. Modification of equipment to reduce noise impacts. 4. Implementation of a quiet mode drilling plan or other sound reduction technology or practices as documented in a report submitted to the County. 5. Arranging for the voluntary, temporary relocation of the occupants of the sensitive receptor during the construction period. 6. Use the following setback distances for the activities specified: **Construction Noise Setbacks** **Activity** — **Setback Distance (feet)**	Provide with Application Package; During construction and operation	KC PCDD		
		Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			

Impact	Mitigation Measure	Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
	Drilling (Well Advancement) 1550 Drilling (Pull Out Of Well/Borehole) 820 Large-Scale Exploratory Drilling[1] 3270 Well Workover 930 Hydraulic Fracturing 1090 Note: Note: [1]Kenai Drill Rig #7 Information submitted with the Site Plan Application must detail the combination and methods used to determine the level of reduction and shall not exceed 65 dB DNL or any ambient levels in excess of 65 dB DNL or more than 1 dB DNL higher than the ambient noise levels, if in excess of 65 dB DNL .				
	MM 4.12-2 **Operation:** New oil and gas wells shall be a minimum 210 feet from the closest sensitive receptor. Geophysical testing methods using vibroseis vehicles to generate sound waves shall be a minimum 150 feet from the closest occupied building, water well, sewer system, and septic tank. Geophysical testing methods using shotholes that employ explosives shall be a minimum 300 feet from the closest occupied building, water well, sewer system, and septic tank, and shall be in full compliance with all laws governing explosives.	Provide with Application Package; During construction and operation	KC PCDD		
		Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			
4.12-3	Implement MM 4.12-2 Steps to Compliance				
4.12-4	Implement MM 4.12-1 Steps to Compliance				
4.12-5 4.12-6 4.12-7	Implement MM 4.12-1 and MM 4.12-2 Steps to Compliance.				
Public Services					
4.14-1	**MM 4.14-1** Applicant shall contribute to funding the acquisition of a Combination Walk-in/Non-Walk-in Industrial Firefighting vehicle capable of responding with a minimum of five firefighters with the tools and equipment necessary for industrial firefighting and rescue. Each Applicant shall pay $150 per well on each Oil and Gas Conformity Review permit until the total cost of the vehicle purchase is reached, not to exceed $850,000, to be paid through mitigation fees on Oil and Gas Conformity Review permits. Subsequent Applicants shall not be	Provide with Application Package; During construction and operation	Kern County KC PCDD		
		Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures.			

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	subject to this mitigation measure.	B. The Kern County Planning and Community Development Department will verify.			
	MM 4.14-2 Applicant shall provide funding in the amount of $425 per Oil and Gas Conformity Review permit issued for the Sheriff's Rural Crime Unit. Funding shall be used for one Sergeant, two Senior Deputies (investigators), three Deputies, One Support Technician (clerical), and helicopter usage, based on the amount of funding provided by this permit mitigation fee. The fee shall be in addition to any general funds received by the Sheriff's Department. The Sheriff's department shall annually report on the expenditure of funds for the Rural Crimes Unit, including incident reports and response times. If other sources of funding for the Rural Crimes Unit are secured, then the mitigation fee amount shall be adjusted to pay only the gap between actual costs and funding provided from other sources. The first 100 permits issued in a calendar year to certified small producers under the Small Producers Program included in the Project shall not pay this mitigation fee based on their very low proportionate use of the Rural Crimes Unit (100 permits are estimated to generally be less than 5% of the permits issued annually).	Provide with Application Package; During construction and operation	KC PCDD		
		Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			
4.14-2	Implement MM 4.14-1 and MM 4.14-2 Steps to Compliance.				
Traffic and Transportation					
4.16-1	**MM 4.16-1** The Applicant shall pay a road maintenance mitigation fee of $1,500 per permit for new wells to pay for roadway maintenance and related improvements to address wear and tear on roads caused by oil and gas industry traffic. The Kern County Public Works Department shall annually report on the expenditure of funds from the Oil and Gas Roadway Maintenance Fee. Expenditures from the fund shall be as determined by the Roads Commissioner, using as a reference the list of roadways identified in the Environmental Impact Report as being used for traffic by the oil and gas industry. If Kern County secures funding from a sales tax dedicated to transportation funding, then the amount of the traffic mitigation fee shall be re-evaluated at the time the County becomes a self-help county. The first 100 permits issued in a calendar year to certified small producers under the Small Producers Program included in the Project shall not pay this mitigation fee based on their very low proportionate roadway use (100 permits are estimated to generally be less than 5% of the permits issued annually).	Provide with Application Package; During construction and operation	KC PCDD; Kern County Public Works Department		
		Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			
	MM 4.16-2 Applicants who are using an arterial or collector, or Caltrans route, for access to a construction site, shall consult with the Kern County Public Works Department to determine if a Construction Traffic Control Plan is required based on the timing and volume of larger vehicle rigs and the volume of traffic to address public safety and congestion management. If a Plan is required, the Applicant shall prepare and submit a Construction Traffic Control Plan to the Kern County Public Works Department and to the California Department of	Provide with Application Package; During construction and operation	Kern County Public Works Department		
		Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures.			

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	Transportation (District 9 office) for approval. The Construction Traffic Control Plan must be prepared in accordance with both the California Department of Transportation Manual on Uniform Traffic Control Devices and Work Area Traffic Control Handbook and shall include, but not be limited to, the following issues: a. Timing of deliveries of heavy equipment and building materials. b. Placing temporary signing, lighting, and traffic control devices as necessary to indicate the presence of heavy vehicles and construction traffic. c. Determining the need for construction work hours and arrival/departure times outside peak traffic periods. d. Ensuring access for emergency vehicles to the Project site. e. Any temporary closure of travel lanes or disruptions to street segments and intersections during well development. f. Maintaining access to adjacent property.	B. The Kern County Public Works Department will verify.			
4.16-2	Implement MM 4.16-2 Steps to Compliance.				
4.16-3	Implement airport-related mitigation measures, as described in Section 4.8, Hazards and Hazardous Materials.				
4.16-4 4.16-5 4.16-6	Implement MM 4.16-2 Steps to Compliance.				
4.16-7	Implement of MM 4.16-1 and MM 4.16-2 Steps to Compliance.				
Utilities and Service System					
4.17-2	**MM 4.17-1** The Applicant shall pay a road maintenance mitigation fee of $1,500 per permit for new wells to pay for roadway maintenance and related improvements to address wear and tear on roads caused by oil and gas industry traffic. The Roads department shall annually report on the expenditure of funds from the Oil and Gas Roadway Maintenance Fee. Expenditures from the fund shall be as determined by the Roads Commissioner, using as a reference the list of roadways identified in the Environmental Impact Report as being used for traffic by the oil and gas industry. If Kern County secures funding from a sales tax dedicated to transportation funding, then the amount of the traffic mitigation fee shall be re-evaluated at the time the County becomes a self-help county. The first 100 permits issued in a calendar year to certified small producers under the Small Producers Program included in the Project shall not pay this mitigation fee based on the their very low proportionate roadway use (100 permits are estimated to generally be less than 5% of the permits issued annually).	Provide with Application Package; During construction and operation	Kern County Public Works Department		
		Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			
4.17-4	**MM 4.17-2** Applicant shall increase the re-use of produced water, and reduce its use of municipal and industrial-quality ground or surface water use to the extent	During construction and operation	KC PCDD		

Impact	Mitigation Measure		Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
		feasible. By the end of 2016, the Applicants shall work with the County to review water use data submitted to Division of Oil Gas and Geothermal Resources under Senate Bill 1281 and identify the five biggest oil industry users of municipal and industrial water by volume. The five biggest oil industry users of municipal and industrial water shall work together to develop and implement a plan identifying new measures to reduce municipal and industrial water use by 2020. The plan shall address the following activities, as appropriate: steam generation; drilling and completions (including hydraulic fracturing); dust control; compaction activities related to construction; and landscaping. Through the KernFLOWS initiative or other efforts (e.g., Groundwater Sustainability Agency), the five biggest oil industry users of municipal-and-industrial water shall also work with local agricultural producers and water districts to identify new opportunities to increase the use of produced water for agricultural irrigation and other activities, as appropriate. Any produced water treated and used for agricultural irrigation or other activities shall be tested and monitored to assure compliance with applicable standards for such agricultural irrigation or other uses.	**Steps to Compliance:** A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			
	MM 4.17-3	In the County's required participation for the formulation of a Groundwater Sustainability Agency, the Applicant shall work with the County to integrate into the Groundwater Sustainability Plan for the Tulare Lake-Kern Basin, best practices from the oil and gas industry to encourage the re-use of produced water from oil and gas activities, and (with appropriate treatment) to produce new water supplies for other uses such as agricultural irrigation and groundwater recharge. The produced water re-use goal is 30,000 acre-feet per year, which would offset more than the current use of imported water and groundwater from non-oil bearing zones by the oil and gas industry.	Provide with Application Package; During construction and operation	KC PCDD		
			Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			
	MM 4.17-4	The Applicant shall work with the County on the Groundwater Sustainability Plan to increase Applicant use of reclaimed water and reduce the Applicant's use of municipal-and-industrial quality imported surface water or groundwater. The Applicant will provide copies of water use reports produced under SB 1281 to the Groundwater Management Agency, which will then integrate this information into the Groundwater Sustainability Plan required under the Sustainable Groundwater Management Act.	Provide with Application Package; During construction and operation	KC PCDD		
			Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development Department will verify.			
4.17-5	Implement MM 4.17-1 Steps to Compliance.					
4.17-6	**MM 4.17-5**	During construction activities for Project facilities, the Applicant shall not store construction waste onsite for longer than the duration of the construction activity, or transport any waste to any unpermitted facilities. The Applicant shall also reduce construction waste transported to landfills by recycling solid waste construction materials, such as taking materials to recycling and reuse	During construction	KC PCDD		
			Steps to Compliance: A. The Applicant shall implement measures as specified in the mitigation measures. B. The Kern County Planning and Community Development			

Impact	Mitigation Measure	Time Frame for Implementation	Responsible Monitoring Agency	Date	Initials
	locations listed in the brochure on recycling construction and demolition materials available on the Kern County Waste Management Department website.	Department will verify.			
4.17-7	Implement MM 4.17-5 Steps to Compliance.				
4.17-8	Implement MM 4.17-1 through MM 4.17-5 Steps to Compliance.				

Appendix B

FILED
SUPERIOR COURT, METROPOLITAN DIVISION
COUNTY OF KERN
APR 20 2018
TERRY McNALLY, CLERK
BY _____ DEPUTY

SUPERIOR COURT OF THE STATE OF CALIFORNIA

COUNTY OF KERN

VAQUERO ENERGY, INC., a California corporation; and HUNTER EDISON OIL DEVELOPMENT LIMITED PARTNERSHIP, a California limited partnership; Petitioners and Plaintiffs, vs. COUNTY OF KERN; and KERN COUNTY BOARD OF SUPERVISORS; Respondents and Defendants. CALIFORNIA INDEPENDENT PETROLEUM ASSOCIATION, a California non-profit mutual benefit corporation; INDEPENDENT OIL PRODUCERS' AGENCY, a California corporation; and WESTERN STATES PETROLEUM ASSOCIATION, a California non-profit mutual benefit corporation; Real Parties in Interest.	Case No. BCV-15-101645-EB (Lead case) [Consolidated w/ Case No. BCV-15-101666-EB and Case No. BCV-15-101679-EB] **JUDGMENT in Case Nos. BCV-15-101645-EB**

The above-referenced consolidated cases (BCV-15-101645-EB, BCV-15-101666-EB and BCV-15-101679-EB) came on regularly for trial on June 13-14, 2017, August 10, 2017 and December 13, 2017, in Dept. T-2 of the Kern County Superior Court, the Honorable J. Eric

Bradshaw presiding. In case no. BCV-15-101645-EB, petitioners/plaintiffs VAQUERO ENERGY, INC., a California corporation, and HUNTER EDISON OIL DEVELOPMENT LIMITED PARTNERSHIP, a California limited partnership (collectively "Vaquero"), respondents/defendants COUNTY OF KERN (including its Planning Commission, and Planning and Natural Resources Department) and KERN COUNTY BOARD OF SUPERVISORS (collectively "County"), and real parties in interest CALIFORNIA INDEPENDENT PETROLEUM ASSOCIATION, INDEPENDENT OIL PRODUCERS' AGENCY, and WESTERN STATES PETROLEUM ASSOCIATION (collectively "Real Parties"), appeared through counsel.

The court reviewed and considered the evidence, record of proceedings, pleadings, briefs and papers on file herein, and the comments of counsel, and the causes were argued and submitted for decision. The court issued its ruling dated March 12, 2018 (hereinafter "Ruling"), fully resolving all claims, causes of action and issues in consolidated case nos. BCV-15-101645-EB, BCV-15-101666-EB and BCV-15-101679-EB. A separate judgment was entered in consolidated case nos. BCV-15-101666-EB and BCV-15-101679-EB. Accordingly, in case no. BCV-15-101645-EB,

IT IS HEREBY ORDERED, ADJUDGED AND DECREED that:

1. The causes of action and claims for relief alleged in the operative petition/complaint filed by Vaquero, against County and Real Parties, are DENIED, and Vaquero shall take nothing by way of the petition/complaint.

2. Costs of suit and attorneys' fees may be claimed in accordance with applicable law and rules of court.

Dated: April 20, 2018

JUDGE OF THE SUPERIOR COURT
J ERIC BRADSHAW

FILED
SUPERIOR COURT, METROPOLITAN DIVISION
COUNTY OF KERN
APR 20 2018
TERRY McNALLY, CLERK
BY _____ DEPUTY

SUPERIOR COURT OF THE STATE OF CALIFORNIA

COUNTY OF KERN

VAQUERO ENERGY, INC., a California corporation; and HUNTER EDISON OIL DEVELOPMENT LIMITED PARTNERSHIP, a California limited partnership; Petitioners and Plaintiffs, vs. COUNTY OF KERN; and KERN COUNTY BOARD OF SUPERVISORS; Respondents and Defendants. CALIFORNIA INDEPENDENT PETROLEUM ASSOCIATION, a California non-profit mutual benefit corporation; INDEPENDENT OIL PRODUCERS' AGENCY, a California corporation; and WESTERN STATES PETROLEUM ASSOCIATION, a California non-profit mutual benefit corporation; Real Parties in Interest.	Case No. BCV-15-101645-EB (Lead case) [Consolidated w/ Case No. BCV-15-101666-EB and Case No. BCV-15-101679-EB] **JUDGMENT in Case Nos. BCV-15-101666-EB and BCV-15-101679-EB**

The above-referenced consolidated cases (BCV-15-101645-EB, BCV-15-101666-EB and BCV-15-101679-EB) came on regularly for trial on June 13-14, 2017, August 10, 2017 and December 13, 2017, in Dept. T-2 of the Kern County Superior Court, the Honorable J. Eric

Bradshaw presiding. In case nos. BCV-15-101666-EB and BCV-15-101679-EB, petitioner/plaintiff King and Gardiner Farms, LLC ("KGF"), petitioners/plaintiffs Committee for a Better Arvin, Committee for a Better Shafter, Greenfield Walking Group, Natural Resources Defense Council, Sierra Club, and Center for Biological Diversity (collectively "Arvin Petitioners"), respondents/defendants County of Kern (including its Planning Commission, and Planning and Natural Resources Department) and Kern County Board of Supervisors (collectively "County"), and real parties in interest California Independent Petroleum Association, Independent Oil Producers' Agency, and Western States Petroleum Association (collectively "Real Parties"), appeared through counsel.

The court reviewed and considered the evidence, record of proceedings, pleadings, briefs and papers on file herein, and the comments of counsel, and the causes were argued and submitted for decision. The court issued its ruling dated March 12, 2018, a copy of which is attached hereto as Exhibit "A" (hereinafter "Ruling") fully resolving all claims, causes of action and issues in consolidated case nos. BCV-15-101645-EB, BCV-15-101666-EB and BCV-15-101679-EB. A separate judgment was entered in case no. BCV-15-101645-EB. Accordingly, in consolidated case nos. BCV-15-101666-EB and BCV-15-101679-EB,

IT IS HEREBY ORDERED, ADJUDGED AND DECREED that:

1. The causes of action and claims for relief alleged in the operative petitions/complaints filed by KGF and Arvin Petitioners, against County and Real Parties, under the California Environmental Quality Act (Pub. Res. Code §§ 21000 et seq.) (hereinafter "CEQA") challenging the adequacy of County's analysis of the project's environmental impacts to rangeland/grazing land, and the environmental impacts from road paving as an air emissions mitigation measure, including related determinations, are GRANTED, and a writ will issue as more particularly stated herein. Except as otherwise expressly stated herein, the petitions/complaints of KGF and Arvin Petitioners are DENIED, and KGF and Arvin Petitioners shall take nothing by way of their respective petitions/complaints.

2. A peremptory writ of mandate directed to County will issue under seal of this court, ordering County to do the following:

(a) Within 45 days from service of the writ of mandate, County shall transmit to the San Joaquin Valley Air Pollution Control District copies of this court's Ruling, this judgment, and the related peremptory writ of mandate.

(b) Consistent with the Ruling and the procedures set forth in CEQA and CEQA Guidelines, County shall prepare such analysis as is necessary to address the EIR's deficient analysis of the Project's (i) environmental impacts to rangeland/grazing land, and (ii) environmental impacts from road paving as an air emissions mitigation measure ("Supplemental Analysis"). In the event the Supplemental Analysis determines that any such environmental impacts are potentially significant, the Supplemental Analysis shall identify feasible mitigation measures and/or alternatives to mitigate or avoid such impacts consistent with CEQA's requirements, unless County makes findings of infeasibility and overriding considerations as provided by CEQA.

(c) Upon completion of the Supplemental Analysis described in Part 2(b) above, County shall: (i) reconsider its approval of the Project and its Statement of Overriding Considerations adopted in connection with that project, in light of any new information in the Supplemental Analysis, and (ii) take any and all further action that may be necessary to bring the approval of the project and the related findings and mitigation monitoring and reporting program into compliance with CEQA.

(d) County shall file an initial return to the writ not later than 75 days after the service of the writ of mandate, setting forth what it has done to comply with paragraph 2(a) above. County shall file a supplemental return to the writ of mandate no later than 180 days after the initial return, setting forth whether it has complied with paragraphs 2(b) and 2(c) above. County shall thereafter file supplemental returns every 60 days until it has fully complied with paragraphs 2(b) and 2(c) above.

3. The court finds that the writ authorized by Public Resources Code section 21168.9(a)(3), mandating that County "take specific action as may be necessary to bring the

determination, finding, or decision into compliance with [CEQA]," is the appropriate remedy under the circumstances of this case, and that the mandates described in Public Resources Code section 21168.9(a)(1) and (a)(2) are not appropriate remedies under the circumstances of this case.

(a) Regarding rangeland/grazing land, the writ of mandate is limited to those portions of County's determinations, findings, decisions, permits and approvals under the project that are implicated by the EIR's deficient analysis of impacts to rangeland/grazing land because: (i) County's determinations, findings, decisions, permits and approvals relating to oil and gas activities on rangeland/grazing land are severable, (ii) severance will not prejudice complete and full compliance with CEQA because County will consider the information required by CEQA before new oil and gas activities subject to the project will be permitted or allowed on rangelands/grazing land, and (iii) with the exception of the EIR's discussion of road paving as an air emissions mitigation measure (discussed *infra*), the court has not found the remainder of the project to be in noncompliance with CEQA or CEQA Guidelines.

(b) Regarding road paving as an air emissions mitigation measure, the writ of mandate is limited to those portions of County's determinations, findings, decisions, permits and approvals under the project that are implicated by the EIR's deficient analysis of road paving as an air emissions mitigation measure because: (i) County's determinations, findings, decisions, permits and approvals relating to the use of road paving as an air emissions mitigation measure are severable, (ii) severance will not prejudice complete and full compliance with CEQA because County will consider the information required by CEQA before taking any action to permit or allow the use of road paving as an air emissions mitigation measure, and (iii) with the exception of the EIR's discussion of impacts to rangeland/grazing land (discussed *supra*), the court has not found the remainder of the project to be in noncompliance with CEQA or CEQA Guidelines.

4. Pursuant to Public Resources Code section 21168.9(c), nothing in this judgment or

the writ(s) issued hereunder may be construed as an order that County exercise its lawful discretion in a particular way.

5. Costs of suit and attorneys' fees may be claimed in accordance with applicable law and rules of court.

6. The court retains jurisdiction in consolidated case nos. BCV-15-101666-EB and BCV-15-101679-EB to ensure compliance with this judgment, and the writ(s) issued pursuant to this judgment.

Dated: April 20, 2018

JUDGE OF THE SUPERIOR COURT

J ERIC BRADSHAW

Exhibit "A"

Superior Court of California
County of Kern
1415 Truxtun Ave
Bakersfield, CA 93301

Date: 03/12/2018 **Time:** 8:00 AM - 5:00 PM

BCV-15-101645

VAQUERO ENERGY VS COUNTY OF KERN

Courtroom Staff

Honorable: J. Eric Bradshaw **Clerk:** Y. Torres

Court reporter: N/A **Bailiff:** N/A
Interpreter: **Language of:**

PARTIES:

CALIFORNIA INDEPENDENT PETROLEUM ASSOCIATION, Real Party Interest, not present	KELI OSAKI, Attorney, not present
CALIFORNIA INDEPENDENT PETROLEUM ASSOCIATION, Real Party Interest, not present	KELI OSAKI, Attorney, not present
CALIFORNIA INDEPENDENT PETROLEUM ASSOCIATION, A CALIFORNIA NON-PROFIT MUTUAL BENEFIT CORPORATION, Real Party Interest, not present	CRAIG MOYER, Attorney, not present
CENTER FOR BIOLOGICAL DIVERSITY, Petitioner, not present	HOLLIN KRETZMANN, Attorney, not present
COMMITTEE FOR A BETTER ARVIN, Petitioner, not present	CAROLINE FARRELL, Attorney, not present
COMMITTEE FOR A BETTER SHAFTER, Petitioner, not present	CAROLINE FARRELL, Attorney, not present
COUNTY OF KERN, Respondent, not present	CHARLES COLLINS, Attorney, not present
COUNTY OF KERN, Respondent, not present	CHARLES COLLINS, Attorney, not present
GREENFIELD WALKING GROUP, Petitioner, not present	CAROLINE FARRELL, Attorney, not present
HUNTER EDISON OIL DEVELOPMENT LIMITED PARTNERSHIP, A CALIFORNIA LIMITED PARTNERSHIP, Petitioner, not present	EDWARD RENWICK, Attorney, not present
INDEPENDENT OIL PRODUCERS AGENCY, Real Party Interest, not present	BLAINE GREEN, Attorney, not present
INDEPENDENT OIL PRODUCERS AGENCY, Real Party Interest, not present	NORMAN CARLIN, Attorney, not present
INDEPENDENT OIL PRODUCERS' AGENCY, A CALIFORNIA CORPORATION, Real Party Interest, not present	NORMAN CARLIN, Attorney, not present
KERN COUNTY, Respondent, not present	CHARLES COLLINS, Attorney, not present
KERN COUNTY BOARD OF SUPERVISORS, Respondent, not present	CHARLES COLLINS, Attorney, not present

MINUTE ORDER

KERN COUNTY BOARD OF SUPERVISORS, Respondent, not present	CHARLES COLLINS, Attorney, not present
KERN COUNTY BOARD OF SUPERVISORS, Respondent, not present Kern County Counsel, Defendant, not present	CHARLES COLLINS, Attorney, not present
KERN COUNTY PLANNING AND COMMUNITY DEVELOPMENT DEPARTMENT, Respondent, not present	CHARLES COLLINS, Attorney, not present
KERN COUNTY PLANNING AND COMMUNITY DEVELOPMENT DEPARTMENT, Respondent, not present	CHARLES COLLINS, Attorney, not present
KERN COUNTY PLANNING COMMISSION, Respondent, not present	CHARLES COLLINS, Attorney, not present
KING AND GARDINER FARMS, LLC, Petitioner, not present	RACHEL HOOPER, Attorney, not present
NATURAL RESOURCES DEFENSE COUNCIL, Petitioner, not present	WILLIAM ROSTOV, Attorney, not present
Natural Resources Defense Council, Petitioner, not present	MARGARET HSIEH, Attorney, not present
SIERRA CLUB, Petitioner, not present	WILLIAM ROSTOV, Attorney, not present
VAQUERO ENERGY INC., A CALIFORNIA CORPORATION, Petitioner, not present	EDWARD RENWICK, Attorney, not present
WESTERN STATES PETROLEUM ASSOCIATION, Real Party Interest, not present	BLAINE GREEN, Attorney, not present
WESTERN STATES PETROLEUM ASSOCIATION, Real Party Interest, not present	NORMAN CARLIN, Attorney, not present
WESTERN STATES PETROLEUM ASSOCIATION, A CALIFORNIA NON-PROFIT MUTUAL BENEFIT CORPORATION, Real Party Interest, not present	NORMAN CARLIN, Attorney, not present

NATURE OF PROCEEDINGS: RULING ON CONSOLIDATED PETITIONS FOR WRITS OF MANDATE, AND COMPLAINTS FOR DECLARATORY AND INJUNCTIVE RELIEF (BCV-15-101645, BCV-15-101666, and BCV-15-101679) HERETOFORE SUBMITTED:

SEE ATTACHED RULING, INCORPORATED HEREIN.

MINUTE ORDER FINALIZED BY: YESENIA TORRES *ON:* MARCH 12, 2018

Consolidated Cases
BCV-15-101645-EB (Lead case)
BCV-15-101666-EB
BCV-15-101679-EB

CONSOLIDATED PETITIONS FOR WRITS OF MANDATE, AND COMPLAINTS FOR DECLARATORY AND INJUNCTIVE RELIEF (BCV-15-101645, BCV-15-101666, and BCV-15-101679) HERETOFORE SUBMITTED:

* * * * *

DISPOSITION

BCV-15-101645 (Lead case)

The first amended petition/complaint of Vaquero Energy, Inc. ("Vaquero"), and Hunter Edison Oil Development Limited Partnership ("Hunter") (sometimes collectively "Vaquero petitioners"), for a writ of mandate, and for declaratory and injunctive relief, is DENIED. Judgment shall be entered in favor of respondents/defendants, against Vaquero petitioners, and Vaquero petitioners shall take nothing by way of their petition/complaint. Costs of suit and attorneys' fees may be claimed in accordance with applicable law and rules of court. Respondent/defendant County of Kern shall prepare a separate judgment for BCV-15-101645.

BCV-15-101666 & BCV-15-101679

The petition/complaint of King and Gardiner Farms, LLC ("KGF"), and the petition/complaint of Committee for a Better Arvin, Committee for a Better Shafter, Greenfield Walking Group, Natural Resources Defense Council, Sierra Club, and Center for Biological Diversity (collectively "Arvin Petitioners"), for a writs of mandate, and for declaratory, injunctive and other relief, are GRANTED IN PART, and DENIED IN PART, consistent with the issue-specific rulings herein. Judgment and other appropriate relief shall be entered consistent with the rulings herein. Arvin Petitioners' request for judicial notice of the unpublished superior court decision (Ex. 1) is DENIED. Costs of suit and attorneys' fees may be claimed in accordance with applicable law and rules of court.

A case management conference is hereby scheduled in these two consolidated cases (BCV-15-101666 and BCV-15-101679), in Dept. T-2 of the Kern County Superior Court, located at 3131 Arrow Street, Bakersfield, CA, on April 4, 2018 at 8:30 a.m., for the purpose of discussing remedy and relief. The parties are ordered to meet and confer in good faith prior to the case management conference to discuss the foregoing, and if possible, to submit to the court for review and signature an agreed form of judgment, writ or other orders/decrees as may be appropriate.

DISCUSSION

This discussion organizes rulings on issues according to the plaintiff/petitioner principally responsible for arguing the particular issue at trial.

Vaquero Petitioners' Issues

1. Contract Clause

Vaquero petitioners have failed to prove that Kern County Ordinance Code sections 19.98.100, 19.98.140, 19.98.085, 19.98.090, or 19.98.130, unconstitutionally impair a contract in violation of the Contract Clauses of the U. S. Constitution or California Constitution. It is undisputed that Vaquero is a lessee under oil and gas leases in "Tier 2" areas in Kern County where surface ownership has been severed from mineral ownership, and that Hunter operates those leases. The specific provisions of the leases and agreements under which Vaquero petitioners hold their interests and operate, however, have not been proven. Thus, no impairment of a particular contract or obligation, substantial or otherwise, has been proven.

Similarly, assuming *arguendo*, the Vaquero petitioners' "bargaining power" vis-à-vis surface owners is a "contract" or "obligation" that can be "impaired" within the meaning of the Contract Clause, the impairment is slight under the circumstances. The oil and gas industry is heavily regulated. The burden of successfully negotiating a surface owner's consent, or obtaining a ministerial permit by following the "second pathway," is justified by the County's interest in protecting agricultural land use, and minimizing land use conflicts. Regulations substantially more restrictive than the County's ordinance have been upheld against Contract Clause challenges. *See, e.g., Energy Reserves Group, Inc. v. Kansas Power and Light Co. (1983) 459 U.S. 400; Exxon Corp. v. Eagerton (1983) 462 U.S. 176; Hermosa Beach Stop Oil Coalition v. City of Hermosa Beach (2001) 86 Cal.App.4th 534.*

2. Equal Protection

Vaquero petitioners have failed to prove that the ordinance denies them equal protection under the U.S. Constitution, or the California Constitution. The "two pathway" provisions of the ordinance do not involve a suspect class or a fundamental right. The differential regulatory treatment for split estate mineral owners, based on surface owner consent or refusal to consent, is rationally related to the County's legitimate interest in promoting cooperation, protecting agricultural land use, and minimizing land use conflicts.

3. Due Process

Vaquero petitioners have failed to prove that the ordinance denies them due process of the law under the U.S. Constitution, or the California Constitution, and no impermissible regulatory "taking" has been shown. The purposes of the County's ordinance, establishing

tiers and "two pathways" to a ministerial permit, include protecting agricultural land use, minimizing land use conflicts, promoting cooperation where mineral and surface ownership has been severed, and protecting health, safety and the environment. The subject ordinance contains reasonable provisions substantially aimed at achieving these legitimate purposes. *See, Murphy v. Amoco Production Co. (1984) 729 F.2d 552, 556.*

Vaquero petitioners' reliance on *Eubank v. City of Richmond (1912) 226 U.S. 137 ("Eubank")*, is misplaced. In *Eubank*, the Supreme Court invalidated a city ordinance that conferred the power to establish building setback lines upon the owners of two-thirds of the property abutting any street. In the present case, County's ordinance does not give surface owners the power to "veto" a mineral owner's activity, just the power to consent or withhold consent. When either the surface owner or the mineral owner is unwilling to agree, for whatever reason, the mineral owner has the "second pathway" option. *Eubank* precludes the unlawful *delegation* of legislative authority; it does not apply to circumstances where—as here—the law allows private parties to *waive* a requirement ("first pathway"), or obtain a permit by alternate means ("second pathway"). *See, Thomas Cusack Co. v. City of Chicago (1917) 242 U.S. 526 ("Cusack"); see also, Kentucky Div., Horsemen's Benev. & Protective Assn., Inc. v. Turfway Park Racing Assn., Inc. (1994) 20 F.3d 1406* [discussing *Eubank* and *Cusack*].

CEQA Standard of Review

Public Resources Code § 21168.5 applies in cases seeking traditional ("ordinary") mandamus and cases other than those to which Public Resources Code § 21168 applies, such as cases where an agency has made a "legislative," "nonjudicial" or "nonadjudicative" determination or decision. *Pub. Res. Code § 21168.5; Laurel Heights Improvement Assn. of San Francisco, Inc. v. Regents of Univ. of Calif. (1988) 47 Cal.3d 376, fn. 5; Vineyard Area Citizens for Responsible Growth, Inc., v. City of Rancho Cordova (2007) 40 Cal.4th 412, fn. 4; Center for Biological Diversity v. California Dept. of Fish & Wildlife ("Center") (2015) 62 Cal.4th 204, 214-215.* The court reviews an agency's determination or decision under Section 21168.5 to see if the agency committed a "prejudicial abuse of discretion." *Pub. Res. Code § 21168.5.* An "abuse of discretion" occurs under Section 21168.5 if: (1) "the agency has not proceeded in a manner required by law," or (2) "the [agency's] determination or decision is not supported by substantial evidence." *Pub. Res. Code § 21168.5; Vineyard, supra, at p. 435.* Judicial review of these two types of error differs significantly: the court determines *de novo* whether the agency has employed the correct procedures, "scrupulously enforc[ing] all legislatively mandated CEQA requirements," *Vineyard, supra, at p. 435 [quoting Citizens Goleta Valley v. Board of Supervisors (1990) 52 Cal.3d 553, 564]*; the court accords greater deference to the agency's substantive factual conclusions, and reviews them for substantial evidence. *Laurel Heights, supra, 47 Cal.3d at p. 393; Vineyard, supra, at p. 435.* Thus, in evaluating an EIR for CEQA compliance under Section 21168.5, the court must adjust its scrutiny to the nature of the alleged defect, depending on whether the claim is predominantly one of improper

procedure or a dispute over the facts. *Vineyard, supra, at p. 435; Center, supra, 62 Cal.4th 204, 214-215.*

An EIR will be found legally inadequate—and subject to independent review for procedural error—where it omits information that is both required by CEQA and necessary to informed discussion." *California Native Plant Society v. City of Santa Cruz (2009) 177 Cal.App.4th 957, 986.* Omission of required information constitutes a failure to proceed in a manner required by law where it precludes informed decision-making by the agency or informed public participation by the public. *Id. at p. 987.*

The substantial evidence standard is applied to conclusions, findings, and determinations, to challenges regarding the scope of an EIR's analysis of a topic, the methodology used for studying an impact, and the reliability or accuracy of data upon which the EIR relied, because these types of challenges involve factual questions. *Ibid.; see also, Santa Monica Baykeeper v. City of Malibu (2011) 193 Cal.App.4th 1538, 1546.*

In applying the "substantial evidence" standard to an agency's factual determinations under both Section 21168 and Section 21168.5, the court must resolve reasonable doubts in favor of the administrative finding and decision. *Topanga Association for a Scenic Community v. County of Los Angeles (1974) 11 Cal.3d 506, 514; Laurel Heights, supra, 47 Cal.3d at p. 393.* A court may not set aside an agency's approval of an EIR on the ground that an opposite conclusion would have been equally or more reasonable. *Greenbaum v. City of Los Angeles (1984) 153 Cal.App.3d 401-402; Laurel Heights, supra, 47 Cal.3d at p. 393.* The court does not pass upon the correctness of the EIR's environmental conclusions, but only upon its sufficiency as an informative document. *Laurel Heights, supra, 47 Cal.3d at p. 392.* The court must resolve reasonable doubts in favor of the administrative finding and decision. *Id. at p. 393.*

KGF Issues

1. CUP Alternative.

Petitioner argues that no substantial evidence supports the County's determinations that: (1) the CUP alternative would impede a project objective; and (2) the CUP alternative is environmentally inferior to the project ordinance.

Would Not Achieve Basic Objective

County's findings regarding the CUP alternative state, in part: the "[CUP alternative] would not achieve the Project's basic objective[;]" it "would not streamline the County's current oil and gas permitting procedures because it would impose a lengthy and cumbersome discretionary permitting process on all new oil and gas development...[;]" "County currently contains approximately 75 active oil and gas fields, and over 2,500 wells are drilled in the County every year[;]" "it is not practical to subject every well permit to

an individual discretionary approval process, or for environmental reviews to be conducted on every single well or groups of wells[;]" "County lacks the resources to process thousands of oil and gas Negative Declarations and/or EIRs each year[;]" "the economic consequences for operators would be severe, delaying drilling for many months during the preparation of costly individualized CEQA documents[;]" "such individualized review would be highly repetitive, as the thousands of Negative Declarations and EIR's would re-analyze the same impacts and prescribe the same mitigation for each new well or group of wells throughout the County[;]" "the basic objective of the Project and this EIR is to eliminate time-consuming and costly discretionary reviews of individual well and field development activities by establishing a ministerial site plan review process which incorporates mitigation identified in this EIR." Substantial evidence supported County's findings.

Petitioner argues that County rejected the CUP alternative because it would not achieve "one of the 13 project objectives, the streamlining of oil and gas environmental review and permitting." Petitioner cites Guideline § 15126.6(b), and argues that County may not "reject an alternative because it has some adverse impact on a single project objective." Petitioner's interpretation of the findings is unreasonably narrow. Several project objectives obviously overlap and interrelate. It is reasonably apparent that County's findings discuss "streamlining" regulations and the consequences of doing so, from the standpoint of both County administration and industry compliance. The finding is sufficiently informative and cannot reasonably be understood as involving only "one of 13 project objectives." Moreover, Guideline § 15126.6(b) governs the assessment of "*potentially*" feasible alternatives in the EIR. County's ultimate decision to reject an infeasible alternative is governed by Guideline § 15091(a)(3). *California Native Plant Soc. v. City of Santa Cruz (2009) 177 Cal.App.4th 957, 998-999.*

Petitioner argues the CUP alternative "would not impede efficient and streamlined environmental review," and that "no actual evidence" supports County's determinations regarding the administrative burden imposed by the CUP alternative. Petitioner is incorrect. Petitioner's opinion the CUP alternative "would *enable*" streamlined review in some abstract sense does not address objectives and practical constraints with which County was obviously considered. County considered an actual workload, and was entitled to rely on oral and written presentations and analyses regarding the estimated number of permits to be issued, County's experience with oil and gas development, CUPs, EIRs, negative declarations, costs, the discretionary approval process, how long that process actually takes, County's own resources and the limitations, as well as the severe negative consequences of individualized discretionary review to an industry so economically significant to County.

Petitioner argues that County refused to consider a variation of the CUP alternative. This argument appears as part of petitioner's broader contention that County's findings are not supported by substantial evidence. To the extent the perceived error is a lack of substantial evidence to support a finding, infeasibility findings are only required for "alternatives *identified in the environmental impact report.*" *Pub. Res. Code § 21081(a)(3).*

County made findings regarding the CUP alternative, and was not required to make specific findings regarding a proposed variation or variations of the CUP alternative. Nevertheless, substantial evidence in the record shows the CUP variant was criticized as infeasible for the same reasons as the CUP alternative, although it would have involved fewer CUPs. To the extent the perceived error is a failure to proceed in a manner required by law for failing to discuss a variation of the CUP alternative in the EIR, County considered and discussed a range of reasonable alternatives, as required. County was not required to discuss each proposed variation of a project alternative in the EIR. *Mira Mar Mobile Community v. City of Oceanside (2004) 119 Cal.App.4th 477, 491.*

County's findings and decision to reject the CUP alternative, including the CUP alternative variation, are supported by substantial evidence. There was no failure to proceed in a manner required by law. There was no prejudicial abuse of discretion.

Environmentally Inferior

County determined the "[CUP alternative] is ultimately environmentally inferior to the proposed Project." County found the "mitigation program...established by the Project would provide mitigation at levels in excess of that which would occur if new wells were subject to discretionary approval following individual environmental review, and "[i]n this sense, the Project is environmentally superior to [the CUP alternative] and will better serve regional conservation priorities...."

Substantial evidence shows the project mitigation measures were developed using "worst-case scenarios" and conservative assumptions. The mitigation is applied, including site-specific mitigation, whether or not the new project activity, e.g., new well, actually causes an impact. Petitioner may be correct that case-by-case analysis of each new well under a discretionary approval process, if reasonably practicable, might result in more tailored mitigation for particular wells. Petitioner might be wrong. Substantial evidence supports the determination, however, that subjecting all new wells to the project's mitigation measures over many years will produce environmentally superior results. County's judgment regarding the relative environmental merit of the project compared to the CUP alternative was informed by substantial evidence. There was no failure to proceed in a manner required by law. There was no prejudicial abuse of discretion.

2. Agricultural Impacts

Farmland Conversion / "Footprint"

Petitioner argues the EIR underestimated farmland conversion by considering only the infrastructure "footprint." The EIR determined that the project's incremental contribution to the conversion of farmland to non-agricultural uses would be cumulatively considerable. The EIR's analysis of project-related farmland conversion was not limited to infrastructure "footprint." Substantial evidence supports the determination that, of the

total farmland acreage in the project area (828,973 acres), the project will impact ("disturb") 298 acres (.04%) per year, or a total of approximately 7,450 acres between 2015 and 2040, less than 1% of total farmland acreage. The EIR's "disturbance factors," the methodology used to achieve them, the scope of the analysis, and determinations regarding farmland conversion are supported by substantial evidence. There was no failure to proceed in a manner required by law. There was no prejudicial abuse of discretion.

Clustering

Petitioner argues that it and others proposed a mitigation requirement that oil and gas infrastructure be "clustered" on farmland to minimize ground disturbance, and that County "completely ignored the proposal." Commenters asserted that the DEIR "must identify mitigation measures requiring oil and gas facilities to be clustered together, instead of being spread out across contiguous parcels of land" or "a farm." Petitioner's attorneys commented that the mitigation measures in the DEIR "fail[ed] to adequately remedy land use conflicts between oil and gas and agricultural operations," and "there are no measures that require wells and facilities to be clustered to avoid unnecessary disruptions of agricultural activities." Petitioner asserts that general plan policies require industrial uses to be clustered.

An EIR must adequately respond to specific suggestions for mitigating a significant environmental impact unless the suggested mitigation is facially infeasible. *Guideline § 15088; Los Angeles Unified School Dist. v. City of Los Angeles (1997) 58 Cal.App.4th 1019, 1029.* Clustering oil and gas facilities would not appear to be facially infeasible. Also, some of County's responses to comments regarding clustering directed commenters to responses that did not exist. In other responses and analyses, however, County directly and indirectly responded to comments on clustering.

County considered a range of reasonable alternatives to the project, including Alternative 3, the reduced ground disturbance alternative, which would limit the disturbance footprint on existing agricultural lands by requiring clustering of new wells in locations immediately adjacent to existing oil and gas equipment. Alternative 3 was adequately analyzed, and rejected. In other responses to comments regarding clustering, County: noted that for more than a century, there has been co-location of oil and gas operations with agricultural operations, including on split estate lands, with "little evidence of problems and conflicts;" referred to Global Response 4, [discussing legal rights of surface and mineral owners on "split estates," the origin of those rights, e.g., laws, regulations, leases and other agreements between oil and gas operators and surface landowners that may affect surface use, and the legal dominance of the mineral estate over the surface estate vis-à-vis use of the surface to extract minerals]; discussed general plan policies that promote clustering industrial uses, and "numerous and more specific policies" regarding oil and gas activities that do not require clustering uses, noting that the project ordinance balances these competing interests; discussed ordinance provisions requiring

notice to surface owners regarding oil and gas site plans and the surface owner signoff process, creating incentive for cooperation between mineral owners and surface owners.

The information provided in direct response to the comments on clustering mitigation could have been better structured, but County was responding to a number of comments, and the information provided was reasonably adequate for informational and decision-making purposes. The responses were supported by substantial evidence. There was no failure to proceed in a manner required by law There was no prejudicial abuse of discretion.

Rangeland

Petitioner argues that the EIR fails to include a determination regarding the significance of project impacts on rangeland. The DEIR's description of the environmental setting shows that Kern County encompasses 8,202 square miles, which includes approximately 2,317 square miles of rangeland. The total project area consists of approximately 3,700 square miles in the western part of the county, which includes 982,166 acres (approximately 1,535 square miles) designated as rangeland. The EIR discloses that over the 25-year life of the project, 832 acres of "uncultivated" land (which includes dairy farms, grazing land, and other agricultural production not dependent on cultivated land) out of the total 982,166 acres of rangeland in the project area, could be converted due to the project. The EIR also discloses that the Kern County General Plan projects a net loss of 55,000 acres of grazing land based on land use conversions consistent with existing land use plans, which are unrelated to the project. Petitioner points out that this statistical information does not address the significance of the rangeland conversion due to the project. Petitioner is correct.

An EIR must include a statement of "[a]ll significant effects on the environment of the proposed project," *Pub. Res. Code § 21100(b)(1)*, or alternatively, a "statement briefly indicating the reasons for determining that various effects on the environment of a project are not significant and consequently have not been discussed in detail in the environmental impact report" *Pub. Res. Code § 21100(c); Guideline § 15128. See also, Protect the Historic Amador Waterways v. Amador Water Agency (2004) 116 Cal.App.4th 1099, 1110-1111.* There appears to be no such statement in the project EIR.

County properly utilized Appendix "G" to determine the significance of impacts on agricultural resources, and real party argues that "agricultural" land as defined in Appendix "G" does not include rangeland. That conclusion, however, does not relieve County of its obligation to analyze significant impacts. The use "NOTE" at the top of Appendix "G" states, "Substantial evidence of potential impacts that are not listed on this form must also be considered." It is thus necessary in appropriate circumstances to modify or augment the checklist to ensure that all potentially significant impacts are adequately addressed. *See, Protect the Historic Amador Waterways v. Amador Water Agency, supra, 116 Cal.App.4th 1099, 1110-1111; 1 Kostka & Zischke, "Practice Under the Calif. Environmental*

Quality Act" (2d ed.) § 13.15.

The EIR's omission of a discussion regarding the significance of the project's impact on rangeland, or a statement briefly indicating the reason for determining that the project's impact on rangeland is not significant and consequently has not been discussed, amounts to a failure to proceed in a manner required by law, and a prejudicial abuse of discretion.

Mitigation Measure 4.2-1: Non-existent Programs and 1:1 Ratio

Petitioner argues that the EIR's determination mitigation measure ("MM") 4.2-1 would reduce the impact of farmland conversion to a level of less than significant is not supported by substantial evidence. MM 4.2-1 sets forth a performance standard requiring agricultural land mitigation at a ratio of 1:1, using one or more of several specified measures. It does not contain "numerous loopholes," and it does not rely on "nonexistent" preservation programs for its effectiveness. The impact being mitigated is the temporary loss of agricultural production caused by project-related activities. The applicant must demonstrate compliance with the 1:1 mitigation requirement through one or more specified measures prior to ground disturbance. The fact that County has not yet adopted an agricultural farmland mitigation bank or equivalent agricultural preservation or mitigation program, does not change the 1:1 mitigation requirement or limit the effectiveness of the mitigation measure through other specified options.

County identified and evaluated the potentially significant impact, and identified measures to mitigate that impact. County was not required to commit to a particular measure in the EIR as long as it committed to effectively mitigating the impact. *Guideline § 15127.4; North Coast Rivers Alliance v. Marin Municipal Water Dist. Bd. of Dir. (2013) 216 Cal.App.4th 614, 629-630; San Joaquin Raptor Rescue Center v. City of Merced (2007) 149 Cal.App.4th 645, 671.* The mitigation is not limited to a maximum acreage based on estimated land conversion. Specific mitigation acreage for each project activity will be based on a 1:1 ratio and determined at the time the project-related activities occur. This is an appropriate level of mitigation. *Masonite Corp. v. City of Mendocino (2013) 218 Cal.App.4th 230, 236-238.* County committed itself to mitigation through specified alternative measures over the 25-year life of the project.

Substantial evidence supports County's determination that MM 4.2-1 will reduce the related project impact to a level of less than significant. There was no failure to proceed in a manner required by law, and there was no prejudicial abuse of discretion.

3. Water Supply

Localized Impacts

Petitioner argues the EIR's analysis of water supply obscured the project's local impacts and lacked sufficient detail. The EIR water supply assessment described current

and projected water demands, surface and ground water sources, and water usage by sector in wet, single-dry and multiple-dry years, separately analyzing the defined "subareas" within the project area and their distinct characteristics. The water supply assessments utilized public reports and management plans from water districts and agencies, including quantitative data from each subarea, describing specific groundwater aquifers in the project area and the hydrological properties of aquifers in each subarea. The final water supply assessment projected urban water demand by water district, supply *and demand projections by subarea, and surpluses and deficits within subareas. Produced* water re-use was projected for each subarea. The EIR disclosed that oil and gas production currently generates, and will continue to generate, sufficient quantities of "produced" water to satisfy more than 90% of project-related water demands over the project's life, which does not take away from, or compete with, water usage/demand by other sectors.

The EIR disclosed that project M&I quality water demand is currently 8,778 AF annually, and will increase to an estimated 11,760 AF in 2040. The project M&I demand is compared to annual agricultural demand of 2,630,029 AF, and average annual urban demand of 301,736 AF. The EIR did not merely compare project M&I use to the total project area M&I demand. In the final water supply assessment, project M&I use was compared to agricultural, urban, and recycled "produced" water use, separately, for each subarea, in normal, single-dry and multiple-dry years. The EIR determined that project M&I demand would contribute to overdraft conditions in an existing water shortage, disclosed the water supply impacts, and mitigation measures were adopted.

A more detailed analysis that included more specific water supply impacts in particular locations, or to individual farmers, was not required. The EIR represents a good faith effort at full disclosure, and was reasonably adequate to inform decision-makers and the public of the project's water supply impacts. Substantial evidence supports the EIR's methodology, scope of analysis, and determinations regarding water supply impacts. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

Impacts on Other Water Users

Petitioner argues the EIR lacks sufficient information about the project's impacts on other water users. Petitioner argues the EIR does not evaluate whether lowered groundwater levels could affect water wells near oil and gas development, does not mention that water shortages can result in abandoned crops and idled agricultural lands, and does not disclose the extent of water rationing that water agencies would impose on users as a result of projected water shortages.

Substantial evidence shows that total oil industry M&I water use will be 0.4% of projected agricultural use from 2015-2035. It would be speculative to assume such a small percentage would cause water rationing for famers, particularly when agricultural

demand, and localized agricultural supply and demand, is influenced by so many factors. Based on existing water constraints in the project area, the EIR determined the project would continue to create existing, as well as projected future, increases in water demand, and there are no feasible mitigation measures available to reduce such impacts to a less than significant level. The EIR determined that implementation of MM 4.17-2, MM 4.17-3, and MM 4.17-4 could reduce water supply impacts, "but the allocation of water supplies and water demands, the complex laws affecting water rights, the many water districts that have legal jurisdiction over one or more sources of water in the Project Area, the varied technical feasibility of treating produced water, and the produced water reuse opportunities all present complex variables that fall outside the scope of the County's jurisdiction or control under CEQA." The EIR concluded the project's impacts to water supplies would be significant and unavoidable, and mitigation measures were adopted. Substantial evidence supports the EIR's methodology, scope of analysis, and determinations, and the EIR was adequate as an informational document. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

Drought Conditions

Petitioner argues the EIR should have been updated to account for the "historic" drought. Drought conditions were adequately addressed in the water supply assessments and EIR, using best available historical data. In its findings regarding project impacts, County determined the project would not have a sufficient M&I water supplies to serve project demand from existing entitlements and resources, or new or expanded entitlements would be required. County explained:

> With respect to the Project's demand for M&I water, however, current drought conditions have severely restricted the availability of imported and local surface supplies throughout California, including the Project Area, and groundwater is being used more heavily to meet Project Area demand, including for oil and gas activities. Surplus M&I-quality water is not available in the Project Area. Any new use reduces the availability of M&I-quality water to another Project Area user, or increases the regional groundwater overdraft if supply shortfalls are addressed by increased groundwater extraction. Consequently, existing entitlements and resources are insufficient to meet current and projected future M&I water demand in the Project Area. Increasing water demand under overdraft conditions is considered to be a significant impact.

Updating the EIR to provide more recent drought information was not required. The EIR was sufficiently informative. Substantial evidence supports the EIR's methodology, scope of analysis, and determinations. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

Consistency with General Plan Water Supply Policies

Petitioner argues the project is inconsistent with General Plan policy # 41, and Metro Bakersfield General Plan # 3, requiring an adequate water supply for "development proposals." County determined that the project was consistent with these policies, and made the necessary findings. The policies are not implementation measures, distinguishing them from the specific implementation measure involved in *Spring Valley Lake Assn. v. City of Victorville (2016) 248 Cal.App.4th 91. See generally, Friends of Lagoon Valley v. City of Vacaville (2007) 154 Cal.App.4th 807, 817* [distinguishing guiding policies from implementing policies.]

Also, in the context of County's general plan policies, County could properly view the project is an "energy project proposal," not a "development proposal" as that designation is used in General Plan policy # 41, and Metro Bakersfield General Plan # 3. The EIR considered and discussed the policies. County's energy policies encourage orderly energy development, and protect oil and gas resources, as well as water resources. County's determinations of consistency are entitled to deference, and were reasonable. Petitioner's interpretation of the policies is not reasonable, and would effectively impose a moratorium on all County land use permitting because any impact on water supply by any source would be significant. Substantial evidence supports County's determinations regarding consistency with the general plan policies. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

4. Noise

Petitioner argues the EIR's noise analysis violates CEQA because: (1) the EIR fails to disclose the project's impacts on ambient noise levels, and (2) the EIR fails to mitigate those significant impacts.

Ambient Noise Impact:

Petitioner argues the EIR fails to disclose significant noise impacts by concluding that all increases to ambient noise levels are insignificant if they occur under 65 dB. Petitioner argues, in essence, that the EIR misapplies the thresholds of significance stated in the EIR.

The EIR identified three significance thresholds to evaluate noise impacts from the project. The first threshold evaluated noise impacts based on standards in applicable general plans, which the EIR determined was 65 dB DNL (day/night average sound level). The second threshold evaluated whether the project would create a "substantial temporary or periodic increase" in ambient noise levels. The third threshold evaluated whether the project would create a "substantial permanent increase" in ambient noise levels.[1]

[1] The parties' briefs and the AR are not entirely consistent regarding the order in which the significance thresholds for noise are listed. The DEIR (AR 2002) listed the threshold for

County explained in response to comments:

> The second threshold applies to project construction, and addresses whether the proposed project would create a "substantial temporary or periodic increase in ambient noise levels in the project vicinity above levels existing without the project." The third threshold applies to project operation, and addresses whether the proposed project would create a "substantial *permanent increase in ambient noise levels in the project vicinity above levels existing without the project.*" While these two thresholds *qualitatively* assess temporary or permanent increases over ambient noise without the project, the lead agency – Kern County – maintains discretion to determine the *quantitative* threshold applicable to each project. For this project, the *County applied a quantitative threshold of 65 dB DNL/CNEL*, which represents the exterior noise levels the County has deemed to be acceptable for noise sensitive areas. . . Where a project would exceed 65 dB DNL/CNEL, noise mitigation measures would be required. (Emphasis added.)

Petitioner argues that County's application of the significance thresholds ignores noise increases from existing levels that occur *under* 65 dB. Petitioner argues that County's approach "simply writes the third threshold out of existence." Petitioner cites no authority to suggest that if an EIR has two thresholds of significance, those thresholds may not overlap, or arrive at the same result, or use the same numerical metric, evaluating an impact.

County's "quantitative" measure (65 dB DNL/CNEL) to determine whether an increase in ambient noise was "substantial" is supported by substantial evidence. County's noise study included ambient noise measurements from multiple locations in each of the subareas, with the results expressed using several discreet metrics, including "DNL/CNEL." Substantial evidence explains how noise is measured, the existing noise environment in the project area, how the noise study was conducted in the subareas, the

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"substantial *permanent* increase" (associated with operations) before "substantial *temporary* or periodic increase" (associated with construction). The responses to comments refer to temporary increases as the "second" threshold and "permanent" increases as the "third" threshold, which appears to be consistent with the parties' briefs. This ruling will refer to permanent increases as the "third" threshold to remain consistent with the briefs. The text of the DEIR (AR 2002), however, stated that a "project would normally be considered to have a significant impact if it would result in:

- Exposure of persons to, or generate, noise levels in excess of standards established in the local general plan or noise ordinance or applicable standards of other agencies;

* * * * *

- A substantial permanent increase in ambient noise levels in the project vicinity above levels existing without the project;
- A substantial temporary or periodic increase in ambient noise levels in the project vicinity above levels existing without the project[.]" (Emphasis added.)

results of the study, and applicable regulations. Part of this discussion included: OSHA's noise exposure limit for workers (90 dBA over an 8-hour work shift); California State Dept. of Health "acceptable" noise level for land use compatibility (60 dBA DNL/CNEL); Kern County General Plan limit in noise sensitive areas (65 dBA DNL); Metro Bakersfield General Plan limit (65 dB CNEL). The EIR's noise study expert stated:

> The Noise Element of the Kern County General Plan establishes a land use compatibility criterion of 65 dB DNL for exterior noise levels in outdoor activity areas of residential uses. Additionally, *the 65 dB DNL exterior noise level criterion is commonly applied throughout incorporated areas of Kern County, and therefore should be used to determine project compliance in most instances.* (Emphasis added.)

The record provides substantial evidence to support County's use of "65 dB DNL/CNEL" as a quantitative measure for determining whether an increase in noise was "substantial." County acted within its discretion to make that determination, and was not compelled by CEQA, case law, or experts to do otherwise.

CEQA does not define what constitutes a "substantial" increase in noise. Petitioner cites *Berkeley Keep Jets Over the Bay Committee v. Board of Port Commissioners ("Berkeley Keep Jets") (2001) 91 Cal.App.4th 1344*, a case that demonstrates the fact-dependent nature of the court's evaluation of an EIR's noise impact analysis. In *Berkeley Keep Jets*, the Port Commissioners evaluated an airport expansion, but failed to select an additional significance threshold, beyond the 24-hour weighted average ("CNEL"), to determine if 27,000 additional flights annually—approx. 73/day, mostly at night—would have a significant effect on sleep in neighborhoods. Applying a 65 CNEL average, the Port Commissioners essentially found there would be little or no significant noise impacts from the additional flights. Many people objected. The court in *Berkeley Keep Jets* held the EIR was deficient for failing to specifically evaluate the impact of the increased flights. *Id. at p. 1382.* The court's analysis emphasized the unique circumstance of "the effect on sleep patterns from a proposed increase in overnight flights over noise-sensitive residential areas." *Id. at p. 1379.*

The present case does not involve thousands of additional nighttime flights over noise-sensitive residential areas. Averages are capable of "watering down" or obscuring important facts. That obviously occurred in *Berkeley Keep Jets.* But it did not occur here. The EIR provided more than just the DNL/CNEL weighted average. County's determination to use the 65 dB DNL/CNEL value to assess what increases were "substantial" from a standpoint of land use compatibility was within County's discretion, informed by substantial evidence. County explained why it used its general plan standard to define "substantial." See, *National Parks & Conservation Assn. v. City of Riverside (1999) 71 Cal.App.4th 1341, 1353* [upholding use of 65 dB as noise threshold]; *Oakland Heritage Alliance v. City of Oakland (2011) 195 Cal.App.4th 884, 896* [agency discretion to rely on

adopted standards]. County was not required to accept petitioner's suggestion that *any* "5 dB increase" be deemed "substantial."

County's determination to use 65 dB DNL to define what was "substantial" within the meaning of its stated noise significance threshold is supported substantial evidence. County acted within its discretion to select a quantitative measure. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

Noise Mitigation:

Petitioner argues the noise mitigation violated CEQA because "significant increases" in noise levels below 65 dB were not addressed in the EIR, and thus, not mitigated. The EIR determined that noise impacts would be significant, but would be reduced to a level of less than significant after mitigation. In light of this court's ruling above, and in light of the record, substantial evidence supports County's determination that noise impacts would be less than significant after mitigation. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

5. Recirculation of EIR - Revised Health Risk Assessment

Petitioner argues the EIR should have been recirculated after it had been revised to include an analysis of cumulative health risks from multiple wells in the same area. The DEIR included a health risk assessment ("HRA"). In response to comments by SJVAPCD, the HRA was revised. In response to comments that the first 2 HRAs did not address the combined effects of multiple wells, County prepared a third HRA. KGF argues the third HRA should have been recirculated for comments.

Real parties' contention that the multiple-well HRA was not a "cumulative impact" analysis within the meaning of CEQA is incorrect. "Cumulative impacts" refers to two or more individual *effects* which, when considered together, are considerable or which compound or increase other environmental impacts. *Guideline § 15355.* The "individual effects may be *changes resulting from a single project* or a number of separate projects." (Emphasis added.) *Guideline § 15355(a).*

However, County determined based on substantial evidence that the cumulative HRA confirmed conclusions reached earlier. Those conclusions were presented for review and comment, and petitioner commented on the cumulative HRA. The cumulative HRA presented no significant new information; it amplified an earlier conclusion. The record does not show that the draft EIR was so "fundamentally and basically inadequate and conclusory in nature that public comment on the draft was in effect meaningless." *Center for Biological Diversity v. California Dept. of Forestry and Fire Protection (2014) 197 CalApp.4th 931, 949.* The decision not to recirculate the EIR is supported by substantial evidence. There was no prejudicial abuse of discretion.

Arvin Petitioners' Issues

1. "Ministerial" v. "Discretionary" Permits

Arvin Petitioners assert a "facial challenge" to the project ordinance. They argue the permit approval process is "inherently discretionary" because "many of the 88 mitigation measures ask the County to make subjective, discretionary decisions...." Arvin Petitioners' complaint seeks a declaratory judgment determining that the project ordinance "[d]oes not, within the meaning of CEQA, establish a ministerial, non-discretionary permitting scheme...." In their opening brief, Arvin Petitioners ask for a declaratory judgment that the "Ordinance's permitting scheme is discretionary, not ministerial, and does not exempt approval of future oil and gas activities from CEQA review." There is no challenge to a particular permit decision or approval.

The project ordinance establishes "Conformity Review" and "Minor Activity Review" permits in designated tier areas. "Conformity Review" permits are generally applicable to major oil and gas development activities, and "Minor Activity Review" permits are applicable to less intensive activities such as replacing tanks and pipelines. County has determined that the permits are ministerial. Applicants for either permit must demonstrate compliance with specified mandatory mitigation measures.

County's determinations regarding the ministerial nature of the permits and the permit approval process are supported by substantial evidence. There was no failure to proceed in a manner required by law. There was no prejudicial abuse of discretion. Declaratory relief is not warranted or appropriate, for several reasons.

First, County's legislative decision to establish a ministerial permit process, and its characterization of the permits as "ministerial," are entitled to deference. CEQA exempts ministerial permits from CEQA review. *Pub. Res. Code § 21080(b)(1).* CEQA Guidelines state, "The determination of what is 'ministerial' can most appropriately be made by the particular public agency involved based upon its analysis of its own laws...." *Guidelines § 15268(a).* Public agencies are urged to make a determination, in advance, what projects, actions and permits are ministerial. *Guidelines §§ 15022(a)(1)(B), 15268(c); Sierra Club v. Napa County Bd. of Supervisors (2012) 205 Cal.App.4th 162, 178.*

Second, the declaratory judgment Arvin Petitioners seek would effectively rewrite the project ordinance and create a new discretionary permitting system that County does not intend. When an agency's determination, finding, or decision does not comply with CEQA, Pub. Res Code § 21168.9 *requires* the court (i.e., "shall") to enter an order that "*includes*" one or more specified "mandates" to the agency, but only those "necessary to achieve [CEQA]compliance." Thus, while the equitable remedy of declaratory relief is expressly *not* precluded by section 21168.9, see *Pub. Res Code § 21168.9(c)*, such relief would seem to have limited value in the present case given the mandates required by section 21168.9. If the court determined that a particular mitigation measure gave County discretion, the

mandate necessary to achieve CEQA compliance might not require re-characterizing all permits issued under the ordinance as discretionary. The court cannot ignore County's determination, based on substantial evidence, that discretionary review of 2,000 plus permits per year is infeasible, or County's legislative judgment that ministerial permits are the most appropriate way to transition from "by-right" oil and gas development, to permits.

Third, just as declaratory relief is not available to review CEQA decisions subject to Pub. Res. Code § 21168, declaratory relief does not appear to be available in this ordinary ("traditional") mandamus proceeding governed by Pub. Res. Code § 21168.5. Judicial review of CEQA decisions that are subject to Pub. Res. Code § 21168 ("adjudicative" decisions) must be brought as administrative mandamus proceedings under CCP § 1094.5, and "[a] party...may not challenge an agency action that is reviewable under section 1094.5 by seeking *declaratory* or injunctive relief, either instead of or in addition to relief by administrative mandamus." *2 Kostka and Zischke, Practice Under the California Environmental Quality Act (2nd ed. 2017), § 23.59.* (Emphasis added.) Adoption of an ordinance is a "legislative" act to which Pub. Res. Code § 21168.5 applies, and related CEQA determinations are reviewed by ordinary mandamus under Code Civ. Proc., § 1085. *Western States Petroleum Assn. v. Superior Court (1995) 9 Cal.4th 559, 566; Friends of Sierra Madre v. City of Sierra Madre (2001) 21 Cal.4th 165, 172 fn.2.*

> An ordinary mandamus proceeding under CCP section 1085 is the method for reviewing a CEQA decision governed by Pub Res C section 21168.5. (Citation omitted). The same limitations on the scope of judicial review that apply in CEQA cases reviewed under CCP section 1094.5 apply in most CEQA cases reviewed under CCP section 1085....*The rule prohibiting other forms of review should apply in those cases as well.* (Emphasis added.) *2, Kostka and Zischke, Practice Under the California Environmental Quality Act (2nd ed. 2017), § 23.59.*

Fourth, the subject mitigation measures are not "inherently discretionary." They contain objective standards, or require compliance with existing regulations, or defer to discretionary decisions of other agencies, all of which confirm the essential "ministerial" nature of the implementation standards and conditions, including the mitigation measures. *See, Guidelines § 15126.4(a)(1)(B); Citizens for a Sustainable Treasure Island v. City and County of San Francisco (2014) 227 Cal.App.4th 1036, 1059; North Coast Rivers Alliance v. Marin Municipal Water Dist. Bd. of Dir. (2013) 216 Cal.App.4th 614, 629-631; Oakland Heritage Alliance v. City of Oakland (2011) 195 Cal.App.4th 884, 906-907; Health First v. March Joint Powers Authority (2009) 174 Cal.App.4th 1135, 1142-1145.* The permit process requires County to determine whether a proposed activity *conforms* to specified standards. County is not given discretion to "shape" the repairs to, or development of, oil or gas wells. Neither the substance of the mitigation measures nor the permit approval process is discretionary to any substantial degree, thus distinguishing the present case from the circumstances involved in *Friends of Westwood, Inc. v. City of Los Angeles ("Westwood")*

(1987) 191 Cal.App.3d 259, and *Natural Resource Defense Council, Inc. v. Arcata Nat. Corp. ("NRDC/Arcata") (1976) 59 Cal.App.3d 959.*

Fifth, Arvin Petitioners have not shown in their facial challenge that "no set of circumstances exists under which the [ordinance] would be valid." See, *Sierra Club v. Napa County Bd. of Supervisors (2012) 205 Cal.App.4th 162, 173.* Arvin Petitioners do not challenge a particular permit, such as the challenges involved in *Westwood, supra, 191 Cal.App.3d 259*, and *NRDC/Arcata, supra, 59 Cal.App.3d 959. Westwood* and *NRDC/Arcata* both emphasize the fact-specific nature of determining whether an act is ministerial or discretionary under CEQA, and *Westwood* carefully avoids finding that the entire regulatory process was discretionary, or that the exercise of *any* discretion renders a particular permit decision discretionary. *Id. at p. 280.* The breadth of possible activities subject to the permit requirement make it very difficult, if not impossible, to know, over time, and in every situation, which mitigation measures will actually apply to a given application, or *how* the measure will be applied. Some activities *may* involve all of the mitigation measures with predictability, while others may not. The parties' briefs pose and analyze hypothetical scenarios, and there are no doubt many scenarios that *could* be envisioned where there is less predictability about the mitigation measures. It is conceivable the mitigation measures with which Arvin Petitioners are concerned will not apply to a particular project activity.

2. Spanish Language Translation.

Arvin Petitioners argue that County unlawfully denied Spanish-speaking residents meaningful participation in the CEQA process.

Neither CEQA nor the CEQA Guidelines require translation or interpretation in the manner suggested by Arvin Petitioners. No reported case has concluded that CEQA requires lead agencies to translate documents or provide interpreters. Public Res. Code § 8 requires CEQA notices, reports, statements and records to be made "in writing in the English language." Pub. Res. Code § 21083.1 precludes courts from interpreting CEQA or the Guidelines "in a manner which imposes procedural or substantive requirements beyond those explicitly stated in [CEQA] or in the [Guidelines]."

The issue in *San Franciscans for Reasonable Growth v. City and County of San Francisco (1987) 193 Cal.App.3d 1544* ("*San Franciscans*"), cited by Arvin Petitioners, was the *comprehensibility* of an EIR. An EIR "must be written and presented in such a way that its message can be understood by . . . members of the public who have reason to be concerned with the impacts which the document studies." *Id. at p. 1549.* CEQA Guidelines contain specific "plain language" requirements. Public Res. Code § 8 contains a specific English-language requirement. The plain meaning of Public Res. Code § 8 is not limited to publication of notices. The statutory language is not ambiguous: "[A]ny notice, report, statement or record [] required by [CEQA] . . . shall be made in writing in the English language." An EIR is a "report" within the meaning of section 8.

Arvin Petitioners argue that Public Res. Code § 8 "does not mean . . . documents governed by [the Public Resources Code] may be published only in English." The issue is whether translation was required, not whether it was *permitted*. Petitioners cite examples in the Public Resources Code where translation is specifically addressed, but these examples demonstrate how clear the Legislature can be when it imposes a translation requirement, e.g., *Pub. Res. Code § 3465* [oil sellers to post recycling signs in languages other than English under specified circumstances]; *Pub. Res. Code § 30315.5* [Coastal Commission "shall" make meeting notices available "in both English and Spanish"]; *Pub. Res. Code § 71113* [environmental working group to provide "guidance for determining when it is appropriate . . . to translate crucial public documents, notices, and hearings . . . for limited-English-speaking populations" by April 2002].

Imposing or implying a requirement to translate and interpret in the manner suggested by Arvin Petitioners would impermissibly add new procedural and substantive requirements that are not explicitly required by CEQA. There was no prejudicial abuse of discretion. Respondent County did not fail to proceed in a manner required by law. Arvin Petitioners have not shown by a preponderance of the evidence, or by the weight of the evidence, that "meaningful participation" was denied. No prejudicial abuse of discretion has been shown.

3. Water Supply Mitigation Measures

Arvin Petitioners argue that MM 4.17-2, MM 4.17-3 and MM 4.17-4 unlawfully defer formulation of mitigation. They argue the EIR defers mitigation to future groundwater plans that will not be completed until years after project approval, while failing to commit the County to measures that will satisfy specific performance criteria articulated at the time of project approval. They argue the Sustainable Groundwater Management Act ("SGMA"), and the 30,000 AF re-use goal for produced water are not sufficiently specific performance criteria under CEQA.

County did not unlawfully defer mitigation in violation of CEQA. County was not precluded from adopting measures that might not be effective in mitigating water supply impacts that County determined were "significant and unavoidable." County approved the project, adopting a statement of overriding economic and other considerations, and acknowledged uncertainty regarding the effectiveness of MM 4.17-2, MM 4.17-3 and MM 4.17-4. That was sufficient. See, *Gray v. County of Madera (2008) 167 Cal.App.4th 1099, 1119* ("County could have approved the Project even if the Project would cause significant and unavoidable impacts on water despite proposed mitigation measures if the County had adopted a Statement of Overriding Considerations that made such findings," but failed to do so.); *see also, Citizens for Open Government v. City of Lodi (2012) 205 Cal.App.4th 296, 332; 1 Kostka and Zischke, Practice Under the California Environmental Quality Act (2nd ed. 2017), § 14.9.*

Substantial evidence supports County's determination the water supply impacts were significant and unavoidable, the uncertainty regarding the effectiveness of the mitigation measures, and County's statement of overriding considerations approving the project. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

4. Air Quality

Arvin Petitioners argue the EIR inadequately analyzed and inadequately mitigated the project's air quality impacts, in that: (1) MM 4.3-8 violates the CEQA requirement that a project activity not be undertaken without mitigation measures in place; (2) the EIR fails to adequately mitigate PM 2.5 emissions; and (3) the EIR fails to assess the environmental impacts of road paving as mitigation.

MM4.3-8 - Deferral

The EIR discloses the project will cause significant air quality impacts, and mitigation measures were adopted. Among those measures, MM 4.3-8 requires an emission reduction agreement ("ERA") between County and the SJVAPCD whereby County will collect mitigation fees that the SJVAPCD will use for emission reduction projects, or, *alternatively, the applicant may conduct its own emission reduction projects approved by* SJVAPCD.

The legal principles governing deferral of the formulation of mitigation are discussed in *POET, LLC v. California Air Resources Board ("POET") (2013) 218 Cal.App.4th 681, at p. 738*:

> [W]e glean two principles that are important to this case. First, the deferral of the formulation of mitigation measures requires the agency to commit itself to *specific performance criteria* for evaluating the efficacy of the measures implemented. Second, the "activity" constituting the CEQA project may not be undertaken without mitigation measures being in place "to minimize any significant adverse effect on the environment of the activity." (Citation) In other words, the deferral relates only to the *formulation* of mitigation measures, not the mitigation itself. Once the project reaches the point where activity will have a significant adverse effect on the environment, the mitigation measures must be in place.

A project's contribution to an impact is less than cumulatively considerable if the project is required to implement or fund its fair share of a mitigation measure or measures designed to alleviate the cumulative impact. *Guidelines § 15130(a)(3).* CEQA allows a project to mitigate by paying a fee to fund its fair share of a measure designed to mitigate that project's cumulative impact, so long as the funding contributions are part of a reasonable plan of actual mitigation that the responsible agency commits itself to

implementing. See, *Gray v. County of Madera (2008) 167 Cal.App.4t 1099, 1121-1122; Anderson First Coalition v. City of Anderson (2005) 130 Cal.App.4th 1173, 1187; 1 Kostka and Zischke, Practice Under the California Environmental Quality Act (2nd ed. 2017), § 14.14.*

Substantial evidence shows that MM 4.3-8 is one of five measures adopted to reduce emissions to a performance standard of "no net increase." Substantial evidence shows there are a variety of available emission reduction programs that could be completed with fee proceeds which satisfy CEQA requirements for fee-based mitigation, notwithstanding opinions to the contrary. Substantial evidence shows there is a history of funding such emission reduction programs within Kern County and the SJVAPCD. It is presumed that County will comply with its own ordinance and will spend the fees it collects for the required air quality mitigation purposes. *Save Our Peninsula Comm. v. Monterey County Bd. of Sup. (2001) 87 Cal.App.4th 99, 140-141.* If a fee program is not available, MM 4.3-8 allows the project applicant to undertake its own emission reduction program, verified by SJVAPCD. Substantial evidence shows that if an applicant does not comply with MM 4.3-8, no permit will issue.

The formulation of mitigation under MM4.3-8 was not improperly deferred. Substantial evidence shows that MM 4.3-8 satisfies the requirements for fee-based mitigation, and supports County's determinations regarding MM 4.3-8. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

PM 2.5 Emissions

Arvin Petitioners argue that only respirable particulate matter (PM 10) emissions are mentioned in MM 4.3-8,[2] and that the absence of specific mitigation for fine particulate matter (PM 2.5) in MM 4.3-8 means the EIR's determination the project will "fully offset" emissions is not supported by substantial evidence. The EIR determines the project will make a cumulatively significant contribution of criteria pollutant emissions (NOx, PM 10, PM 2.5, CO and SO2), for which the project region is in nonattainment under applicable federal and state air quality standards. The draft EIR discloses that PM 2.5 was treated as a subset of PM 10. Five measures (MMs 4.3-1 through 4.3-4, and 4.3-8) were implemented

[2] MM 4.3-8 states, in relevant part:

> For Project facilities or equipment that are not required to offset emissions under a District rule as described in MM 4.3-1, and for Project vehicle and other mobile source emissions, the County will enter into emission reduction agreement with the San Joaquin Valley Air Pollution Control District, pursuant to which the Applicant shall pay fees to fully offset Project emissions of oxides of nitrogen, reactive organic gases, and particulate matter of 10 microns or less in diameter (including as applicable mitigating for reactive organic gases by additive reductions of particulate matter of 10 microns or less in diameter) (collectively, "designated criteria emissions") to avoid any net increase in these pollutants.... (Emphasis added)

to mitigate the project's contribution to criteria emissions. The EIR determined that even with implementation of the mitigation measures, the impacts will remain significant and unavoidable.

Substantial shows the air quality mitigation measures are designed to work together to mitigate project emissions, each measure achieving a portion of the required emissions mitigation. MM 4.3-8 requires an emission reduction agreement "[f]or Project facilities or equipment that are not required to offset emissions under a District rule as described in MM 4.3-1, and for Project vehicle and other mobile source emissions." Substantial evidence shows the EIR's "no net increase" standard for NOx, ROG and PM 10 is based on SJVAPCD policy, which can result, and historically has resulted, in direct and indirect reductions of PM 2.5 when viewed as a subset or component of PM 10. PM 2.5 represents approximately 35% of the total estimated particulate matter emissions from the project (PM 2.5 and PM 2.5-10). Substantial evidence shows that NOx generates PM 2.5 through chemical reactions in the atmosphere, that MM 4.3-8 emission reduction agreement programs for diesel vehicles and equipment will reduce PM 2.5 more than PM 10 emissions, and that NOx emission reductions are part of the SJVAPCD's strategy for reducing PM 2.5. Substantial evidence supports the determination that all feasible and reasonable changes or alterations have been required in, or incorporated into, the project that substantially reduce the potentially significant effects of PM 2.5 identified in the EIR.

The EIR does not fail to adequately mitigate PM 2.5 emissions. There may have been some lack of clarity regarding PM 2.5 in the EIR, but absolute perfection is not required. The EIR is adequate as an informational document, and substantial evidence supports the EIR's determinations, as stated, regarding MM 4.3-8. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

Road Paving:

Arvin Petitioners argue the EIR fails to assess the environmental impacts of road paving as mitigation. Arvin Petitioners are correct.

Impacts of mitigation measures must be discussed in the EIR if such measures "would cause one or more significant effects in addition to those that would be caused by the project as proposed." *Guidelines § 15126.4 (a)(1)(D)).* County argues that MM 4.3-8 requires payment of a per-well mitigation fee and that *potential* emission reduction projects, such as road paving, are examples and not commitments concerning mitigation.

As Arvin Petitioners correctly observe, "[I]t is far from speculative that road paving will be proposed and approved."

County adopted a resolution committing County to implementing measures aimed at reducing PM 10 emissions, including road paving. The project applicant requested recognition of paving as an emission reduction measure. The SJVAPCD repeatedly cites

road paving as a pollution reduction option. In the realm of what is merely possible, County's argument might have merit. *In the realm of what reasonable decision-makers* and informed citizens would have understood from reading the EIR, road paving was and is a reasonably likely air quality mitigation measure under MM 4.3-8. Road paving impacts should have been addressed in the EIR.

County failed to proceed in a manner required by law, and there was a prejudicial abuse of discretion.

5. Biological Resources

Arvin Petitioners argue that: (1) the EIR fails to adequately analyze impacts to special-status species;[3] (2) the EIR's analysis of impacts to habitat adjacent to worksites is inadequate; (3) the EIR unlawfully defers mitigation of impacts to species; and (4) the EIR fails to ensure adequate mitigation of harm to species' habitats.

Analysis of Impacts to Special-Status Species

CEQA guidelines do not compel use of a particular methodology for assessing impacts to special-status species. See, *Save Round Valley Alliance v. County of Inyo (2007) 157 Cal.App.4th 1437, 1468.* CEQA Guideline § 15065 describes the circumstances under which a lead agency "shall find that a project may have a significant effect on the environment *and thereby require an EIR*..." It is a preliminary step, not a mandatory methodology or significance threshold. CEQA Guideline § 15151 states:

> An EIR should be prepared with a sufficient degree of analysis to provide *decisionmakers with information which enables them to make a decision* which intelligently takes account of environmental consequences. An evaluation of the environmental effects of a proposed project need not be exhaustive, but the sufficiency of an EIR is to be reviewed in the light of what is reasonably feasible. Disagreement among experts does not make an EIR inadequate, but the EIR should summarize the main points of disagreement among the experts. The courts have looked not for perfection but for adequacy, completeness, and a good faith effort at full disclosure.

The EIR divided species into three 3 categories for analysis. Category 1 species included plants and animals known or likely to occur in the project area, and for which one of four types of habitat modeling data was available and used to quantify and analyze potential impacts by subarea and tier. Potential habitat, by tier and subarea, was modeled for nine Category 1 plant species and 28 animal species identified in the project area. Project impacts to high quality and low-to-moderate quality habitat for each Category 1

[3] Arvin Petitioners use the term "sensitive species." The EIR and County use the term "special-status species."

species were estimated. The EIR analysis of habitat impacts to Category 1 species allowed quantification of impacts without knowing the actual occurrence of a species at a particular place, focusing on the importance of habitat to a species rather than occupation levels "that tend to change over time."

Category 2 included species known or likely to occur in the project area but for which no modeling data was available. Impacts to Category 2 species were evaluated by identifying the subarea and tiers where those species could occur and by considering the level of potential new disturbance in each location. The EIR identified 31 Category 2 special-status plant species and 19 special-status animal species, summarized the likelihood of habitat occurrence by species, and analyzed the species on the basis of species-specific occurrence information. This analysis included an assessment of which species could occur in each subarea and tier, and identified key habitat requirements or constraints that could affect the spatial distribution of special-status species.

The EIR's impact analyses for Category 1 and Category 2 species were based on several assumptions: that all new wells will occur on undisturbed land, when that is likely not the case; "potential" land disturbance to poor quality habitat was deemed a potential impact for Category 1 species; the occurrence was considered possible for Category 2 species even if there were only limited historical observations or an extremely low likelihood of species activity in a tier or subarea. The EIR discussed the potential level of habitat modification for each Category 1 species, and assessed the likelihood of occurrence of habitat for every Category 2 species. Potential impacts to modeled special status species were characterized in terms of annual impacts to all identified habitat categories for each species analyzed within the project area, which included urbanized, agricultural, or high-density oil and gas production areas where predicted habitat values have been reduced or eliminated. Potential impacts to non-modeled special status species were analyzed, assuming that impacts would occur even in areas where there was an extremely low likelihood of species impact.

Category 3 included "potentially occurring" species. Category 3 species were identified through literature review, database searches, or by local experts as "potentially occurring" in the vicinity of the project area, and for which suitable habitat is present. Based on the evaluation by County's biologist, a total of 53 plants and 24 wildlife species were included in Category 3 and not further analyzed in the EIR, because they either did not occur in the project area, or had the potential to occur in the project area but lacked official status. The determination that species were Category 3 species if they were absent from the project area was based on a reasonable screening analysis, followed by a biologist's review to determine those warranting further study. Species were screened from further consideration when: no records for a species were found in the project area and suitable habitat was not present or not expected; species occurrence in the project area was migratory or transient, with little or no chance of impact from project activities; and occurrence data for species within project area was found to be erroneous. "Watch list" species were included in Category 3 unless review of their distribution and status indicated

that the portion of the species' distribution within the project area warranted further consideration of impacts. Appendix "N" of the EIR identified and discussed all Category 3 species excluded from further analysis based on County's biologist's review. No Category 3 species were excluded from Category 3 analysis. Category 3 species are part of the project-related preconstruction surveys. All applicable mitigation applies to Category 3 species.

Detailed findings were made regarding each Category 1 and Category 2 species. The EIR determined that without mitigation, the project had the potential to cause substantial adverse effects, either directly or through habitat modification, on identified special-status species. The methodology and scope of analyses for impacts to plant and wildlife special-status species were adequate, complete and a good faith effort at full disclosure. Site-specific or further analysis was not required. See; *Save Round Valley Alliance v. County of Inyo, supra, 157 Cal.App.4th 1437, 1468; Center for Biological Diversity v. Dept. of Fish & Wildlife (2015) 234 Cal.App.4th 214, 234.*

The EIR adequately analyzed impacts to special-status species and mitigated where required. The EIR's methodology, scope of analysis, and determinations regarding impacts to special-status species are supported by substantial evidence. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

Habitat Adjacent to Worksites–Edge Effects

The EIR discusses affected species, their habitat needs and distribution across the *entire project area, existing efforts to conserve species and protect habitat*, and the harmful effects of habitat fragmentation. Potential impacts to plant and wildlife species outside the construction or operations "footprint" are described. Both quantitative and qualitative approaches were utilized. The EIR discussed research specific to the area to analyze impacts, including local studies, that showed wildlife's ability to move across an active oil field was less impeded than with agricultural and urban lands, even where the oil field was moderately developed.

Mitigation measures to avoid or minimize impacts to species both at, and outside of, the development site were discussed and incorporated, including preconstruction surveys that must extend a specified distance beyond the ground disturbance, distance requirements in species-specific survey protocols where adjacent landowner approval is obtained, species-specific setbacks from occupied nests, burrows and other sensitive locales, and setbacks of up to one-half mile from certain active nests. The EIR was not required to quantify the acreage for "edge effects," and represents an adequate, complete and good faith effort at full disclosure.

The EIR specifically and adequately analyzed impacts to habitat outside the "footprint" of project-related development, including in the impact analysis and the formulation of mitigation measures. The EIR's methodology and scope of analysis regarding habitat

adjacent to worksites is supported by substantial evidence. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

MM 4.4-1 - Deferral of Mitigation

The EIR determined that impacts to special-status species were potentially significant, and mitigation measures were identified. MM 4.4-1[4] is part of a comprehensive mitigation plan expressed in fifteen separate measures to which County is committed, and which contain sufficiently specific performance criteria for valid mitigation under CEQA. County stated in response to comments, "When considered as a whole, the mitigation measures for biological resources comprise a comprehensive approach that emphasizes avoidance of impacts and mitigation of the remaining impacts through conservation of species and habitats in a manner that has the greatest likelihood of success."

MM 4.4-1 requires a biological reconnaissance survey to advise on potential project impacts, potential surveying needs, and the need for focused special status surveys. Focused/protocol surveys are conducted to "confirm the presence or absence" of sensitive species and to identify and implement "feasible avoidance and minimization measures for such species." In addition to MM 4.4-1, there are 14 other mandatory measures with which the applicant must comply, and which County considered in determining that impacts *would be mitigated to less than significant. Pre-disturbance surveys are required by* Mitigation Measures 4.4-1 (special status wildlife), 4.4-5 (bats), 4.4-8 (golden eagle nests), 4.4-10 (active birds' nests), 4.4-11 (blunt-nosed leopard lizard), 4.4-12 (protected and sensitive plant species), and 4.4-17 (sensitive natural communities, including waters and wetlands). The mitigation measures specify that surveys must be completed by qualified biologists in accordance with approved protocols. Surveys must be conducted at times that will provide relevant information regarding the presence of sensitive species at the site.

MM 4.4-1 is distinguishable from the mitigation measure expressing a "generalized goal" involved in *San Joaquin Raptor Rescue Center v. City of Merced (2007) 149 Cal.App.4th 645, 670.* The reconnaissance surveys required by MM 4.4-1 are part of a series of mandatory measures that work together to impose specific avoidance measures, prohibit the wrongful take of protected species, and require specific mitigation ratios where habitat disturbance is unavoidable. The decision in *Gentry v. City of Murrieta (1995) 36*

[4] MM 4.4-1 states in relevant part: "A qualified biologist shall conduct a biological reconnaissance survey in potential special-status species habitat to advise the project proponent of potential project impacts, potential surveying needs, and advise on the need for focused special status surveys...Based on the information gathered from the biological reconnaissance survey and any informal consultation with United States Fish and Wildlife Service and California Department of Fish and Wildlife, focused/protocol surveys shall be conducted by a qualified or permitted biologist (whichever is applicable) well in advance of ground disturbing activities to determine the presence/absence of sensitive species protected by state and federal Endangered Species Acts and potential project impacts to those species..."

Cal.App.4th 1359, is similarly distinguishable because *Gentry* held the city was required to further analyze mitigation measures to support a negative declaration, applying the "fair argument" standard. *Gentry* stated, however, that, "a condition could validly allow for deferred mitigation, provided other mitigation measures were clearly adequate..." *Gentry, supra, 36 Cal.App.4th at p. 1396*. The mitigation measures, of which MM 4.4-1 forms a part, contain adequate performance criteria.

MM 4.4-1 does not unlawfully defer mitigation of impacts. Substantial evidence supports County's determination that impacts to biological resources will be less than significant after mitigation. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

MM 4.4-16 - Mitigation of Harm to Habitats

Arvin Petitioners argue that MM 4.4-16[5] fails because it does not require that habitat be replaced with habitat of the equivalent type or quality. Arvin Petitioners cite *Preserve Wild Santee v. City of Santee (2012) 210 Cal.App.4th 260*. In *Santee*, which involved the Quino butterfly, the court stated at page 281:

> The absence of standards or guidelines in the EIR for active management of the Quino within the preserve is problematic because the draft habitat plan indicates vegetation management is the key consideration for the Quino's conservation and the City will not be utilizing prescribed burns or grazing in the preserve, the only two methods of vegetation management the draft habitat plan identifies. In addition, the timing and specific details for implementing other Quino management activities discussed in the draft habitat plan are subject to the discretion of the preserve manager based on prevailing environmental conditions. *Consequently, these activities are not guaranteed to occur at any particular time or in any particular manner.* (Emphasis added.)

[5] *MM 4.4-16 states in relevant part: "Ground disturbance shall be mitigated at a 1.0 to 1.0 ratio (one-acre of new disturbance shall require one-acre of mitigation) except in Tier 1 areas that contain existing disturbance of 70% or greater which shall be mitigated at a 1.0 to 0.5 ratio (one-acre of new disturbance shall require one-half acre of mitigation), for the land included in the Site Plan...New disturbance mitigation may be satisfied by one or a combination of the following measures: a. The recordation of a conservation easement or similar permanent, long-term conservation management agreement...b. Acquisition of land preservation credits from a mitigation bank... c. Removal of legacy oil and gas equipment...complete a reseeding effort using native species...d. Enhancement or restoration of existing habitat on lands already subject to a conservation easement or similar agreement, or which become subject to a conservation easement or similar agreement subsequent to the certification of this Environmental Impact Report...e. Payment of a biological resources mitigation fee for the acquisition and management of mitigation lands, legacy equipment removal, and/or land enhancement..."*

Santee does not hold that compensatory habitat must be of the same quality or nature as the habitat destroyed. *Santee* held that the mitigation was deficient because it lacked specific performance criteria regarding vegetation management.

The EIR's evaluation and determination of significance regarding biological resources was based on six separately-stated criteria. Habitat modification, alone, was not identified as a significant impact; replacement of habitat, alone, was not identified as adequate mitigation. County relied on multiple, complementary measures to mitigate impacts, and the entire "suite of measures" constitutes substantial evidence supporting the County's findings. Arvin Petitioners have not shown that the EIR's measures, acting together, will not mitigate the impacts to less than significant.

MM 4.4-16 is part of a comprehensive mitigation plan that adequately ensures mitigation of harm to species' habitats. The EIR's determinations are supported by substantial evidence. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

6. GHG Emissions

Mitigation – MM 4.7-4

County determined that GHG emissions from the project would be potentially significant, and implemented four mitigation measures to reduce impacts to less than significant. The first three measures rely on regulations to mitigate impacts. For emissions not captured by the first three measures, MM 4.7-4[6] applies and requires each applicant to reduce emissions to "no net increase" in one of three ways: (1) applicant reduction of GHG emissions verified by County; (2) acquisition of offset credits; or (3) inclusion in an emission reduction agreement ("ERA"). County determined the project's GHG impacts after mitigation would be less than significant, and determined the project's cumulative GHG impacts would be significant and unavoidable.

Arvin Petitioners argue there is no substantial evidence of the effectiveness of GHG mitigation through offset purchases. Arvin Petitioners specifically argue there is no substantial evidence: (1) that GHG offset programs exist, or that credits are available from

[6] MM 4.7-4 states: "Each Applicant shall offset all greenhouse gas emissions not covered by the Cap-and-Trade program or other mandatory greenhouse gas emission reduction measures through Applicant reductions of greenhouse gas emissions as verified by Kern County, through acquisition of offset credits from the California Air Pollution Control Officers Association Exchange Register or other third party greenhouse gas reductions, with consultation as to the validity of methodology for calculating reductions verified by the San Joaquin Valley Air Pollution Control District and accepted by Kern County, or through inclusion in an Emission Reduction Agreement, to offset Project-related greenhouse gas emissions that are not included in the Cap and Trade program to assure that no net increase in greenhouse gas emissions from the Project." (Emphasis added.)

existing programs; or (2) that offsets will satisfy CEQA's requirement that only GHG reductions "not otherwise required" may be used to offset emissions, i.e., the requirement of "additionality." Regarding ERAs, Arvin Petitioners argue there is no established program to support ERAs for project GHG emissions.

Arvin Petitioners' did not object to the effectiveness of the option under MM 4.7-4 permitting an applicant to directly reduce GHG emissions. That failure renders Arvin Petitioners' substantial evidence challenge to the remaining options academic. There is no reason that direct GHG reductions, verified by County, will not meet the performance standard.

In *San Joaquin Raptor Rescue Center v. County of Merced (2007) 149 Cal.App.4th 645*, the court found a mitigation measure adequate where only one of the two mitigation options available under the measure would be effective. The mitigation measure required mitigation in the form of replacement by either creating wetlands on site, or by offsite purchases of wetland banking credits. There was no wetlands conservation bank in the County, but the court held the mitigation measure was adequate, stating:

> Finally, Petitioners note that in mitigation measure 3.6-2d, if the Project causes loss to functioning and value of vernal pool areas, there must be mitigation in the form of replacement by either creating vernal pools or swales within the conservation area on site, or by off-site purchase of wetland banking credits. Since there are no wetlands conservation banks present in the County of Merced, the latter alternative is unavailable. The FEIR acknowledges this fact, but emphasizes that the other option—i.e., creating new vernal pools in the conservation area onsite—remains a reasonable mitigation measure. And if mitigation credits become available within the watershed, the FEIR further explains, then 'such acquisition would become an additional available measure.' In light of this clarification in the FEIR, petitioners have failed to demonstrate this particular mitigation measure is inadequate or unsubstantiated." *Id. at pp. 671-672.*

Arvin Petitioners' substantial evidence challenge regarding MM 4.7-4 fails on other grounds.

County and real parties in interest argue that during the administrative process, petitioners did not question the availability of offsets or credits, or whether the offsets would satisfy the requirement of GHG reductions "not otherwise required" ("additionality"). Exhaustion of administrative remedies is a jurisdictional prerequisite to maintenance of a CEQA action. *Bakersfield Citizens for Local Control v. City of Bakersfield (2004) 124 Cal.App.4th 1184, 1199.* Arvin Petitioners must show that an objection was made during the administrative process that was sufficiently specific so that County had the opportunity to evaluate and respond. *Citizens for Responsible Equitable Environmental Dev. v. City of San Diego (2011) 196 Cal.App.4th 515, 527.* The petitioners' objections:

during the administrative proceeding regarding MM 4.7-4 did not give County the opportunity to evaluate and respond to comments or arguments regarding the availability of offset programs or credits, or the requirement of "additionality." Petitioners failed to exhaust their administrative remedy on those issues.

Nevertheless, substantial evidence supports the EIR's determinations regarding MM 4.7-4. The EIR discloses that the GHG mitigation measures were not intended to individually provide full mitigation for project GHG emissions. The measures were designed as a package, such that mitigating project GHG emissions to a level of "net zero" is achieved by all four of the mitigation measures working in concert. The record shows that lower GHG emission levels through compliance with MM 4.7-1, 4.7-2, and 4.7-3 will require smaller quantities of offsetting emission reductions, but emissions remaining after application of MM 4.7-1, 4.7-2 and 4.7-3 must be offset in accordance with MM 4.7-4. The record shows that at the time of filing an application for conformity review, applicants must specify their expected GHG emissions and identify how those emissions will be mitigated. According to the EIR:

> Emission-reducing measures may include the measures listed by ARB at http://www.arb.ca.gov/cc/non-co2-clearinghouse/non-co2-clearinghouse.htm, but those measures are not required. All reductions will be verified by the County.

In addition to mitigation through direct applicant reductions under MM 4.7-4, the applicant may acquire offset credits through the CAPCOA Exchange or other third party offset programs. Substantial evidence shows that offset programs exist, including Climate Action Reserve, the SoCal Climate Solutions Exchange, CARB-approved Offset Project Registries, and programs outside California. CEQA's "additionality" requirement is adequately addressed in MM 4.7-4. For third party offsets, MM 4.7-4 requires the SJVAPCD to verify, and County to accept, the methodology used to calculate GHG reductions, thus providing the mechanism to ensure that offsets will be reductions "not otherwise required." The court will presume the SJVAPCD and County will properly undertake those responsibilities.

Arvin Petitioners complain that real parties cite "a few passing references to offset programs scattered across an almost random collection of documents." This statement serves to underscore the reason it is necessary to make a sufficiently specific objection during the administrative process. From this court's vantage point, *petitioners* should have brought to this court's attention *all* references to offset programs as part of their "no substantial evidence" argument in the opening brief.

Arvin Petitioners cite *Kings County Farm Bureau v. City of Hanford ("Kings County") (1990) 221 Cal.App.3d 692*, where the appellants challenged an EIR's water impacts analysis that found no significant impact. The project applicant agreed to contribute financially to a water recharge program, but the appellants referred to a memo from the

city public works director stating there was no water available to purchase for a water recharge program. The record did not disclose whether the city relied on the applicant's agreement to help fund the water recharge program in making its "no significant impact" determination. The court stated:

> To the extent the GWF-KCWD agreement was an independent basis for finding no significant impact, the failure to evaluate whether the agreement was feasible and to what extent water would be available for purchase was fatal to a meaningful evaluation by the city council and the public. *Id at p. 728.*

MM 4.7-4's mitigation through direct GHG reduction, verified by County, is not analogous to paying a mitigation fee for a water recharge program where there is no water to buy, or no evidence of it. Moreover, substantial evidence in the present case shows that offset programs exist and that MM 4.7-4 would be effective, unlike the absence of analysis or information in *Kings County*.

MM 4.7-4 specifically refers to the CAPCOA Exchange Register. The EIR refers to emission-reducing measures "listed by ARB at http://www.arb.ca.gov/cc/non-co2-clearinghouse/non-co2-clearinghouse.htm." The administrative record discussed Climate Action Reserve, the SoCal Climate Solutions Exchange, CARB-approved Offset Project Registries and programs outside California.

Substantial evidence supported the effectiveness of offset programs as a method of mitigating GHG impacts. In general, the *effectiveness* of "market-based" solutions such as offsets is embedded in the Global Warming Solutions Act of 2006 ("Act"), and the regulations adopted to achieve that Act's objectives. The legislature specifically authorized the Air Resources Board to adopt regulations which establish market-based compliance mechanisms "in furtherance of achieving the statewide [GHG] emissions limit." *Health & Safety Code §§ 38562(b), 38570(a)* [authorizing regulation for "use of market-based compliance mechanisms to comply with the regulations"]. The Act defines a market-based compliance mechanism, which includes GHG exchanges, banking, credits, and other transactions. *Health & Safety Code § 38505(k).*

More directly, MM 4.7-4 specifically requires the SJVAPCD to validate the methodology for calculating the GHG reductions, and the County to accept it. Decision-makers could reasonably infer from the EIR that MM 4.7-4 would be effective.

County's determinations were supported by substantial evidence. The EIR was adequate as an informational document. There was no failure to proceed in a manner required by law of prejudicial abuse of discretion.

Long-term Impacts

Arvin Petitioners also argue that the EIR failed to adequately disclose and analyze long-term impacts to climate, and specifically, GHG emissions from 2035 through 2050 by: (1) failing to provide "meaningful analysis" of the conflict between the project's "rising emissions over time and the long-term reductions climate scientists and California policymakers deem necessary," including failure to analyze consistency with the Governor's executive order target for 2050; and (2) wrongfully assuming Cap-and-Trade would extend past 2020.

In July 2017, essentially between the second and third days of trial in this case, the California Supreme Court decided *Cleveland National Forest Foundation v. San Diego Association of Governments ("SANGAG") (2017) 3 Cal.5th* 497. The Supreme Court held that the agency considering a regional transportation plan did not abuse its discretion in declining to explicitly analyze the consistency of projected GHG emissions with the statewide GHG goals expressed in executive order. *Id. at p. 517.* The *SANDAG* opinion acknowledged the challenges that agencies face in analyzing GHG emissions in a climate of evolving regulations and science. *Ibid.*

Also in July 2017, AB 398 was passed by the California legislature and signed into law, extending Cap-and-Trade through 2030.

The EIR adequately disclosed and analyzed GHG emissions and long term impacts. The EIR comprehensively analyzed all project-related activities, including all phases of construction and operations. The EIR discussed direct and indirect emissions from all sources. It conservatively assumed for purposes of analysis that more wells would be drilled each year than are authorized under the project ordinance, and provided technical estimates based on the assumption Cap-and-Trade would *end* in 2020. The EIR used mandatory reporting regulation ("MRR") emissions as baseline, even though for some companies MRR-reported emissions include all activities in the San Joaquin Valley, not just the local area. It included these baseline emissions in calculating project emissions. The EIR mitigated the projects GHG emissions to "net zero," which is below the applicable threshold of significance.

The existence and content of the long-term statewide goals expressed in executive order was plainly discussed in the EIR. Nothing was obscured. The EIR included discussion and analysis for informational purposes regarding the project's consistency with the executive orders. County discussed and acknowledged the uncertainty in trying to predict what the oil and gas industry would be required to do in order to achieve statewide 2030 and 2050 targets. The EIR also acknowledged the project's long-term increases in GHG emissions, and discussed project GHG emissions in relation to statewide reduction goals. The EIR estimated the project GHG emissions at full build out in 2035. County determined and disclosed the project's cumulative GHG impacts would be significant and unavoidable. The project was approved based on a statement of overriding considerations.

In addition, County's technical analysis assumed Cap-and Trade would end in 2020 (the law at the time), but at the same time, included mitigation in the EIR based on the continued existence of Cap-and-Trade, as well as measures not covered by Cap-and-Trade. County disclosed its reasons for the EIR's approach, and stated that it believed Cap-and-Trade would "almost certainly" extend beyond 2020. County was correct.

Substantial evidence supports the EIR's determinations regarding GHG thresholds of significance, and Arvin Petitioners clarified in their reply brief that they do *not* contend the EIR should have used different significance thresholds. Substantial evidence supports the EIR's methodology, scope of analysis, and determinations regarding GHG emissions, including County's determination that project-related GHG impacts would be less than significant after mitigation. The EIR was adequate as an informational document. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

SUPERIOR COURT OF THE STATE OF CALIFORNIA

COUNTY OF KERN

VAQUERO ENERGY, INC., a California corporation; and HUNTER EDISON OIL DEVELOPMENT LIMITED PARTNERSHIP, a California limited partnership; Petitioners and Plaintiffs, vs. COUNTY OF KERN; and KERN COUNTY BOARD OF SUPERVISORS; Respondents and Defendants. CALIFORNIA INDEPENDENT PETROLEUM ASSOCIATION, a California non-profit mutual benefit corporation; INDEPENDENT OIL PRODUCERS' AGENCY, a California corporation; and WESTERN STATES PETROLEUM ASSOCIATION, a California non-profit mutual benefit corporation; Real Parties in Interest.	Case No. BCV-15-101645-EB (Lead case) [Consolidated w/ Case No. BCV-15-101666-EB and Case No. BCV-15-101679-EB] **PEREMPTORY WRIT OF MANDATE**

TO: Respondents COUNTY OF KERN (including its Planning Commission, and Planning and Natural Resources Department) and KERN COUNTY BOARD OF SUPERVISORS (collectively "County"):

The court has entered judgment ordering that a peremptory writ of mandate issue under the seal of the court in the above-referenced consolidated actions [BCV-15-101645-EB (Lead case), consolidated w/ Case Nos. BCV-15-101666-EB and BCV-15-101679-EB] challenging respondent County's decision to approve and adopt Ordinance No. G-8605 and Resolution No. 2015-298, which, together, amended the Kern County Zoning Ordinance governing oil and gas activities (the "Project"), certified the Environmental Impact Report ("EIR") for the Project, and made related findings and determinations. Accordingly,

YOU ARE HEREBY COMMANDED, upon receipt of this writ, to do the following:

1. Within 45 days from service of the this peremptory writ of mandate, County shall transmit to the San Joaquin Valley Air Pollution Control District copies of this peremptory writ of mandate, and the JUDGMENT in Case Nos. BCV-15-101666-EB and BCV-15-101679-EB (the "Judgment"), including a copy of the Ruling attached as Exhibit "A" to said Judgment.

2. Consistent with the Ruling and the procedures set forth in California Environmental Quality Act, Public Resources Code sections 21000 et seq. ("CEQA") and CEQA Guidelines, County shall prepare such analysis as is necessary to address the EIR's deficient analysis of the Project's (i) environmental impacts to rangeland/grazing land, and (ii) environmental impacts from road paving as an air emissions mitigation measure ("Supplemental Analysis"). In the event the Supplemental Analysis determines that any such environmental impacts are potentially significant, the Supplemental Analysis shall identify feasible mitigation measures and/or alternatives to mitigate or avoid such impacts consistent with CEQA's requirements, unless County makes findings of infeasibility and overriding considerations as provided by CEQA.

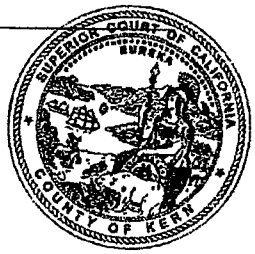
3. Upon completion of the Supplemental Analysis described in paragraph 2 above, County shall: (a) reconsider its approval of the Project and its Statement of Overriding Considerations adopted in connection with that Project, in light of any new information in the Supplemental Analysis, and (b) take any and all further action that may be necessary to bring the approval of the Project and the related findings and mitigation monitoring and reporting program into compliance with CEQA. County shall file an initial return to this writ not later than 75 days after the service of the writ of mandate, setting forth what it has done to comply with paragraph 1

above. County shall file a supplemental return to the writ of mandate not later than 180 days after the initial return, stating whether it has complied with paragraphs 2 and 3 above, and describing what it has done to do so. County shall thereafter file supplemental returns every 60 days until it has fully complied with paragraphs 2 and 3 above.

4. Nothing in this writ may be construed as an order that County exercise its lawful discretion in a particular way.

5. The court retains jurisdiction in consolidated case nos. BCV-15-101666-EB and BCV-15-101679-EB to ensure compliance with the Judgment, and the writ(s) issued pursuant to the Judgment.

Dated: APR 24 2018



Y. TORRES
CLERK OF THE SUPERIOR COURT

Appendix C

Lorelei H. Oviatt, AICP, Director
2700 "M" Street, Suite 100
Bakersfield, CA 93301-2323
Phone: (661) 862-8600
Fax: (661) 862-8601 TTY Relay 1-800-735-2929
Email: planning@kerncounty.com
Web Address: http://kernplanning.com/

PLANNING AND NATURAL RESOURCES DEPARTMENT

Planning
Community Development
Administrative Operations

May 16, 2018

File: Oil and Gas EIR

San Joaquin Valley Air Pollution Control District
Attn; Seyed Sadredin , Executive Director
1990 E. Gettysburg Avenue
Fresno, California 93726

RE: Kern County Oil and Gas Ordinance: Resolution of *Vaquero* Litigation (Kern County Superior Court Case No. BCV-15-101645, consolidated with Case Nos. BCV-15-101666 and BCV-15-101679).

Dear Mr. Sadredin,

This correspondence provides you with clarification and further information on the implementation of our Oil and Gas Emission Reduction Agreement (20160168 – County agreement #890-2016) executed between the Air District Board and the Kern County Board of Supervisors in August of 2016 to implement the adopted Oil and Gas Permitting Ordinance Air Quality mitigation measure.

Attached is the judgment of Superior Court Judge Eric Bradshaw in *Vaquero Energy, Inc. et al. v. County of Kern et al., King & Gardiner Farms LLC v. County of Kern et al.*, and *Committee for a Better Arvin et al. v. County of Kern et al.* (Kern County Superior Court Case No. BCV-15-101645, consolidated with Case Nos. BCV-15-101666 and BCV-15-101679) (hereafter, "Vaquero Judgment").

On November 9, 2015, the Kern County Board of Supervisors approved amendments to Title 19 of the Kern County Zoning Ordinance, focused on Chapter 19.98 (Oil and Gas Production), to include new site development standards and permitting procedures for oil and gas exploration, extraction, operations, and production activities in unincorporated Kern County. The Board of Supervisors certified a final Environmental Impact Report (EIR) for the Zoning Ordinance amendments on the same day. The EIR was subsequently challenged in the above-referenced lawsuit. On April 20, 2018, Judge Bradshaw issued the Vaquero Judgment and upheld both the Ordinance and the EIR on all but two narrow issues.

Judge Bradshaw concluded that the EIR did not evaluate the environmental impacts of road paving, which was identified in the County's staff report and discussed in the EIR as a potential future offset for particulate matter emissions that could potentially be undertaken by a permit applicant in lieu of paying some portion of the air quality mitigation fee required by Mitigation Measure 4.3-8 in the EIR. Road paving is not currently allowed as an emission offset measure in the Mitigation Monitoring and Reporting Program (MMRP) adopted for the Zoning Ordinance amendments. Appendix M-3 of the EIR includes a draft Emission Reduction Agreement (ERA) that sets forth the required procedures for considering road paving and other potential direct applicant emission reduction activities in lieu of paying some portion of the required air quality mitigation fee. The ERA was executed by the County and the San Joaquin Valley Air Pollution Control District (District) in August 2016. Pursuant to the ERA, road paving could have been accepted as an emission reduction measure if and only if in the future both the District and the County

accepted a future applicant request for an approved protocol for quantifying the emission reduction benefits of road paving.

In compliance with the Vaquero Judgment, please be advised that any future applicant request for recognition of emission reduction offsets for road paving will require future discretionary approvals by the County and District, and will further trigger the need for additional environmental review and compliance with the California Environmental Quality Act (CEQA).

Pursuant to the ERA, and in further compliance with the Vaquero Judgement, the County declines to approve of road paving as a potential future applicant air emission offset. The County has informed applicant representatives that any future road paving request that is proposed to be undertaken instead of paying the required air quality mitigation fee must first be submitted to the County, which will again serve as the CEQA lead agency for any such proposed applicant activity. The County will thereafter coordinate with the District, and complete the required CEQA process (inclusive of public notice and outreach), prior to making a determination as to whether or under what conditions road paving would be eligible as an applicant emission reduction activity to satisfy some portion of the air emission mitigation required by the Ordinance. Since road paving is not recognized as an air emission offset in either the Ordinance or EIR, no changes to the Ordinance or EIR are required by the Vaquero Judgment.

As information only, please note that Judge Bradshaw also directed the County to complete additional CEQA analysis concerning potential environmental impacts to rangeland/grazing land. The County is currently undertaking the additional CEQA review of this issue. Since the Air Quality and Greenhouse Gas sections of the EIR were upheld in the Vaquero Judgment, the County does not anticipate that the additional CEQA analysis of potential environmental impacts to rangeland/grazing land will include these issues. The County will continue to communicate with responsible agencies, including the District, as required by CEQA during the additional review process for rangeland/grazing land.

The Vaquero Judgment did not vacate any portion of the Ordinance or EIR, and Judge Bradshaw declined requests by two of the three petitioner groups to halt all or some portion of future oil and gas activities authorized by the Ordinance. The Vaquero Judgment does not affect ongoing reliance on the EIR by responsible agencies, including the District.

Please do not hesitate to contact me at 661-862-8866 or Loreleio@kerncounty.com, if you have any questions or would like to discuss this matter further. I want to again thank the District and your staff for the extensive technical assistance provided during the EIR process for this Ordinance and support for the implementation of our Emission Reduction Agreement.

Sincerely,

LORELEI H OVIATT, AICP, Director
Kern County Planning and Natural Resources Department

cc: County Counsel
SJVAPD Dave Warren
WSPA
CIPA
Holland and Knight

Appendix D

AGENDA

KERN COUNTY PLANNING DEPARTMENT

Scoping Meeting

Kern County Public Services Building
2700 "M" Street, Conference Room 1A, Bakersfield, California

June 15, 2018 – 1:30 p.m.

Pursuant to revised Section 21083.9 of the Public Resources Code, California Environmental Quality Act, effective January 1, 2002, this scoping meeting is being held to receive agency comments on the preparation of Environmental Impact Reports (EIR) on certain projects. The process of determining the scope, focus, and content of the EIR is known as "scoping." Scoping helps to identify the range of actions, alternatives, environmental effects, methods of assessment, and mitigation measures to be analyzed in depth, and eliminate from detailed study those issues that are not important to the decision at hand. This is not a public hearing, however the public may be present and offer comments. If you attend as a member of the public to address an item on the agenda, please let the chairperson know, when discussion begins on that item. Each project will be presented by staff followed by an opportunity for comments for the record.

A. INTRODUCTION: Staff

B. NEW CASES:

EIR – Notice of Preparation:
Supplemental Environmental Impact Report for Approved Amendments to Title 19 - Kern County Zoning Ordinance (2015 C) Focused on Oil and Gas Local Permitting. (PP13284)

C. ADJOURNMENT:

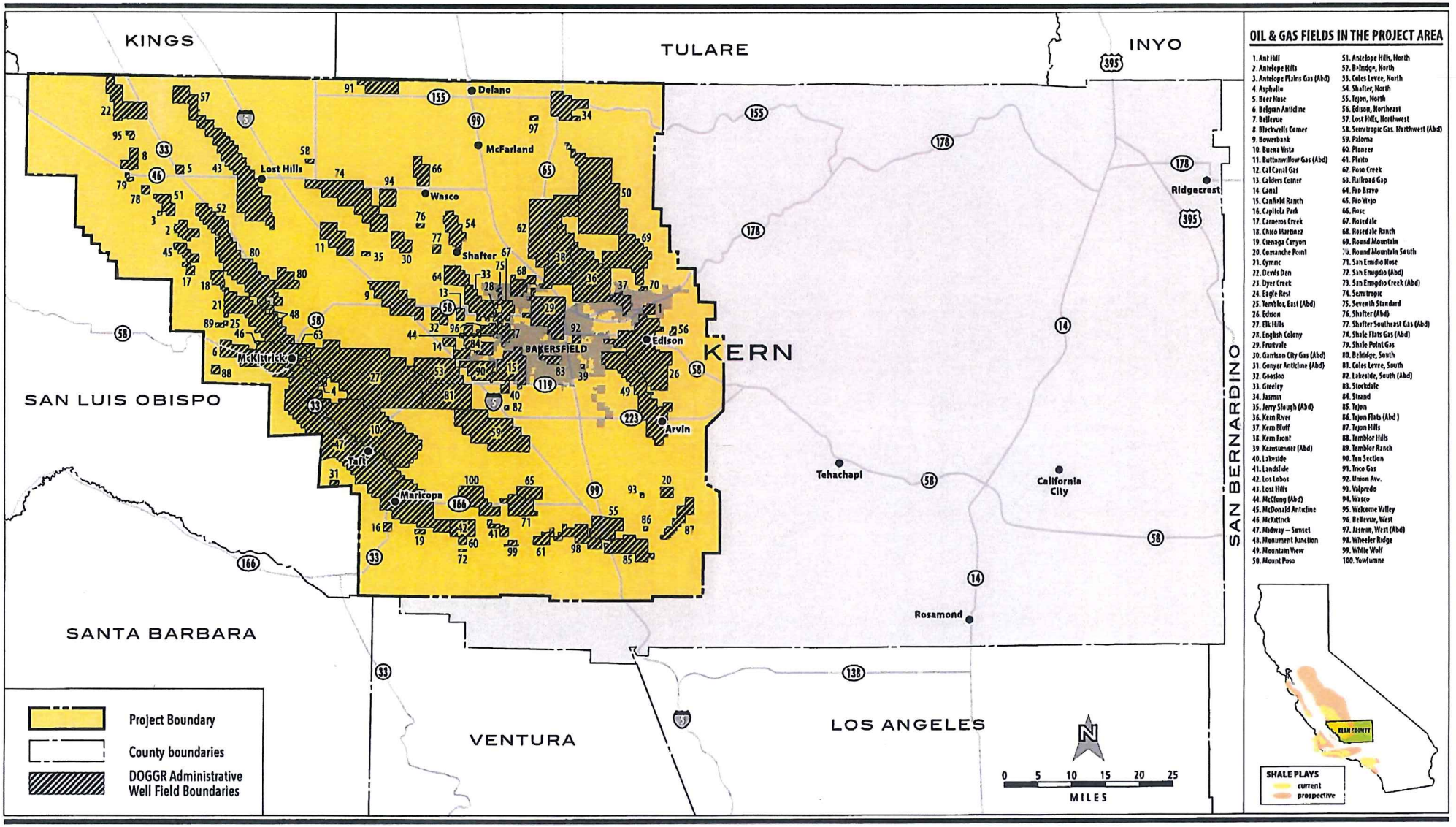
AMERICANS WITH DISABILITIES ACT
(Government Code Section 54953.2)

Disabled individuals who need special assistance to attend or participate in the scoping meeting may request assistance at the Kern County Planning Department or by calling Adrenne Lane-Price at (661) 862-8615. Every effort will be made to reasonably accommodate individuals with disabilities by making meeting materials available in alternative formats. Requests for assistance should be made five (5) working days in advance whenever possible.

Posted: June 13, 2018
CLH

SUBMIT WRITTEN COMMENTS ON THE NOP BY JULY 2, 2018 AT 5PM
Mail to:
Kern County Planning and Natural Resources Department
Attn: Lorelei H. Oviatt
2700 'M' Street, Suite 100
Bakersfield, CA 93301
Phone: (661) 862-8866, **Email:** Loreleio@kerncounty.com

Project Boundary



SUMMARY OF PROCEEDINGS

KERN COUNTY AGENCY SCOPING MEETING

Kern County Planning Department
2700 M Street, Suite 100
Bakersfield, California

Conference Room

Date June 15, 2018

STAFF ATTENDANCE: Lorelei H Oviatt, AICP, Director
Cindi Hoover, Planner I

The meeting convened at 1:30 p.m. with Ms. Oviatt introducing Staff in attendance and outlining the purpose of the scoping meeting. Items were then discussed in order as identified on the agenda.

NOTICE OF PREPARATION PROJECT:

EIR – Notice of Preparation:
Supplemental Environmental Impact Report for Approved Amendments to Title 19 - Kern County Zoning Ordinance (2015 C) Focused on Oil and Gas Local Permitting. (PP13284)

Ms. Oviatt introduced and described the proposed project and asked if there were any comments.

Ms. Caroline Farrell spoke on behalf of Center on Race, Poverty, and the Environment. Ms. Farrell requested clarification on the availability of road paving as a mitigation measure and stated that the EIR should clarify the linkage between the County and the Air District and any agreements regarding road paving. Ms. Farrell further stated that the EIR should also analyze impacts from oil spills on rangeland, as well as incompatibility between oil and gas production, and agricultural and rangeland.

Mr. Adam Livingston spoke on behalf of the Sequoia Riverlands Trust and stated the EIR should analyze impacts from conflicts between surface owners and conservation and/or agricultural easement holders during the ministerial oil and gas permitting process.

No other public comments were presented.

Public testimony closed at approximately 1:53 p.m.

Notes prepared by
Cindi Hoover, Planner I

Lorelei H. Oviatt, AICP, Director
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PLANNING AND NATURAL RESOURCES DEPARTMENT

Planning
Community Development
Administrative Operations

NOTICE OF PREPARATION

DATE: May 31, 2018

TO: See Attached Mailing List

FROM: Kern County Planning and
Natural Resources Department
Attn: Lorelei H. Oviatt AICP
2700 "M" Street, Suite 100
Bakersfield, CA 93301 (661) 862-8866
Loreleio@kerncounty.com

RE: NOTICE OF PREPARATION OF A DRAFT SUPPLEMENTAL ENVIRONMENTAL IMPACT REPORT

The Kern County Planning and Natural Resources Department, as Lead Agency (pursuant to California Environmental Quality Act [CEQA] Guidelines Section 15050 *et seq.*) has determined that preparation of a draft Supplemental Environmental Impact Report (SEIR) (pursuant to CEQA Guidelines Section 15162) is necessary for the project identified below. The Planning and Natural Resources Department solicits the views of your agency as to the scope and content of the environmental information which is germane to your agency's statutory responsibilities about the proposed project. Your agency will need to use the SEIR prepared by our agency when considering your permit or other approval of projects.

Due to the limits mandated by State law, your response must be received by **July 2, 2018 at 5:00 pm.** In addition, comments can be submitted at a scoping meeting to conducted by the Department :

SCOPING MEETING : June 15, 2018 - Friday at 1:30 p.m
Kern County Planning and Natural Resources Department
2700 M Street Room 1 A
Bakersfield California 93301

PROJECT TITLE: Supplemental Environmental Impact Report for Approved Amendments to Title 19 – Kern County Zoning Ordinance (2015 C) Focused on Oil and Gas Local Permitting.

PROJECT LOCATION: The project boundary encompasses approximately 3,700 square miles (approximately 2.3 million acres) and generally includes the San Joaquin Valley Floor portion of Kern County, up to an elevation of 2,000 feet. The boundary includes: west side – the San Luis Obispo County line; north side- the Kings and Tulare county lines, east side – the 2,000-foot elevation contours, squared off to the nearest section line; and south side – the northern boundary of the Los Padres National Forest..

PROJECT DESCRIPTION: The action consists of the preparation of a Supplemental Environmental Impact Report (SEIR) for approved amendments to Title 19 of the Kern County Zoning Ordinance (2015C) (Ordinance) focused on Oil and Gas local permitting for text amendments to various chapters, which include site development standards and permitting procedures for oil and gas exploration, extraction, operations, and production activities in unincorporated Kern County. The County certified a final Environmental Impact Report (EIR), and approved the amendments to the Ordinance, on November 9, 2015.

Several parties filed lawsuits challenging the adequacy of the certified EIR, and the cases were consolidated before Judge Eric Bradshaw of the Kern County Superior Court (*Vaquero Energy, Inc. et al. v. County of Kern et al.*, *King & Gardiner Farms LLC v. County of Kern et al.*, and *Committee for a Better Arvin et al. v. County of Kern et al.*, Kern County Superior Court Case No. BCV-15-101645, consolidated with Case Nos. BCV-15-101666 and BCV-15-101679). On April 20, 2018, the Court issued a judgment (Judgment) that upheld the EIR in its entirety except for requiring supplemental analysis under the California Environmental Quality Act (CEQA) for two issues: (i) impacts to rangeland/grazing land, and (ii) impacts from road paving as a potential future means of mitigation to reduce designated air emissions. The Judgment did not vacate any portion of the Ordinance or the EIR. Pursuant to the Judgment, the Court issued a writ of mandate (Writ) to the County that states:

> (a) Within 45 days from service of the writ of mandate, County shall transmit to the San Joaquin Valley Air Pollution Control District copies of this court's Ruling, this judgment, and the related peremptory writ of mandate.
>
> (b) Consistent with the Ruling and the procedures set forth in CEQA and CEQA Guidelines, County shall prepare such analysis as is necessary to address the EIR's deficient analysis of the Project's (i) environmental impacts to rangeland/grazing land, and (ii) environmental impacts from road paving as an air emissions mitigation measure ("Supplemental Analysis"). In the event the Supplemental Analysis determines that any such environmental impacts are potentially significant, the Supplemental Analysis shall identify feasible mitigation measures and/or alternatives to mitigate or avoid such impacts consistent with CEQA's requirements, unless County makes findings of infeasibility and overriding considerations as provided by CEQA.
>
> (c) Upon completion of the Supplemental Analysis described in Part 2(b) above, County shall: (i) reconsider its approval of the Project and its Statement of Overriding Considerations adopted in connection with that project, in light of any new information in the Supplemental Analysis, and (ii) take any and all further action that may be necessary to bring the approval of the project and the related findings and mitigation monitoring and reporting program into compliance with CEQA.

Consistent with the Writ, the County will prepare a draft Supplemental Environmental Impact Report (SEIR), pursuant to CEQA Guidelines Section 15162, to address potential environmental impacts to rangeland/grazing land. Cattle and sheep grazing have historically occurred, and are expected to continue within the project area, including at locations affected by future oil and gas operations under the amended Ordinance. As required by the Court, the SEIR will address the project's potential environmental impacts to grazing/rangelands and identify feasible mitigation measures and/or alternatives to mitigate or avoid impacts determined to be potentially significant. Consistent with

CEQA, the County may also make findings of infeasibility and overriding considerations for any such impacts. The certified EIR provided a comprehensive analysis of all probable environmental effects of the project, and the Judgment upheld the EIR in its entirety except for the two narrow issues discussed above. The Vaquero Judgment did not vacate any portion of the Ordinance or the EIR.

On May 16, 2018, the County transmitted a copy of the Judgment to the San Joaquin Valley Air Pollution Control District (District), as directed by the Court. As discussed in the transmittal letter to the District (see Attachment A), road paving was identified in the County's staff report and in the EIR as an example of a potential future means of mitigation to offset criteria emissions that could potentially be undertaken by a permit applicant under Mitigation Measure (MM) 4.3-8 in the adopted EIR and Mitigation Monitoring and Reporting Program (MMRP) for the project. Road paving is not an approved air quality mitigation measure in the EIR or the Ordinance. Appendix M-3 of the EIR includes a draft Emission Reduction Agreement (ERA) (which was executed by the County District in August 2016) that sets forth the required procedures for considering road paving and any other potential direct emission reduction activities by applicant (air emission offset) as an alternative to paying some portion of air quality mitigation fees. Pursuant to the ERA, road paving could have been accepted as an air emission offset if and only if in the future both the District and the County accepted a future applicant request for an approved protocol for quantifying the emission reduction benefits of road paving. The County's attached transmittal letter to the District confirmed that any project applicant request for recognition of emission reduction offsets for road paving will require future discretionary approvals by the County and District, will further trigger the need for additional environmental review and compliance with CEQA, and that the County has declined to approve of road paving as a potential future applicant air emission offset. Any future road paving request must first be submitted to the County, which will coordinate with the District and complete the CEQA process, inclusive of public notice and outreach, prior to making a determination as to whether or under what conditions road paving would be eligible as a direct applicant emission reduction activity at the conclusion of the required CEQA process. Since road paving is not authorized as an air emission offset in either the Ordinance or EIR, and no changes to the Ordinance or EIR are required by the Judgment, the SEIR will not address potentially significant impacts of road paving.

Documents can be viewed online at : https://kernplanning.com/final-environmental-impact-report-revisions-kern-county-zoning-ordinance-2015-c-focused-oil-gas-local-permitting/

Signature: _____

Name: Lorelei H. Oviatt, AICP Director

Zoning Ordinance SEIR - Oil & Gas
WO #13284
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OG ZO - SEIR - Oil & Gas All
Contacts.docx
Sc 05/24/18

City of Maricopa
P.O. Box 548
Maricopa, CA 93252

City of Arvin
P.O. Box 548
Arvin, CA 93203

Bakersfield City Planning Dept
1715 Chester Avenue
Bakersfield, CA 93301

Bakersfield City Public Works Dept
1501 Truxtun Avenue
Bakersfield, CA 93301

California City Planning Dept
21000 Hacienda Blvd.
California City, CA 93515

Delano City Planning Dept
P.O. Box 3010
Delano, CA 93216

City of Shafter
336 Pacific Avenue
Shafter, CA 93263

City of McFarland
401 West Kern Avenue
McFarland, CA 93250

City of Ridgecrest
100 West California Avenue
Ridgecrest, CA 93555

City of Wasco
764 E Street
Wasco, CA 93280

City of Taft
Planning & Building
209 East Kern Street
Taft, CA 93268

City of Tehachapi
Attn: John Schlosser
115 South Robinson Street
Tehachapi, CA 93561-1722

Los Angeles Co Reg Planning Dept
320 West Temple Street
Los Angeles, CA 90012

Inyo County Planning Dept
P.O. Drawer "L"
Independence, CA 93526

Kings County Planning Agency
1400 West Lacey Blvd, Bldg 6
Hanford, CA 93230

Santa Barbara Co Resource Mgt Dept
123 East Anapamu Street
Santa Barbara, CA 93101

San Bernardino Co Planning Dept
385 North Arrowhead Avenue, 1st Floor
San Bernardino, CA 92415-0182

San Luis Obispo Co Planning Dept
Planning and Building
976 Osos Street
San Luis Obispo, CA 93408

U.S. Bureau of Land Management
Caliente/Bakersfield
3801 Pegasus Drive
Bakersfield, CA 93308-6837

Tulare County Planning & Dev Dept
5961 South Mooney Boulevard
Visalia, CA 93291

Ventura County RMA Planning Div
800 South Victoria Avenue, L1740
Ventura, CA 93009-1740

U.S. Forest Service
Los Padres National Forest
6755 Hollister Avenue, Suite 150
Goleta, CA 93117

U.S. Bureau of Land Management
Ridgecrest Field Office
300 South Richmond Road
Ridgecrest, CA 93555

China Lake Naval Weapons Center
Tim Fox, RLA - Comm Plans & Liaison
429 E Bowen, Building 981
Mail Stop 4001
China Lake, CA 93555

Edwards AFB, Sustainability Office
412 TW/XPO, Bldg 2750, Rm 204-38
195 East Popson Avenue
Edwards AFB, CA 93524

Federal Aviation Administration
Western Reg Office/
Airport Div - Room 3000
15000 Aviation Boulevard
Lawndale, CA 90261

Federal Communications Comm
18000 Studebaker Road, #660
Cerritos, CA 90701

U. S. Fish & Wildlife Service
Division of Ecological Services
2800 Cottage Way #W-2605
Sacramento, CA 95825-1846

U.S. Fish & Wildlife Service
Hopper Mountain (Bitter Creek)
2493 Portola Road, Suite A
Ventura, CA 93003

Environmental Protection Agency
Region IX Office
75 Hawthorn Street
San Francisco, CA 94105

U.S. Dept of Agriculture/NRCS
5000 California Avenue, Ste 100
Bakersfield, CA 93309-0711

U.S. Army Corps of Engineers
P.O. Box 997
Lake Isabella, CA 93240

State Air Resources Board
Stationary Resource Division
P.O. Box 2815
Sacramento, CA 95812

So. San Joaquin Valley Arch Info Ctr
California State University of Bkfd
9001 Stockdale Highway
Bakersfield, CA 93311

Caltrans/Dist 6
Planning/Land Bank Bldg.
P.O. Box 12616
Fresno, CA 93778

Caltrans/Dist 9
Planning Department
500 South Main Street
Bishop, CA 93514

Caltrans/
Division of Aeronautics, MS #40
P.O. Box 942873
Sacramento, CA 94273-0001

Caltrans/
Division of Structures
Attn: Jim Roberts
P.O. Box 1499
Sacramento, CA 95807

State Clearinghouse
Office of Planning and Research
1400 10th Street, Room 222
Sacramento, CA 95814

State Dept of Conservation
Director's Office
801 "K" Street, MS 24-01
Sacramento, CA 95814-3528

State Dept of Conservation
Division of Oil & Gas
4800 Stockdale Highway, Ste 108
Bakersfield, CA 93309

State Dept of Conservation
Division of Oil & Gas
801 "K" Street, MS 20-20
Sacramento, CA 95814-3530

Office of the State Geologist
Headquarters
801 "K" Street, MS 12-30
Sacramento, CA 95814

State Dept of Conservation
Office of Land Conservation
801 "K" Street, MS 18-01
Sacramento, CA 95814

State Dept of Conservation
Office of Mine Reclamation
801 "K" Street MS 09-06
Sacramento, CA 95814-3529

State Dept of Conservation
Div Recycling Cert. Sec.
801 "K" Street, MS 19-01
Sacramento, CA 95814

State Mining and Geology Board
801 K Street, MS 20-15
Sacramento, CA 95814

California State University
Bakersfield - Library
9001 Stockdale Highway
Bakersfield, CA 93309

California Energy Commission
James W. Reed, Jr.
1516 Ninth Street
Mail Stop 17
Sacramento, CA 95814

California Fish & Wildlife
1234 East Shaw Avenue
Fresno, CA 93710

State Dept of Food & Agriculture
1220 "N" Street
Sacramento, CA 95814

California Highway Patrol
Planning & Analysis Division
P.O. Box 942898
Sacramento, CA 94298-0001

State Office of Historical Pres
Attention Susan Stratton
P.O. Box 942896
Sacramento, CA 95296-0001

Integrated Waste Management
P.O. Box 4025, MS #15
Sacramento, CA 95812-4025

State Dept of Parks & Recreation
Tehachapi District
Angeles District - Mojave Desert Sector
15701 E. Avenue M
Lancaster, CA 93535

State Water Resources Control Board
Division of Drinking Water
Attn: Jesse Dhaliwal, Sr. Sanitary Eng
4925 Commerce Drive, Suite 120
Bakersfield, CA 93309

Public Utilities Comm Energy Div
505 Van Ness Avenue
San Francisco, CA 94102

California Regional Water Quality
Control Board/Central Valley Region
1685 E Street
Fresno, CA 93706-2020

Sequoia National Forest
Kern River Ranger Station
P.O. Box 3810
Lake Isabella, CA 93240-3810

State Lands Commission
Attn: Jennifer Lucchesi
100 Howe Avenue, Ste 100-South
Sacramento, CA 95825-8202

State Dept of Toxic Substance Control
Environmental Protection Agency
1515 Tollhouse Road
Clovis, CA 93612

State Department of Toxic Substances Control
1000 "I" Street
P.O. Box 806
Sacramento, CA 95812

State Dept of Water Resources
San Joaquin Dist.
3374 East Shields Avenue, Room A-7
Fresno, CA 93726

State Dept of Water Resources
Div. Land & Right-of-Way
P.O. Box 942836
Sacramento, CA 94236

CalRecycle
Dept of Resources, Recycling, and Recovery
1001 "I" Street
Sacramento, CA 95812

Kern County
Agriculture Department

Kern County Airports Department

County Clerk

Kern County Administrative Officer

Kern County Engineering, Surveying, & Permit Svs/Floodplain

Kern County Engineering, Surveying, & Permit Svs/Survey

Kern County
Env Health Services Department

Kern County Fire Dept
Brian Marshall, Fire Chief

Kern County Fire Dept
Derek Tisinger, Fire Marshal

Kern County Fire Dept
Dave Goodell

Kern County Library/Beale
Local History Room

Kern County Library/Beale
Sherry Gomez

Kern County Museum
3801 Chester Avenue
Bakersfield, CA 93301

Kern County Parks & Recreation

Kern County Sheriff's Dept
Administration

Kern County Roads Department

Kern County
Waste Management Department

Kern County ESS Dept/
Code Compliance Div

Inyokern Municipal Advisory Council
1429 Broadway Avenue
P.O. Box 1418
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Mojave Town Council
Bill Deaver, President
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Rosamond Municipal Advisory Council
P.O. Box 626
Rosamond, CA 93560

Tehachapi Municipal Advisory Council
117 Sunrise Way
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KernCOG
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Kern High School Dist
5801 Sundale Avenue
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Kern County Superintendent of Schools
Attention Mary Baker
1300 17th Street
Bakersfield, CA 93301

East Kern Air Pollution
Control District

Local Agency Formation Comm/LAFCO
5300 Lennox Avenue, Suite 303
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Kern County Water Agency
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Bakersfield, CA 93302-0058

Delano Mosquito Abatement Dist
Attention John G. Davis
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San Joaquin Valley
Air Pollution Control District
Attn: David Warner
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Golden Empire Transit
1830 Golden State Avenue
Bakersfield, CA 93301

West Side Mosquito
Abatement Dist.
P.O. Box 205
Taft, CA 93268

Kern Mosquito Abatement Dist
4705 Allen Road
Bakersfield, CA 93314

South Fork Mosquito Abatement Dist
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Kernville, CA 93238-1298

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Pleistocene Foundation
2362 Lumill Street
Ridgecrest, CA 93555

Bakersfield Municipal Airport
4101 Truxtun Avenue
Bakersfield, CA 93309

California City Airport
22636 Airport Way, #8
California City, CA 93505

Mojave Airport
1434 Flightline
Mojave, CA 93501

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Inyokern, CA 93527

Minter Field Airport District
201 Aviation Street
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4220 Poplar Street
Lake Isabella, CA 93240-9536

East Kern Airport Dist
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Mojave, CA 93501

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4000 Knox Avenue
Rosamond, CA 93560

Mountain Valley Airport
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Tehachapi, CA 93581

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P.O. Box 2567
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Construction Materials Assoc of CA
1029 "J" Street, Suite 420
Sacramento, CA 95814

Tehachapi City Hall/Airport
115 South Robinson Street
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Center for Biological Diversity
Attn: Adam Lazar
351 California Street, #600
San Francisco, CA 94104

Adams, Broadwell, Joseph & Cardozo
Attention: Janet M. Laurain
601 Gateway Boulevard, Suite 1000
South San Francisco, CA 94080

AT&T California
OSP Engineering/Right-of-Way
4540 California Avenue, 4th Floor
Bakersfield, CA 93309

Kern Audubon Society
Attn: Harry Love
13500 Powder River Avenue
Bakersfield, CA 93314

Los Angeles Audubon
926 Citrus Avenue
Los Angeles, CA 90036-4929

Center on Race, Poverty
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Defenders of Wildlife/
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Desert Tortoise Preserve Committee
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California Farm Bureau
2300 River Plaza Drive, NRED
Sacramento, CA 95833

Friant Water Users Authority
854 North Harvard Avenue
Lindsay, CA 93247-1715

Mojave Chamber of Commerce
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Vallejo, CA 94592

Anitra Kass
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Bermuda Dunes, CA 92203

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Land Mgt
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Bakersfield, CA 93301

Pacific Gas & Electric Co
Land Projects
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Smart Growth - Tehachapi Valleys
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Tehachapi, CA 93581-1894

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120 Woodlands Drive
Wofford Heights, CA 93285

Southern California Edison
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Long Beach, CA 90801

Southern California Edison
Planning Dept.
421 West "J" Street
Tehachapi, CA 93561

Southern California Edison
Planning Dept.
510 S. China Lake Blvd.
Ridgecrest, CA 93555

Southern California Edison
Planning Dept.
25625 West Rye Canyon
Valencia, CA 91355

Southern California Gas Co
1510 North Chester Avenue
Bakersfield, CA 93308

Southern California Gas Co
Transportation Dept
9400 Oakdale Avenue
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Attention Engineering Department
520 South China Lake Boulevard
Ridgecrest, CA 93555

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Kern Valley Indian Council
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Kern Valley Indian Council
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Kathy Morgan, Chairperson
1731 Hasti-acres Drive, Suite 108
Bakersfield, CA 93309

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Tubatulabals of Kern County
Attn: Robert Gomez, Chairperson
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Tule River Indian Tribe
Neal Peyron, Chairperson
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Tehachapi, CA 93561-6529

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Environmental Control Committee
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George Borba
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Bakersfield, CA 93311

Bill Bondorov
21073 Old Farm Road
Bakersfield, CA 93312

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Bakersfield, CA 93312

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Attn: Brad DeBranch
2000 Oak Street, Suite 250
Bakersfield, CA 93301

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Sacramento, CA 95821-2640

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PO Box 1424
Tehachapi, CA 93581

Crimson Resource Management
Attention Kristine Boyer
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Bakersfield, CA 93309

Cummings Valley Protective Association
P.O. Box 1020
Tehachapi, CA 93581

Center on Race, Poverty
& the Environmental/
CA Rural Legal Assistance Foundation
1012 Jefferson Street
Delano, CA 93215

Eight Bar Ranch
Jon and Helen Lantz
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Fairview Ranch Owners Assoc
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Fairmont Town Council
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Native American Heritage Council
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Bakersfield, CA 93303

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Attn: Carolyn Belli
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Mary Ann Lockhart
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Kern River Valley Chamber of Commerce
Katherine Evans
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Lake Isabella, CA 93240

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Attention: Kris Cardoza, Secretary
P.O. Box 83
Bodfish, CA 93205

Kern River Watermaster
P.O. Box 81435
Bakersfield, CA 93380-1435

Kern Wheelmen
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Bakersfield, CA 93389

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McAllister Ranch Irrigation District
1800 - 30th Street, 4th Floor
Bakersfield, CA 93301-1919

Metro Water Dist of So CA
Ms. Rebecca De Leon
Environmental Planning Team
700 N. Alameda Street, US3-230
Los Angeles, CA 90012

Mojave Foundation
Attn: Todd Quelet
16922 Airport Boulevard
Mojave, A 93501

National Public Lands News
941 E. Ridgecrest Blvd
Inyokern, CA 93555

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San Francisco, CA 94105

Thomas Roads Improvement Program
PARSONS
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Bakersfield, CA 93301

Tony Occhionero
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Newport Beach, CA 92660

Tulare Basin Wetlands Association
Attention Dennis Slater
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Bakersfield, CA 93306-9704

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Planning Department
901 Via Piemonte, 5th Floor
Ontario, CA 91764

William Nelson
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Tehachapi, CA 93581-0308

Vintage Petroleum, LLC
Attn: Teri Altenburger
10800 Stockdale Highway
Bakersfield, CA 93311

Wendell Weller
Star Route, Box 3
Granite Station, CA 93308

Kern County Library
Arvin Branch
201 Campus Drive
Arvin, CA 93203

WZI, Inc.
1717 - 28th Street
Bakersfield, CA 93301

Kern County Library
Boron Branch
26967 Twenty Mule Team Road
Boron, CA 93516

Kern County Library
Buttonwillow Branch
116 Buttonwillow Avenue
Buttonwillow, CA 93206

Kern County Library
Baker Branch
1400 Baker Street
Bakersfield, CA 93305

Kern County Library
Delano Branch
925 - 10th Street
Delano, CA 93215

Kern County Library
Frazier Park Branch
3015 Mount Pinos Way
Frazier Park, CA 93225

Kern County Library
California City Branch
9507 California City Boulevard
California City, CA 93505

Kern County Library
Kernville Branch
48 Tobias Street
Kernville, CA 93238

Kern County Library
Kern River Valley Branch
7054 Lake Isabella Boulevard
Lake Isabella, CA 93240

Kern County Library
Holloway/Gonzales Branch
506 East Brundage Lane
Bakersfield, CA 93307

Kern County Library
Jackson/McFarland Branch
500 Kern Avenue
McFarland, CA 93250

Kern County Library
Mojave Branch
16916 1/2 Highway 14, Space D2
Mojave, CA 93501

Kern County Library
Lamont Branch
8304 Segrue Road
Lamont, CA 93241

Kern County Library
Rathburn Branch
200 West China Grade Loop
Bakersfield, CA 93308

Kern County Library
Ridgecrest Branch
131 East Las Flores
Ridgecrest, CA 93555

Kern County Library
Northeast Branch
3725 Columbus Avenue
Bakersfield, CA 93306

Kern County Library
Shafter Branch
236 James Street, Ste 2
Shafter, CA 93263

Kern County Library
Southwest Branch
8301 Ming Avenue
Bakersfield, CA 93311

Kern County Library
Wanda Kirk/Rosamond Branch
3611 Rosamond Boulevard
Rosamond, CA 93560

Kern County Library
Tehachapi Branch
1001 West Tehachapi Blvd - Suite 400
Tehachapi, CA 93561

Kern County Library
Wasco Branch
1102 Seventh Street
Wasco. CA 93280

Kern County Library
Taft Branch
27 Emmons Park Drive
Taft, CA 93268

Bear Mountain Rec & Parks Dist
P.O. Box 658
Lamont, CA 93241

Buttonwillow Rec & Parks Dist
P.O. Box 434
Buttonwillow, CA 93206-9320

Kern County Library
Wofford Heights Branch
6400-B Wofford Boulevard
Wofford Heights, CA 93285

Tehachapi Valley Rec & Parks Dist
P.O. Box 373
Tehachapi, CA 93561

State Dept of Parks/Hungry Valley
PO Box 1360
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Tehachapi Parks & Recreation Dist
P.O. Box 373
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Shafter Rec & Parks Dist
700 East Tulare Avenue
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West Side Rec & Parks Dist
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Bakersfield City Parks & Rec Dept
4101 Truxtun Avenue
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So. San Joaquin Muni Utility Dist
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309 Campus Drive
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Rosamond Community Serv Dist
3179 - 35th Street West
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California City Public Works Dept
8190 California City Blvd.
California City, CA 93505

State Dept of Public Utilities Commission
505 Van Ness Avenue, Rm 2003
San Francisco, CA 94102-3214

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Frazier Park Public Utility Dist
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Lost Hills Utility Dist
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Lost Hills, CA 93249

Lake Isabella Community Serv Dist
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Lake Isabella, CA 93240

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8624 Segrue Road
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15844 "K" Street
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Quail Valley Water Dist
3200 21st Street, Ste 401
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Aerial Acres Water System
19161 Alma Street
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Rosedale-Rio Bravo Water Dist
P.O. Box 20820
Bakersfield, CA 93390-0820

Superior Mutual Water Co
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Bakersfield, CA 93312-9501

Tehachapi-Cummings Co Water Dist
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Water Agency
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Berrenda Mesa Water Dist
14823 Highway 33
Lost Hills, CA 93249-9734

Buttonwillow County Water Dist
P.O. Box 874
Buttonwillow, CA 93206

Brock Mutual Water Co
12001 Brockridge Court
Bakersfield, CA 93309

Buena Vista Water Storage Dist
P.O. Box 756
Buttonwillow, CA 93206

Cawelo Water Dist
17207 Industrial Farm Road
Bakersfield, CA 93308-9801

Tejon-Castaic Water Dist
P.O. Box 1000
Lebec, CA 93243

Casa Loma Water Co
1016 Lomita Drive
Bakersfield, CA 93307

Edmonston Acres Muni Water Co
25465 Barbara Street
Arvin, CA 93203

California Water Service Co
3725 South "H" Street
Bakersfield, CA 93304

North of the River Rec & Parks Dist
405 Galaxy Avenue
Bakersfield, CA 93308

Erskine Creek Water Co
P.O. Box 656
Lake Isabella, CA 93240

Edgemont Acres Water Co
P.O. Box 966
North Edwards, CA 93523

Edmonston Acres Muni Water Co
25465 Barbara Street
Arvin, CA 93203

Vaughn Water Co.
10014 Glenn Street
Bakersfield, CA 93312

Friant Water Users Authority
854 North Harvard Avenue
Lindsay, CA 93247-1715

Goose Lake Water Co
2515 Wheeler
Bakersfield, CA 93308

Gosford Road Water Assoc
13958 Gosford Road
Bakersfield, CA 93313

West Kern Water Dist
P.O. Box 1105
Taft, CA 93268-1105

Wheeler Ridge-Maricopa Water Dist
12109 Highway 166
Bakersfield, CA 93313-9630

Indian Wells Water
Management Committee
P.O. Box 1329
Ridgecrest, CA 93556

Greenfield County Water Dist
551 Taft Highway
Bakersfield, CA 93307

Indian Wells Valley Water Dist
P.O. Box 1329
Ridgecrest, CA 93556

Kern-Tulare Water Dist
5001 California Avenue, Suite 102
Bakersfield, CA 93309-1692

Kern Delta Water Dist
501 Taft Highway
Bakersfield, CA 93307

Kern River Valley Water Co
P.O. Box 1260
Lake Isabella, CA 93240

Lamont Storm Water Dist
P.O. Box 543
Lamont, CA 93241

Kern Water Bank Authority
1620 Mill Rock Way, Suite 500
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Lake of the Woods
Mutual Water Co.
7025 Cuddy Valley Road
Frazier Park, CA 93225

Davenport Mutual Water Assn
P.O. Box 1503
Rosamond, CA 93560

La Hacienda Water Co, Inc.
P.O. Box 60679
Bakersfield, CA 93386-0679

Lebec County Water Dist
P.O. Box 910
Lebec, CA 93243

Mettler County Water Dist
P.O. Box 345, Mettler RB
Bakersfield, CA 93381

Los Angeles Dept of Water & Power
111 North Hope Street, Rm 1121
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Lost Hills Water Dist
3008 Sillect Avenue, Ste 205
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North Kern Water Storage Dist
P.O. Box 81435
Bakersfield, CA 93380-1435

Mountain Mesa Water Co
12707 Highway 178
Lake Isabella, CA 93240

North Edwards Water Dist
13001 Claymine Road
North Edwards, CA 93523

Olcese Water Dist
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Bakersfield, CA 93386-0679

North of the River Muni Water Dist
P.O. Box 5638
Bakersfield, CA 93388-5638

Oildale Mutual Water Co
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Bakersfield, CA 93388

Rand Communities Co Water Dist
P.O. Box 198
Randsburg, CA 93554

Pinion Pines Mutual Water Co
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309 Campus Drive
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44811 Date Avenue, #G
Lancaster, CA 93534-3136

Kern Valley Resource Cons Dist
P.O. Box 58
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Eastern Kern Resource Cons Dist
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331 Shafter Avenue
Shafter, CA 93263

Lost Hills Union School Dist
P.O. Box 158
Lost Hills, CA 93249

Midway School Dist
P.O. Box 39
Fellows, CA 93224

Mojave Unified School Dist
3500 Douglas
Mojave, CA 93501

Mountain View School Dist
8201 Palm Avenue
Lamont, CA 93241

Muroc Unified School Dist
17100 Foothill Avenue
North Edwards, CA 93523

Norris School Dist
6940 Calloway Drive
Bakersfield, CA 93312

Pond Union School District
29585 Pond Road
Wasco, CA 93280-9772

Richland-Lerdo Union School Dist
331 Shafter Avenue
Shafter, CA 93263

Rio Bravo-Greeley Union School Dist
6521 Enos Lane
Bakersfield, CA 93314

Rosedale Union School Dist
2553 Old Farm Road
Bakersfield, CA 93312

Semi Tropic School Dist
25300 Highway 46
Wasco, CA 93280-9540

Shafter High School Dist
526 Mannel Avenue
Shafter, CA 93263

Sierra Sands Unified School Dist
113 Felspar
Ridgecrest, CA 93555

South Fork Union School Dist
5225 Kelso Valley Road
Weldon, CA 93283

Southern Kern Unified School Dist
P.O. Box CC
Rosamond, CA 93560

Standard School Dist
1200 North Chester Avenue
Oildale, CA 93308

Taft City School Dist
820 North 6th Street
Taft, CA 93268

Taft Union High School Dist
701 7th Street
Taft, CA 93268

Tehachapi Unified School Dist
300 S Robinson Street
Tehachapi, CA 93561

Vineland School Dist.
8701 Weedpatch Highway
Bakersfield, CA 93307

Wasco Union High School Dist
P.O. Box 250
Wasco, CA 93280

Wasco Union Elementary School Dist
639 Broadway
Wasco, CA 93280

Maricopa Unified School Dist
955 Stanislaus Street
Maricopa, CA 93252

Arvin High School
900 Varsity Street
Arvin, CA 93203

Bakersfield City School Dist
Education Center
1300 Baker Street
Bakersfield, CA 93305

Beardsley School Dist
1001 Roberts Lane
Bakersfield, CA 93308

Blake School Dist
P.O. Box 53
Woody, CA 93287

Panama-Buena Vista School Dist
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42600 Highway 58
Buttonwillow, CA 93206

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Taft, CA 93268

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1720 Norwalk Street
Delano, CA 93215-1456

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1405 12th Avenue
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DiGiorgio School Dist
Route 1, Box 34
Arvin, CA 93203

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7311 Rosedale Highway
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3340 Erskine Creek Road
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Bakersfield, CA 93311

Javier Lozano
10000 Ming Avenue
Bakersfield, CA 93311

Fabiola Garcia
6127 Ragusa Lane
Bakersfield, CA 93308

Steven Shihady
14809 Lemon Lily Drive
Bakersfield, CA 93314

Scott Lynch
910 3rd Street
Taft, CA 93268

Bobby Hartsock
10809 Thunder Falls Avenue
Bakersfield, CA 93312

Adam Maan
8916 Bridget Leigh Way
Bakersfield, CA 93312

Matt Lusk
6303 Duck Pond Lane
Bakersfield, CA 93312

Patrick Flores
102 Brandon Avenue
Taft, CA 93268

Lorraine Coodey
14758 Blue Wildrye Court
Bakersfield, CA 93314

Sara Palmer
11806 Kenseth Street
Bakersfield, CA 93312

Erica Harper
11418 Lindalee Lane
Bakersfield, CA 93312

Brian Holcombe
5109 Marina Drive
Bakersfield, CA 93313

Wayne Vaughn
2616 Georgia Oak Drive
Bakersfield, CA 93311

Chris Eicher
931 Wegis Avenue
Bakersfield, CA 93314

William L. Trivitt
4509 Devlin Court
Bakersfield, CA 93311

Joy Johnson
8008 Sutherland Drive
Bakersfield, CA 93309

Notice of Completion & Environmental Document Transmittal

Mail to: State Clearinghouse, P. O. Box 3044, Sacramento, CA 95812-3044 (916) 445-0613
For Hand Delivery/Street Address: 1400 Tenth Street, Sacramento, CA 95814

SCH # _____

Project Title: Supplemental Environmental Impact Report for Approved Amendments to Title 19 – Kern County Zoning Ordinance (2015 C) Focused on Oil and Gas Local Permitting.

Lead Agency: Kern County Planning and Natural Resources Department
Contact Person: Lorelei H. Oviatt
Mailing Address: 2700 "M" Street Suite 100
Phone: (661) 862-8866
City: Bakersfield Zip: 93301-2323 County: Kern

Project Location: County: Kern City/Nearest Community: Multiple
Cross Streets: n/a Zip Code: 93301
Lat. / Long.: Total Acres: Approximately 2.3 million square acres
Assessor's Parcel No.: Multiple Section: Multiple Twp.: Multiple Range: Multiple Base: _____
Within 2 Miles: State Hwy #: 99, 58, 43, 46, 119, 223, 204, 33 Waterways: Kern River
Airports: Multiple Railways: Multiple Schools: Multiple

Document Type:

CEQA: ☒ NOP ☐ Early Cons ☐ Neg Dec ☐ Mit Neg Dec ☐ Draft EIR ☐ Supplement/Subsequent EIR (Prior SCH No.) _____ Other _____
NEPA: ☐ NOI ☐ EA ☐ Draft EIS ☐ FONSI
Other: ☐ Joint Document ☐ Final Document ☐ Other _____

Local Action Type:

☐ General Plan Update ☐ General Plan Amendment ☐ General Plan Element ☐ Community Plan
☐ Specific Plan ☐ Master Plan ☐ Planned Unit Development ☐ Site Plan
☐ Rezone ☐ Prezone ☐ Use Permit ☐ Land Division (Subdivision, etc.)
☐ Annexation ☐ Redevelopment ☐ Coastal Permit ☒ SEIR for Adopted Ordinance

Development Type:

☐ Residential: Units _____ Acres _____
☐ Office: Sq.ft. _____ Acres _____ Employees _____
☐ Commercial: Sq.ft. _____ Acres _____ Employees _____
☐ Industrial: Sq.ft. _____ Acres _____ Employees _____
☐ Educational _____
☐ Recreational _____
☐ Water Facilities: Type _____ MGD _____
☐ Transportation: Type _____
☐ Mining: Mineral _____
☐ Power: Type _____ MW _____
☐ Waste Treatment: Type _____ MGD _____
☐ Hazardous Waste: Type _____
☒ Other: Oil and Gas Exploration and Production

Project Issues Discussed in Document:

☐ Aesthetic/Visual ☐ Agricultural Land ☐ Air Quality ☐ Archeological/Historical ☐ Biological Resources ☐ Coastal Zone ☐ Drainage/Absorption ☐ Economic/Jobs
☐ Fiscal ☐ Flood Plain/Flooding ☐ Forest Land/Fire Hazard ☐ Geologic/Seismic ☐ Minerals ☐ Noise ☐ Population/Housing Balance ☐ Public Services/Facilities
☐ Recreation/Parks ☐ Schools/Universities ☐ Septic Systems ☐ Sewer Capacity ☐ Soil Erosion/Compaction/Grading ☐ Solid Waste ☐ Toxic/Hazardous ☐ Traffic/Circulation
☐ Vegetation ☐ Water Quality ☐ Water Supply/Groundwater ☐ Wetland/Riparian ☐ Wildlife ☐ Growth Inducing ☐ Land Use ☐ Cumulative Effects
☒ Other Grazing land with oil and gas exploration and extraction

Present Land Use/Zoning/General Plan Designation: Developed and undeveloped land in Kern County. Current Zoning Classifications and General Map Code Designations to remain the same.

Project Description: The action consists of the preparation of a Supplemental Environmental Impact Report (SEIR) for approved amendments to Title 19 of the Kern County Zoning Ordinance (2015C) (Ordinance) focused on Oil and Gas local permitting in the valley area, for text amendments to various chapters, which include site development standards and permitting procedures for oil and gas exploration, extraction, operations, and production activities in unincorporated Kern County. The County certified a final Environmental Impact Report (EIR), and approved the amendments to the Ordinance, on November 9, 2015.

Reviewing Agencies Checklist

Lead Agencies may recommend State Clearinghouse distribution by marking agencies below with and "X".
If you have already sent your document to the agency please denote that with an "S".

S	Air Resources Board		Office of Emergency Services
	Boating & Waterways, Department of	S	Office of Historic Preservation
S	California Highway Patrol		Office of Public School Construction
	CalFire	S	Parks & Recreation
S	Caltrans District # 6 & 9		Pesticide Regulation, Department of
S	Caltrans Division of Aeronautics	x	Public Utilities Commission
S	Caltrans Planning (Headquarters)	S	Regional WQCB # Central Valley
	Central Valley Flood Protection Board		Resources Agency
	Coachella Valley Mountains Conservancy		S.F. Bay Conservation & Development Commission
	Coastal Commission		San Gabriel & Lower L.A. Rivers and Mtns Conservancy
	Colorado River Board		San Joaquin River Conservancy
S	Conservation, Department of		Santa Monica Mountains Conservancy
	Corrections, Department of		State Lands Commission
	Delta Protection Commission		SWRCB: Clean Water Grants
	Education, Department of		SWRCB: Water Quality
S	Energy Commission		SWRCB: Water Rights
S	Fish & Game Region # Fresno		Tahoe Regional Planning Agency
S	Food & Agriculture, Department of	S	Toxic Substances Control, Department of
	General Services, Department of	S	Water Resources, Department of
	Health Services, Department of		
	Housing & Community Development		Other _____
S	Integrated Waste Management Board		Other _____
S	Native American Heritage Commission		

Local Public Review Period (to be filled in by lead agency)

Starting Date May 31, 2018 Ending Date July 2, 2018

Lead Agency (Complete if applicable):

Consulting Firm: _____
Address: _____
City/State/Zip: _____
Contact: _____
Phone: _____

Applicant: _____
Address: _____
City/State/Zip: _____
Phone: _____

Signature of Lead Agency Representative: /s/ **Date:** May 31, 2018

Authority cited: Section 21083, Public Resources Code. Reference: Section 21161, Public Resources Code.

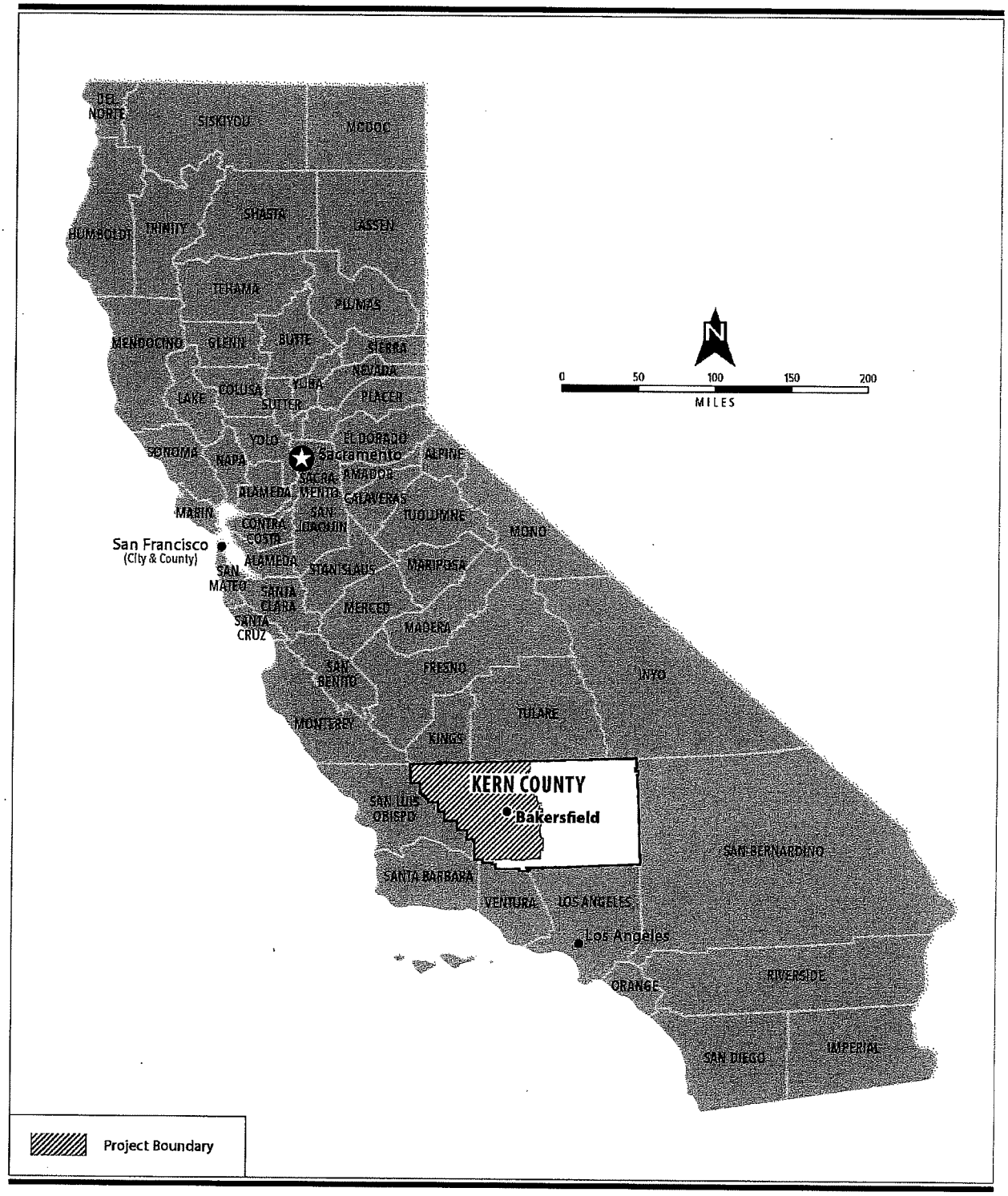
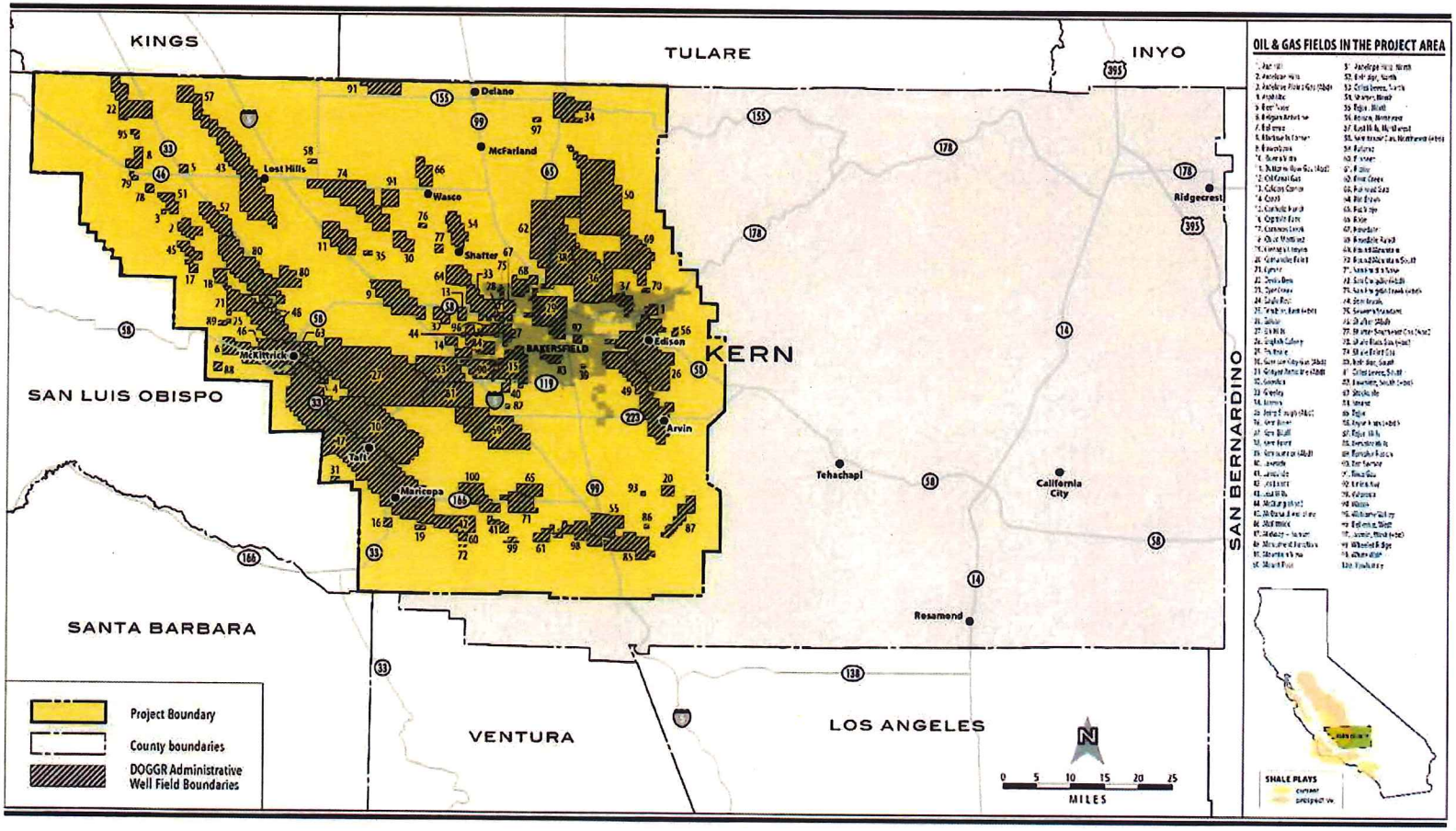


Figure 1

Regional Location

Project Boundary



ATTACHMENT A

May 16, 2018
Letter to the San Joaquin Valley Air Pollution Control District

Lorelei H. Oviatt, AICP, Director
2700 "M" Street, Suite 100
Bakersfield, CA 93301-2323
Phone: (661) 862-8600
Fax: (661) 862-8601 TTY Relay 1-800-735-2929
Email: planning@kerncounty.com
Web Address: http://kernplanning.com/



PLANNING AND NATURAL RESOURCES DEPARTMENT

Planning
Community Development
Administrative Operations

May 16, 2018

File: Oil and Gas EIR

San Joaquin Valley Air Pollution Control District
Attn; Seyed Sadredin , Executive Director
1990 E. Gettysburg Avenue
Fresno, California 93726

RE: Kern County Oil and Gas Ordinance: Resolution of *Vaquero* Litigation (Kern County Superior Court Case No. BCV-15-101645, consolidated with Case Nos. BCV-15-101666 and BCV-15-101679).

Dear Mr. Sadredin,

This correspondence provides you with clarification and further information on the implementation of our Oil and Gas Emission Reduction Agreement (20160168 – County agreement #890-2016) executed between the Air District Board and the Kern County Board of Supervisors in August of 2016 to implement the adopted Oil and Gas Permitting Ordinance Air Quality mitigation measure.

Attached is the judgment of Superior Court Judge Eric Bradshaw in *Vaquero Energy, Inc. et al. v. County of Kern et al.*, *King & Gardiner Farms LLC v. County of Kern et al.*, and *Committee for a Better Arvin et al. v. County of Kern et al.* (Kern County Superior Court Case No. BCV-15-101645, consolidated with Case Nos. BCV-15-101666 and BCV-15-101679) (hereafter, "Vaquero Judgment").

On November 9, 2015, the Kern County Board of Supervisors approved amendments to Title 19 of the Kern County Zoning Ordinance, focused on Chapter 19.98 (Oil and Gas Production), to include new site development standards and permitting procedures for oil and gas exploration, extraction, operations, and production activities in unincorporated Kern County. The Board of Supervisors certified a final Environmental Impact Report (EIR) for the Zoning Ordinance amendments on the same day. The EIR was subsequently challenged in the above-referenced lawsuit. On April 20, 2018, Judge Bradshaw issued the Vaquero Judgment and upheld both the Ordinance and the EIR on all but two narrow issues.

Judge Bradshaw concluded that the EIR did not evaluate the environmental impacts of road paving, which was identified in the County's staff report and discussed in the EIR as a potential future offset for particulate matter emissions that could potentially be undertaken by a permit applicant in lieu of paying some portion of the air quality mitigation fee required by Mitigation Measure 4.3-8 in the EIR. Road paving is not currently allowed as an emission offset measure in the Mitigation Monitoring and Reporting Program (MMRP) adopted for the Zoning Ordinance amendments. Appendix M-3 of the EIR includes a draft Emission Reduction Agreement (ERA) that sets forth the required procedures for considering road paving and other potential direct applicant emission reduction activities in lieu of paying some portion of the required air quality mitigation fee. The ERA was executed by the County and the San Joaquin Valley Air Pollution Control District (District) in August 2016. Pursuant to the ERA, road paving could have been accepted as an emission reduction measure if and only if in the future both the District and the County

accepted a future applicant request for an approved protocol for quantifying the emission reduction benefits of road paving.

In compliance with the Vaquero Judgment, please be advised that any future applicant request for recognition of emission reduction offsets for road paving will require future discretionary approvals by the County and District, and will further trigger the need for additional environmental review and compliance with the California Environmental Quality Act (CEQA).

Pursuant to the ERA, and in further compliance with the Vaquero Judgement, the County declines to approve of road paving as a potential future applicant air emission offset. The County has informed applicant representatives that any future road paving request that is proposed to be undertaken instead of paying the required air quality mitigation fee must first be submitted to the County, which will again serve as the CEQA lead agency for any such proposed applicant activity. The County will thereafter coordinate with the District, and complete the required CEQA process (inclusive of public notice and outreach), prior to making a determination as to whether or under what conditions road paving would be eligible as an applicant emission reduction activity to satisfy some portion of the air emission mitigation required by the Ordinance. Since road paving is not recognized as an air emission offset in either the Ordinance or EIR, no changes to the Ordinance or EIR are required by the Vaquero Judgment.

As information only, please note that Judge Bradshaw also directed the County to complete additional CEQA analysis concerning potential environmental impacts to rangeland/grazing land. The County is currently undertaking the additional CEQA review of this issue. Since the Air Quality and Greenhouse Gas sections of the EIR were upheld in the Vaquero Judgment, the County does not anticipate that the additional CEQA analysis of potential environmental impacts to rangeland/grazing land will include these issues. The County will continue to communicate with responsible agencies, including the District, as required by CEQA during the additional review process for rangeland/grazing land.

The Vaquero Judgment did not vacate any portion of the Ordinance or EIR, and Judge Bradshaw declined requests by two of the three petitioner groups to halt all or some portion of future oil and gas activities authorized by the Ordinance. The Vaquero Judgment does not affect ongoing reliance on the EIR by responsible agencies, including the District.

Please do not hesitate to contact me at 661-862-8866 or Loreleio@kerncounty.com, if you have any questions or would like to discuss this matter further. I want to again thank the District and your staff for the extensive technical assistance provided during the EIR process for this Ordinance and support for the implementation of our Emission Reduction Agreement.

Sincerely,

LORELEI H OVIATT, AICP, Director
Kern County Planning and Natural Resources Department

cc: County Counsel
SJVAPD Dave Warren
WSPA
CIPA
Holland and Knight

FILED
SUPERIOR COURT, METROPOLITAN DIVISION
COUNTY OF KERN
APR 20 2018
TERRY McNALLY, CLERK
BY _____ DEPUTY

SUPERIOR COURT OF THE STATE OF CALIFORNIA

COUNTY OF KERN

VAQUERO ENERGY, INC., a California corporation; and HUNTER EDISON OIL DEVELOPMENT LIMITED PARTNERSHIP, a California limited partnership; Petitioners and Plaintiffs, vs. COUNTY OF KERN; and KERN COUNTY BOARD OF SUPERVISORS; Respondents and Defendants.	Case No. BCV-15-101645-EB (Lead case) [Consolidated w/ Case No. BCV-15-101666-EB and Case No. BCV-15-101679-EB] **JUDGMENT in Case Nos. BCV-15-101645-EB**
CALIFORNIA INDEPENDENT PETROLEUM ASSOCIATION, a California non-profit mutual benefit corporation; INDEPENDENT OIL PRODUCERS' AGENCY, a California corporation; and WESTERN STATES PETROLEUM ASSOCIATION, a California non-profit mutual benefit corporation; Real Parties in Interest.	

The above-referenced consolidated cases (BCV-15-101645-EB, BCV-15-101666-EB and BCV-15-101679-EB) came on regularly for trial on June 13-14, 2017, August 10, 2017 and December 13, 2017, in Dept. T-2 of the Kern County Superior Court, the Honorable J. Eric

Bradshaw presiding. In case no. BCV-15-101645-EB, petitioners/plaintiffs VAQUERO ENERGY, INC., a California corporation, and HUNTER EDISON OIL DEVELOPMENT LIMITED PARTNERSHIP, a California limited partnership (collectively "Vaquero"), respondents/defendants COUNTY OF KERN (including its Planning Commission, and Planning and Natural Resources Department) and KERN COUNTY BOARD OF SUPERVISORS (collectively "County"), and real parties in interest CALIFORNIA INDEPENDENT PETROLEUM ASSOCIATION, INDEPENDENT OIL PRODUCERS' AGENCY, and WESTERN STATES PETROLEUM ASSOCIATION (collectively "Real Parties"), appeared through counsel.

The court reviewed and considered the evidence, record of proceedings, pleadings, briefs and papers on file herein, and the comments of counsel, and the causes were argued and submitted for decision. The court issued its ruling dated March 12, 2018 (hereinafter "Ruling"), fully resolving all claims, causes of action and issues in consolidated case nos. BCV-15-101645-EB, BCV-15-101666-EB and BCV-15-101679-EB. A separate judgment was entered in consolidated case nos. BCV-15-101666-EB and BCV-15-101679-EB. Accordingly, in case no. BCV-15-101645-EB,

IT IS HEREBY ORDERED, ADJUDGED AND DECREED that:

1. The causes of action and claims for relief alleged in the operative petition/complaint filed by Vaquero, against County and Real Parties, are DENIED, and Vaquero shall take nothing by way of the petition/complaint.

2. Costs of suit and attorneys' fees may be claimed in accordance with applicable law and rules of court.

Dated: April 20, 2018

JUDGE OF THE SUPERIOR COURT
J ERIC BRADSHAW

FILED
SUPERIOR COURT, METROPOLITAN DIVISION
COUNTY OF KERN
APR 20 2018
TERRY McNALLY, CLERK
BY _____ DEPUTY

SUPERIOR COURT OF THE STATE OF CALIFORNIA

COUNTY OF KERN

VAQUERO ENERGY, INC., a California corporation; and HUNTER EDISON OIL DEVELOPMENT LIMITED PARTNERSHIP, a California limited partnership; Petitioners and Plaintiffs, vs. COUNTY OF KERN; and KERN COUNTY BOARD OF SUPERVISORS; Respondents and Defendants. CALIFORNIA INDEPENDENT PETROLEUM ASSOCIATION, a California non-profit mutual benefit corporation; INDEPENDENT OIL PRODUCERS' AGENCY, a California corporation; and WESTERN STATES PETROLEUM ASSOCIATION, a California non-profit mutual benefit corporation; Real Parties in Interest.	Case No. BCV-15-101645-EB (Lead case) [Consolidated w/ Case No. BCV-15-101666-EB and Case No. BCV-15-101679-EB] **JUDGMENT in Case Nos. BCV-15-101666-EB and BCV-15-101679-EB**

The above-referenced consolidated cases (BCV-15-101645-EB, BCV-15-101666-EB and BCV-15-101679-EB) came on regularly for trial on June 13-14, 2017, August 10, 2017 and December 13, 2017, in Dept. T-2 of the Kern County Superior Court, the Honorable J. Eric

Bradshaw presiding. In case nos. BCV-15-101666-EB and BCV-15-101679-EB, petitioner/plaintiff King and Gardiner Farms, LLC ("KGF"), petitioners/plaintiffs Committee for a Better Arvin, Committee for a Better Shafter, Greenfield Walking Group, Natural Resources Defense Council, Sierra Club, and Center for Biological Diversity (collectively "Arvin Petitioners"), respondents/defendants County of Kern (including its Planning Commission, and Planning and Natural Resources Department) and Kern County Board of Supervisors (collectively "County"), and real parties in interest California Independent Petroleum Association, Independent Oil Producers' Agency, and Western States Petroleum Association (collectively "Real Parties"), appeared through counsel.

The court reviewed and considered the evidence, record of proceedings, pleadings, briefs and papers on file herein, and the comments of counsel, and the causes were argued and submitted for decision. The court issued its ruling dated March 12, 2018, a copy of which is attached hereto as Exhibit "A" (hereinafter "Ruling") fully resolving all claims, causes of action and issues in consolidated case nos. BCV-15-101645-EB, BCV-15-101666-EB and BCV-15-101679-EB. A separate judgment was entered in case no. BCV-15-101645-EB. Accordingly, in consolidated case nos. BCV-15-101666-EB and BCV-15-101679-EB,

IT IS HEREBY ORDERED, ADJUDGED AND DECREED that:

1. The causes of action and claims for relief alleged in the operative petitions/complaints filed by KGF and Arvin Petitioners, against County and Real Parties, under the California Environmental Quality Act (Pub. Res. Code §§ 21000 et seq.) (hereinafter "CEQA") challenging the adequacy of County's analysis of the project's environmental impacts to rangeland/grazing land, and the environmental impacts from road paving as an air emissions mitigation measure, including related determinations, are GRANTED, and a writ will issue as more particularly stated herein. Except as otherwise expressly stated herein, the petitions/complaints of KGF and Arvin Petitioners are DENIED, and KGF and Arvin Petitioners shall take nothing by way of their respective petitions/complaints.

2. A peremptory writ of mandate directed to County will issue under seal of this court, ordering County to do the following:

(a) Within 45 days from service of the writ of mandate, County shall transmit to the San Joaquin Valley Air Pollution Control District copies of this court's Ruling, this judgment, and the related peremptory writ of mandate.

(b) Consistent with the Ruling and the procedures set forth in CEQA and CEQA Guidelines, County shall prepare such analysis as is necessary to address the EIR's deficient analysis of the Project's (i) environmental impacts to rangeland/grazing land, and (ii) environmental impacts from road paving as an air emissions mitigation measure ("Supplemental Analysis"). In the event the Supplemental Analysis determines that any such environmental impacts are potentially significant, the Supplemental Analysis shall identify feasible mitigation measures and/or alternatives to mitigate or avoid such impacts consistent with CEQA's requirements, unless County makes findings of infeasibility and overriding considerations as provided by CEQA.

(c) Upon completion of the Supplemental Analysis described in Part 2(b) above, County shall: (i) reconsider its approval of the Project and its Statement of Overriding Considerations adopted in connection with that project, in light of any new information in the Supplemental Analysis, and (ii) take any and all further action that may be necessary to bring the approval of the project and the related findings and mitigation monitoring and reporting program into compliance with CEQA.

(d) County shall file an initial return to the writ not later than 75 days after the service of the writ of mandate, setting forth what it has done to comply with paragraph 2(a) above. County shall file a supplemental return to the writ of mandate no later than 180 days after the initial return, setting forth whether it has complied with paragraphs 2(b) and 2(c) above. County shall thereafter file supplemental returns every 60 days until it has fully complied with paragraphs 2(b) and 2(c) above.

3. The court finds that the writ authorized by Public Resources Code section 21168.9(a)(3), mandating that County "take specific action as may be necessary to bring the

determination, finding, or decision into compliance with [CEQA]," is the appropriate remedy under the circumstances of this case, and that the mandates described in Public Resources Code section 21168.9(a)(1) and (a)(2) are not appropriate remedies under the circumstances of this case.

(a) Regarding rangeland/grazing land, the writ of mandate is limited to those portions of County's determinations, findings, decisions, permits and approvals under the project that are implicated by the EIR's deficient analysis of impacts to rangeland/grazing land because: (i) County's determinations, findings, decisions, permits and approvals relating to oil and gas activities on rangeland/grazing land are severable, (ii) severance will not prejudice complete and full compliance with CEQA because County will consider the information required by CEQA before new oil and gas activities subject to the project will be permitted or allowed on rangelands/grazing land, and (iii) with the exception of the EIR's discussion of road paving as an air emissions mitigation measure (discussed *infra*), the court has not found the remainder of the project to be in noncompliance with CEQA or CEQA Guidelines.

(b) Regarding road paving as an air emissions mitigation measure, the writ of mandate is limited to those portions of County's determinations, findings, decisions, permits and approvals under the project that are implicated by the EIR's deficient analysis of road paving as an air emissions mitigation measure because: (i) County's determinations, findings, decisions, permits and approvals relating to the use of road paving as an air emissions mitigation measure are severable, (ii) severance will not prejudice complete and full compliance with CEQA because County will consider the information required by CEQA before taking any action to permit or allow the use of road paving as an air emissions mitigation measure, and (iii) with the exception of the EIR's discussion of impacts to rangeland/grazing land (discussed *supra*), the court has not found the remainder of the project to be in noncompliance with CEQA or CEQA Guidelines.

4. Pursuant to Public Resources Code section 21168.9(c), nothing in this judgment or

the writ(s) issued hereunder may be construed as an order that County exercise its lawful discretion in a particular way.

5. Costs of suit and attorneys' fees may be claimed in accordance with applicable law and rules of court.

6. The court retains jurisdiction in consolidated case nos. BCV-15-101666-EB and BCV-15-101679-EB to ensure compliance with this judgment, and the writ(s) issued pursuant to this judgment.

Dated: April 20, 2018

JUDGE OF THE SUPERIOR COURT

J ERIC BRADSHAW

Exhibit "A"

Superior Court of California
County of Kern
1415 Truxtun Ave
Bakersfield, CA 93301

Date: 03/12/2018 **Time:** 8:00 AM - 5:00 PM

BCV-15-101645

VAQUERO ENERGY VS COUNTY OF KERN

Courtroom Staff

Honorable: J. Eric Bradshaw **Clerk:** Y. Torres

Court reporter: N/A **Bailiff:** N/A
Interpreter: **Language of:**

PARTIES:

CALIFORNIA INDEPENDENT PETROLEUM ASSOCIATION, Real Party Interest, not present	KELI OSAKI, Attorney, not present
CALIFORNIA INDEPENDENT PETROLEUM ASSOCIATION, Real Party Interest, not present	KELI OSAKI, Attorney, not present
CALIFORNIA INDEPENDENT PETROLEUM ASSOCIATION, A CALIFORNIA NON-PROFIT MUTUAL BENEFIT CORPORATION, Real Party Interest, not present	CRAIG MOYER, Attorney, not present
CENTER FOR BIOLOGICAL DIVERSITY, Petitioner, not present	HOLLIN KRETZMANN, Attorney, not present
COMMITTEE FOR A BETTER ARVIN, Petitioner, not present	CAROLINE FARRELL, Attorney, not present
COMMITTEE FOR A BETTER SHAFTER, Petitioner, not present	CAROLINE FARRELL, Attorney, not present
COUNTY OF KERN, Respondent, not present	CHARLES COLLINS, Attorney, not present
COUNTY OF KERN, Respondent, not present	CHARLES COLLINS, Attorney, not present
GREENFIELD WALKING GROUP, Petitioner, not present	CAROLINE FARRELL, Attorney, not present
HUNTER EDISON OIL DEVELOPMENT LIMITED PARTNERSHIP, A CALIFORNIA LIMITED PARTNERSHIP, Petitioner, not present	EDWARD RENWICK, Attorney, not present
INDEPENDENT OIL PRODUCERS AGENCY, Real Party Interest, not present	BLAINE GREEN, Attorney, not present
INDEPENDENT OIL PRODUCERS AGENCY, Real Party Interest, not present	NORMAN CARLIN, Attorney, not present
INDEPENDENT OIL PRODUCERS' AGENCY, A CALIFORNIA CORPORATION, Real Party Interest, not present	NORMAN CARLIN, Attorney, not present
KERN COUNTY, Respondent, not present	CHARLES COLLINS, Attorney, not present
KERN COUNTY BOARD OF SUPERVISORS, Respondent, not present	CHARLES COLLINS, Attorney, not present

MINUTE ORDER

KERN COUNTY BOARD OF SUPERVISORS, Respondent, not present	CHARLES COLLINS, Attorney, not present
KERN COUNTY BOARD OF SUPERVISORS, Respondent, not present Kern County Counsel, Defendant, not present	CHARLES COLLINS, Attorney, not present
KERN COUNTY PLANNING AND COMMUNITY DEVELOPMENT DEPARTMENT, Respondent, not present	CHARLES COLLINS, Attorney, not present
KERN COUNTY PLANNING AND COMMUNITY DEVELOPMENT DEPARTMENT, Respondent, not present	CHARLES COLLINS, Attorney, not present
KERN COUNTY PLANNING COMMISSION, Respondent, not present	CHARLES COLLINS, Attorney, not present
KING AND GARDINER FARMS, LLC, Petitioner, not present	RACHEL HOOPER, Attorney, not present
NATURAL RESOURCES DEFENSE COUNCIL, Petitioner, not present	WILLIAM ROSTOV, Attorney, not present
Natural Resources Defense Council, Petitioner, not present	MARGARET HSIEH, Attorney, not present
SIERRA CLUB, Petitioner, not present	WILLIAM ROSTOV, Attorney, not present
VAQUERO ENERGY INC., A CALIFORNIA CORPORATION, Petitioner, not present	EDWARD RENWICK, Attorney, not present
WESTERN STATES PETROLEUM ASSOCIATION, Real Party Interest, not present	BLAINE GREEN, Attorney, not present
WESTERN STATES PETROLEUM ASSOCIATION, Real Party Interest, not present	NORMAN CARLIN, Attorney, not present
WESTERN STATES PETROLEUM ASSOCIATION, A CALIFORNIA NON-PROFIT MUTUAL BENEFIT CORPORATION, Real Party Interest, not present	NORMAN CARLIN, Attorney, not present

NATURE OF PROCEEDINGS: RULING ON CONSOLIDATED PETITIONS FOR WRITS OF MANDATE, AND COMPLAINTS FOR DECLARATORY AND INJUNCTIVE RELIEF (BCV-15-101645, BCV-15-101666, and BCV-15-101679) HERETOFORE SUBMITTED:

SEE ATTACHED RULING, INCORPORATED HEREIN.

MINUTE ORDER FINALIZED BY: YESENIA TORRES ON: MARCH 12, 2018

CONSOLIDATED PETITIONS FOR WRITS OF MANDATE, AND COMPLAINTS FOR DECLARATORY AND INJUNCTIVE RELIEF (BCV-15-101645, BCV-15-101666, and BCV-15-101679) HERETOFORE SUBMITTED:

* * * * *

DISPOSITION

BCV-15-101645 (Lead case)

The first amended petition/complaint of Vaquero Energy, Inc. ("Vaquero"), and Hunter Edison Oil Development Limited Partnership ("Hunter") (sometimes collectively "Vaquero petitioners"), for a writ of mandate, and for declaratory and injunctive relief, is DENIED. Judgment shall be entered in favor of respondents/defendants, against Vaquero petitioners, and Vaquero petitioners shall take nothing by way of their petition/complaint. Costs of suit and attorneys' fees may be claimed in accordance with applicable law and rules of court. Respondent/defendant County of Kern shall prepare a separate judgment for BCV-15-101645.

BCV-15-101666 & BCV-15-101679

The petition/complaint of King and Gardiner Farms, LLC ("KGF"), and the petition/complaint of Committee for a Better Arvin, Committee for a Better Shafter, Greenfield Walking Group, Natural Resources Defense Council, Sierra Club, and Center for Biological Diversity (collectively "Arvin Petitioners"), for a writs of mandate, and for declaratory, injunctive and other relief, are GRANTED IN PART, and DENIED IN PART, consistent with the issue-specific rulings herein. Judgment and other appropriate relief shall be entered consistent with the rulings herein. Arvin Petitioners' request for judicial notice of the unpublished superior court decision (Ex. 1) is DENIED. Costs of suit and attorneys' fees may be claimed in accordance with applicable law and rules of court.

A case management conference is hereby scheduled in these two consolidated cases (BCV-15-101666 and BCV-15-101679), in Dept. T-2 of the Kern County Superior Court, located at 3131 Arrow Street, Bakersfield, CA, on April 4, 2018 at 8:30 a.m., for the purpose of discussing remedy and relief. The parties are ordered to meet and confer in good faith prior to the case management conference to discuss the foregoing, and if possible, to submit to the court for review and signature an agreed form of judgment, writ or other orders/decrees as may be appropriate.

DISCUSSION

This discussion organizes rulings on issues according to the plaintiff/petitioner principally responsible for arguing the particular issue at trial.

Vaquero Petitioners' Issues

1. Contract Clause

Vaquero petitioners have failed to prove that Kern County Ordinance Code sections 19.98.100, 19.98.140, 19.98.085, 19.98.090, or 19.98.130, unconstitutionally impair a contract in violation of the Contract Clauses of the U. S. Constitution or California Constitution. It is undisputed that Vaquero is a lessee under oil and gas leases in "Tier 2" areas in Kern County where surface ownership has been severed from mineral ownership, and that Hunter operates those leases. The specific provisions of the leases and agreements under which Vaquero petitioners hold their interests and operate, however, have not been proven. Thus, no impairment of a particular contract or obligation, substantial or otherwise, has been proven.

Similarly, assuming *arguendo*, the Vaquero petitioners' "bargaining power" vis-à-vis surface owners is a "contract" or "obligation" that can be "impaired" within the meaning of the Contract Clause, the impairment is slight under the circumstances. The oil and gas industry is heavily regulated. The burden of successfully negotiating a surface owner's consent, or obtaining a ministerial permit by following the "second pathway," is justified by the County's interest in protecting agricultural land use, and minimizing land use conflicts. Regulations substantially more restrictive than the County's ordinance have been upheld against Contract Clause challenges. *See, e.g., Energy Reserves Group, Inc. v. Kansas Power and Light Co. (1983) 459 U.S. 400; Exxon Corp. v. Eagerton (1983) 462 U.S. 176; Hermosa Beach Stop Oil Coalition v. City of Hermosa Beach (2001) 86 Cal.App.4th 534.*

2. Equal Protection

Vaquero petitioners have failed to prove that the ordinance denies them equal protection under the U.S. Constitution, or the California Constitution. The "two pathway" provisions of the ordinance do not involve a suspect class or a fundamental right. The differential regulatory treatment for split estate mineral owners, based on surface owner consent or refusal to consent, is rationally related to the County's legitimate interest in promoting cooperation, protecting agricultural land use, and minimizing land use conflicts.

3. Due Process

Vaquero petitioners have failed to prove that the ordinance denies them due process of the law under the U.S. Constitution, or the California Constitution, and no impermissible regulatory "taking" has been shown. The purposes of the County's ordinance, establishing

tiers and "two pathways" to a ministerial permit, include protecting agricultural land use, minimizing land use conflicts, promoting cooperation where mineral and surface ownership has been severed, and protecting health, safety and the environment. The subject ordinance contains reasonable provisions substantially aimed at achieving these legitimate purposes. *See, Murphy v. Amoco Production Co. (1984) 729 F.2d 552, 556.*

Vaquero petitioners' reliance on *Eubank v. City of Richmond (1912) 226 U.S. 137 ("Eubank")*, is misplaced. In *Eubank*, the Supreme Court invalidated a city ordinance that conferred the power to establish building setback lines upon the owners of two-thirds of the property abutting any street. In the present case, County's ordinance does not give surface owners the power to "veto" a mineral owner's activity, just the power to consent or withhold consent. When either the surface owner or the mineral owner is unwilling to agree, for whatever reason, the mineral owner has the "second pathway" option. *Eubank* precludes the unlawful *delegation* of legislative authority; it does not apply to circumstances where—as here—the law allows private parties to *waive* a requirement ("first pathway"), or obtain a permit by alternate means ("second pathway"). *See, Thomas Cusack Co. v. City of Chicago (1917) 242 U.S. 526 ("Cusack"); see also, Kentucky Div., Horsemen's Benev. & Protective Assn., Inc. v. Turfway Park Racing Assn., Inc. (1994) 20 F.3d 1406* [discussing *Eubank* and *Cusack*].

CEQA Standard of Review

Public Resources Code § 21168.5 applies in cases seeking traditional ("ordinary") mandamus and cases other than those to which Public Resources Code § 21168 applies, such as cases where an agency has made a "legislative," "nonjudicial" or "nonadjudicative" determination or decision. *Pub. Res. Code § 21168.5; Laurel Heights Improvement Assn. of San Francisco, Inc. v. Regents of Univ. of Calif. (1988) 47 Cal.3d 376, fn. 5; Vineyard Area Citizens for Responsible Growth, Inc., v. City of Rancho Cordova (2007) 40 Cal.4th 412, fn. 4; Center for Biological Diversity v. California Dept. of Fish & Wildlife ("Center") (2015) 62 Cal.4th 204, 214-215.* The court reviews an agency's determination or decision under Section 21168.5 to see if the agency committed a "prejudicial abuse of discretion." *Pub. Res. Code § 21168.5.* An "abuse of discretion" occurs under Section 21168.5 if: (1) "the agency has not proceeded in a manner required by law," or (2) "the [agency's] determination or decision is not supported by substantial evidence." *Pub. Res. Code § 21168.5; Vineyard, supra, at p. 435.* Judicial review of these two types of error differs significantly: the court determines *de novo* whether the agency has employed the correct procedures, "scrupulously enforc[ing] all legislatively mandated CEQA requirements," *Vineyard, supra, at p. 435 [quoting Citizens Goleta Valley v. Board of Supervisors (1990) 52 Cal.3d 553, 564]*; the court accords greater deference to the agency's substantive factual conclusions, and reviews them for substantial evidence. *Laurel Heights, supra, 47 Cal.3d at p. 393; Vineyard, supra, at p. 435.* Thus, in evaluating an EIR for CEQA compliance under Section 21168.5, the court must adjust its scrutiny to the nature of the alleged defect, depending on whether the claim is predominantly one of improper

procedure or a dispute over the facts. *Vineyard, supra, at p. 435; Center, supra, 62 Cal.4th 204, 214-215.*

An EIR will be found legally inadequate—and subject to independent review for procedural error—where it omits information that is both required by CEQA and necessary to informed discussion." *California Native Plant Society v. City of Santa Cruz (2009) 177 Cal.App.4th 957, 986.* Omission of required information constitutes a failure to proceed in a manner required by law where it precludes informed decision-making by the agency or informed public participation by the public. *Id. at p. 987.*

The substantial evidence standard is applied to conclusions, findings, and determinations, to challenges regarding the scope of an EIR's analysis of a topic, the methodology used for studying an impact, and the reliability or accuracy of data upon which the EIR relied, because these types of challenges involve factual questions. *Ibid.; see also, Santa Monica Baykeeper v. City of Malibu (2011) 193 Cal.App.4th 1538, 1546.*

In applying the "substantial evidence" standard to an agency's factual determinations under both Section 21168 and Section 21168.5, the court must resolve reasonable doubts in favor of the administrative finding and decision. *Topanga Association for a Scenic Community v. County of Los Angeles (1974) 11 Cal.3d 506, 514; Laurel Heights, supra, 47 Cal.3d at p. 393.* A court may not set aside an agency's approval of an EIR on the ground that an opposite conclusion would have been equally or more reasonable. *Greenbaum v. City of Los Angeles (1984) 153 Cal.App.3d 401-402; Laurel Heights, supra, 47 Cal.3d at p. 393.* The court does not pass upon the correctness of the EIR's environmental conclusions, but only upon its sufficiency as an informative document. *Laurel Heights, supra, 47 Cal.3d at p. 392.* The court must resolve reasonable doubts in favor of the administrative finding and decision. *Id. at p. 393.*

KGF Issues

1. CUP Alternative.

Petitioner argues that no substantial evidence supports the County's determinations that: (1) the CUP alternative would impede a project objective; and (2) the CUP alternative is environmentally inferior to the project ordinance.

Would Not Achieve Basic Objective

County's findings regarding the CUP alternative state, in part: the "[CUP alternative] would not achieve the Project's basic objective[;]" it "would not streamline the County's current oil and gas permitting procedures because it would impose a lengthy and cumbersome discretionary permitting process on all new oil and gas development... [;]" "County currently contains approximately 75 active oil and gas fields, and over 2,500 wells are drilled in the County every year[;]" "it is not practical to subject every well permit to

an individual discretionary approval process, or for environmental reviews to be conducted on every single well or groups of wells[;]" "County lacks the resources to process thousands of oil and gas Negative Declarations and/or EIRs each year[;]" "the economic consequences for operators would be severe, delaying drilling for many months during the preparation of costly individualized CEQA documents[;]" "such individualized review would be highly repetitive, as the thousands of Negative Declarations and EIR's would re-analyze the same impacts and prescribe the same mitigation for each new well or group of wells throughout the County[;]" "the basic objective of the Project and this EIR is to eliminate time-consuming and costly discretionary reviews of individual well and field development activities by establishing a ministerial site plan review process which incorporates mitigation identified in this EIR." Substantial evidence supported County's findings.

Petitioner argues that County rejected the CUP alternative because it would not achieve "one of the 13 project objectives, the streamlining of oil and gas environmental review and permitting." Petitioner cites Guideline § 15126.6(b), and argues that County may not "reject an alternative because it has some adverse impact on a single project objective." Petitioner's interpretation of the findings is unreasonably narrow. Several project objectives obviously overlap and interrelate. It is reasonably apparent that County's findings discuss "streamlining" regulations and the consequences of doing so, from the standpoint of both County administration and industry compliance. The finding is sufficiently informative and cannot reasonably be understood as involving only "one of 13 project objectives." Moreover, Guideline § 15126.6(b) governs the assessment of "*potentially*" feasible alternatives in the EIR. County's ultimate decision to reject an infeasible alternative is governed by Guideline § 15091(a)(3). *California Native Plant Soc. v. City of Santa Cruz (2009) 177 Cal.App.4th 957, 998-999.*

Petitioner argues the CUP alternative "would not impede efficient and streamlined environmental review," and that "no actual evidence" supports County's determinations regarding the administrative burden imposed by the CUP alternative. Petitioner is incorrect. Petitioner's opinion the CUP alternative "would *enable*" streamlined review in some abstract sense does not address objectives and practical constraints with which County was obviously considered. County considered an actual workload, and was entitled to rely on oral and written presentations and analyses regarding the estimated number of permits to be issued, County's experience with oil and gas development, CUPs, EIRs, negative declarations, costs, the discretionary approval process, how long that process actually takes, County's own resources and the limitations, as well as the severe negative consequences of individualized discretionary review to an industry so economically significant to County.

Petitioner argues that County refused to consider a variation of the CUP alternative. This argument appears as part of petitioner's broader contention that County's findings are not supported by substantial evidence. To the extent the perceived error is a lack of substantial evidence to support a finding, infeasibility findings are only required for "alternatives *identified in the environmental impact report.*" *Pub. Res. Code § 21081(a)(3).*

County made findings regarding the CUP alternative, and was not required to make specific findings regarding a proposed variation or variations of the CUP alternative. Nevertheless, substantial evidence in the record shows the CUP variant was criticized as infeasible for the same reasons as the CUP alternative, although it would have involved fewer CUPs. To the extent the perceived error is a failure to proceed in a manner required by law for failing to discuss a variation of the CUP alternative in the EIR, County considered and discussed a range of reasonable alternatives, as required. County was not required to discuss each proposed variation of a project alternative in the EIR. *Mira Mar Mobile Community v. City of Oceanside (2004) 119 Cal.App.4th 477, 491.*

County's findings and decision to reject the CUP alternative, including the CUP alternative variation, are supported by substantial evidence. There was no failure to proceed in a manner required by law. There was no prejudicial abuse of discretion.

Environmentally Inferior

County determined the "[CUP alternative] is ultimately environmentally inferior to the proposed Project." County found the "mitigation program...established by the Project would provide mitigation at levels in excess of that which would occur if new wells were subject to discretionary approval following individual environmental review, and "[i]n this sense, the Project is environmentally superior to [the CUP alternative] and will better serve regional conservation priorities...."

Substantial evidence shows the project mitigation measures were developed using "worst-case scenarios" and conservative assumptions. The mitigation is applied, including site-specific mitigation, whether or not the new project activity, e.g., new well, actually causes an impact. Petitioner may be correct that case-by-case analysis of each new well under a discretionary approval process, if reasonably practicable, might result in more tailored mitigation for particular wells. Petitioner might be wrong. Substantial evidence supports the determination, however, that subjecting all new wells to the project's mitigation measures over many years will produce environmentally superior results. County's judgment regarding the relative environmental merit of the project compared to the CUP alternative was informed by substantial evidence. There was no failure to proceed in a manner required by law. There was no prejudicial abuse of discretion.

2. Agricultural Impacts

Farmland Conversion / "Footprint"

Petitioner argues the EIR underestimated farmland conversion by considering only the infrastructure "footprint." The EIR determined that the project's incremental contribution to the conversion of farmland to non-agricultural uses would be cumulatively considerable. The EIR's analysis of project-related farmland conversion was not limited to infrastructure "footprint." Substantial evidence supports the determination that, of the

total farmland acreage in the project area (828,973 acres), the project will impact ("disturb") 298 acres (.04%) per year, or a total of approximately 7,450 acres between 2015 and 2040, less than 1% of total farmland acreage. The EIR's "disturbance factors," the methodology used to achieve them, the scope of the analysis, and determinations regarding farmland conversion are supported by substantial evidence. There was no failure to proceed in a manner required by law. There was no prejudicial abuse of discretion.

Clustering

Petitioner argues that it and others proposed a mitigation requirement that oil and gas infrastructure be "clustered" on farmland to minimize ground disturbance, and that County "completely ignored the proposal." Commenters asserted that the DEIR "must identify mitigation measures requiring oil and gas facilities to be clustered together, instead of being spread out across contiguous parcels of land" or "a farm." Petitioner's attorneys commented that the mitigation measures in the DEIR "fail[ed] to adequately remedy land use conflicts between oil and gas and agricultural operations," and "there are no measures that require wells and facilities to be clustered to avoid unnecessary disruptions of agricultural activities." Petitioner asserts that general plan policies require industrial uses to be clustered.

An EIR must adequately respond to specific suggestions for mitigating a significant environmental impact unless the suggested mitigation is facially infeasible. *Guideline § 15088; Los Angeles Unified School Dist. v. City of Los Angeles (1997) 58 Cal.App.4th 1019, 1029.* Clustering oil and gas facilities would not appear to be facially infeasible. Also, some of County's responses to comments regarding clustering directed commenters to responses that did not exist. In other responses and analyses, however, County directly and indirectly responded to comments on clustering.

County considered a range of reasonable alternatives to the project, including Alternative 3, the reduced ground disturbance alternative, which would limit the disturbance footprint on existing agricultural lands by requiring clustering of new wells in locations immediately adjacent to existing oil and gas equipment. Alternative 3 was adequately analyzed, and rejected. In other responses to comments regarding clustering, County: noted that for more than a century, there has been co-location of oil and gas operations with agricultural operations, including on split estate lands, with "little evidence of problems and conflicts;" referred to Global Response 4, [discussing legal rights of surface and mineral owners on "split estates," the origin of those rights, e.g., laws, regulations, leases and other agreements between oil and gas operators and surface landowners that may affect surface use, and the legal dominance of the mineral estate over the surface estate vis-à-vis use of the surface to extract minerals]; discussed general plan policies that promote clustering industrial uses, and "numerous and more specific policies" regarding oil and gas activities that do not require clustering uses, noting that the project ordinance balances these competing interests; discussed ordinance provisions requiring

notice to surface owners regarding oil and gas site plans and the surface owner signoff process, creating incentive for cooperation between mineral owners and surface owners.

The information provided in direct response to the comments on clustering mitigation could have been better structured, but County was responding to a number of comments, and the information provided was reasonably adequate for informational and decision-making purposes. The responses were supported by substantial evidence. There was no failure to proceed in a manner required by law There was no prejudicial abuse of discretion.

Rangeland

Petitioner argues that the EIR fails to include a determination regarding the significance of project impacts on rangeland. The DEIR's description of the environmental setting shows that Kern County encompasses 8,202 square miles, which includes approximately 2,317 square miles of rangeland. The total project area consists of approximately 3,700 square miles in the western part of the county, which includes 982,166 acres (approximately 1,535 square miles) designated as rangeland. The EIR discloses that over the 25-year life of the project, 832 acres of "uncultivated" land (which includes dairy farms, grazing land, and other agricultural production not dependent on cultivated land) out of the total 982,166 acres of rangeland in the project area, could be converted due to the project. The EIR also discloses that the Kern County General Plan projects a net loss of 55,000 acres of grazing land based on land use conversions consistent with existing land use plans, which are unrelated to the project. Petitioner points out that this statistical information does not address the significance of the rangeland conversion due to the project. Petitioner is correct.

An EIR must include a statement of "[a]ll significant effects on the environment of the proposed project," *Pub. Res. Code § 21100(b)(1)*, or alternatively, a "statement briefly indicating the reasons for determining that various effects on the environment of a project are not significant and consequently have not been discussed in detail in the environmental impact report" *Pub. Res. Code § 21100(c); Guideline § 15128. See also, Protect the Historic Amador Waterways v. Amador Water Agency (2004) 116 Cal.App.4th 1099, 1110-1111.* There appears to be no such statement in the project EIR.

County properly utilized Appendix "G" to determine the significance of impacts on agricultural resources, and real party argues that "agricultural" land as defined in Appendix "G" does not include rangeland. That conclusion, however, does not relieve County of its obligation to analyze significant impacts. The use "NOTE" at the top of Appendix "G" states, "Substantial evidence of potential impacts that are not listed on this form must also be considered." It is thus necessary in appropriate circumstances to modify or augment the checklist to ensure that all potentially significant impacts are adequately addressed. *See, Protect the Historic Amador Waterways v. Amador Water Agency, supra, 116 Cal.App.4th 1099, 1110-1111; 1 Kostka & Zischke, "Practice Under the Calif. Environmental*

Quality Act" (2d ed.) § 13.15.

The EIR's omission of a discussion regarding the significance of the project's impact on rangeland, or a statement briefly indicating the reason for determining that the project's impact on rangeland is not significant and consequently has not been discussed, amounts to a failure to proceed in a manner required by law, and a prejudicial abuse of discretion.

Mitigation Measure 4.2-1: Non-existent Programs and 1:1 Ratio

Petitioner argues that the EIR's determination mitigation measure ("MM") 4.2-1 would reduce the impact of farmland conversion to a level of less than significant is not supported by substantial evidence. MM 4.2-1 sets forth a performance standard requiring agricultural land mitigation at a ratio of 1:1, using one or more of several specified measures. It does not contain "numerous loopholes," and it does not rely on "nonexistent" preservation programs for its effectiveness. The impact being mitigated is the temporary loss of agricultural production caused by project-related activities. The applicant must demonstrate compliance with the 1:1 mitigation requirement through one or more specified measures prior to ground disturbance. The fact that County has not yet adopted an agricultural farmland mitigation bank or equivalent agricultural preservation or mitigation program, does not change the 1:1 mitigation requirement or limit the effectiveness of the mitigation measure through other specified options.

County identified and evaluated the potentially significant impact, and identified measures to mitigate that impact. County was not required to commit to a particular measure in the EIR as long as it committed to effectively mitigating the impact. *Guideline § 15127.4; North Coast Rivers Alliance v. Marin Municipal Water Dist. Bd. of Dir. (2013) 216 Cal.App.4th 614, 629-630; San Joaquin Raptor Rescue Center v. City of Merced (2007) 149 Cal.App.4th 645, 671.* The mitigation is not limited to a maximum acreage based on estimated land conversion. Specific mitigation acreage for each project activity will be based on a 1:1 ratio and determined at the time the project-related activities occur. This is an appropriate level of mitigation. *Masonite Corp. v. City of Mendocino (2013) 218 Cal.App.4th 230, 236-238.* County committed itself to mitigation through specified alternative measures over the 25-year life of the project.

Substantial evidence supports County's determination that MM 4.2-1 will reduce the related project impact to a level of less than significant. There was no failure to proceed in a manner required by law, and there was no prejudicial abuse of discretion.

3. Water Supply

Localized Impacts

Petitioner argues the EIR's analysis of water supply obscured the project's local impacts and lacked sufficient detail. The EIR water supply assessment described current

and projected water demands, surface and ground water sources, and water usage by sector in wet, single-dry and multiple-dry years, separately analyzing the defined "subareas" within the project area and their distinct characteristics. The water supply assessments utilized public reports and management plans from water districts and agencies, including quantitative data from each subarea, describing specific groundwater aquifers in the project area and the hydrological properties of aquifers in each subarea. The final water supply assessment projected urban water demand by water district, supply *and demand projections by subarea, and surpluses and deficits within subareas. Produced* water re-use was projected for each subarea. The EIR disclosed that oil and gas production currently generates, and will continue to generate, sufficient quantities of "produced" water to satisfy more than 90% of project-related water demands over the project's life, which does not take away from, or compete with, water usage/demand by other sectors.

The EIR disclosed that project M&I quality water demand is currently 8,778 AF annually, and will increase to an estimated 11,760 AF in 2040. The project M&I demand is compared to annual agricultural demand of 2,630,029 AF, and average annual urban demand of 301,736 AF. The EIR did not merely compare project M&I use to the total project area M&I demand. In the final water supply assessment, project M&I use was compared to agricultural, urban, and recycled "produced" water use, separately, for each subarea, in normal, single-dry and multiple-dry years. The EIR determined that project M&I demand would contribute to overdraft conditions in an existing water shortage, disclosed the water supply impacts, and mitigation measures were adopted.

A more detailed analysis that included more specific water supply impacts in particular locations, or to individual farmers, was not required. The EIR represents a good faith effort at full disclosure, and was reasonably adequate to inform decision-makers and the public of the project's water supply impacts. Substantial evidence supports the EIR's methodology, scope of analysis, and determinations regarding water supply impacts. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

Impacts on Other Water Users

Petitioner argues the EIR lacks sufficient information about the project's impacts on other water users. Petitioner argues the EIR does not evaluate whether lowered groundwater levels could affect water wells near oil and gas development, does not mention that water shortages can result in abandoned crops and idled agricultural lands, and does not disclose the extent of water rationing that water agencies would impose on users as a result of projected water shortages.

Substantial evidence shows that total oil industry M&I water use will be 0.4% of projected agricultural use from 2015-2035. It would be speculative to assume such a small percentage would cause water rationing for farmers, particularly when agricultural

demand, and localized agricultural supply and demand, is influenced by so many factors. Based on existing water constraints in the project area, the EIR determined the project would continue to create existing, as well as projected future, increases in water demand, and there are no feasible mitigation measures available to reduce such impacts to a less than significant level. The EIR determined that implementation of MM 4.17-2, MM 4.17-3, and MM 4.17-4 could reduce water supply impacts, "but the allocation of water supplies and water demands, the complex laws affecting water rights, the many water districts that have legal jurisdiction over one or more sources of water in the Project Area, the varied technical feasibility of treating produced water, and the produced water reuse opportunities all present complex variables that fall outside the scope of the County's jurisdiction or control under CEQA." The EIR concluded the project's impacts to water supplies would be significant and unavoidable, and mitigation measures were adopted. Substantial evidence supports the EIR's methodology, scope of analysis, and determinations, and the EIR was adequate as an informational document. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

Drought Conditions

Petitioner argues the EIR should have been updated to account for the "historic" drought. Drought conditions were adequately addressed in the water supply assessments and EIR, using best available historical data. In its findings regarding project impacts, County determined the project would not have a sufficient M&I water supplies to serve project demand from existing entitlements and resources, or new or expanded entitlements would be required. County explained:

> With respect to the Project's demand for M&I water, however, current drought conditions have severely restricted the availability of imported and local surface supplies throughout California, including the Project Area, and groundwater is being used more heavily to meet Project Area demand, including for oil and gas activities. Surplus M&I-quality water is not available in the Project Area. Any new use reduces the availability of M&I-quality water to another Project Area user, or increases the regional groundwater overdraft if supply shortfalls are addressed by increased groundwater extraction. Consequently, existing entitlements and resources are insufficient to meet current and projected future M&I water demand in the Project Area. Increasing water demand under overdraft conditions is considered to be a significant impact.

Updating the EIR to provide more recent drought information was not required. The EIR was sufficiently informative. Substantial evidence supports the EIR's methodology, scope of analysis, and determinations. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

Consistency with General Plan Water Supply Policies

Petitioner argues the project is inconsistent with General Plan policy # 41, and Metro Bakersfield General Plan # 3, requiring an adequate water supply for "development proposals." County determined that the project was consistent with these policies, and made the necessary findings. The policies are not implementation measures, distinguishing them from the specific implementation measure involved in *Spring Valley Lake Assn. v. City of Victorville (2016) 248 Cal.App.4th 91. See generally, Friends of Lagoon Valley v. City of Vacaville (2007) 154 Cal.App.4th 807, 817* [distinguishing guiding policies from implementing policies.]

Also, in the context of County's general plan policies, County could properly view the project is an "energy project proposal," not a "development proposal" as that designation is used in General Plan policy # 41, and Metro Bakersfield General Plan # 3. The EIR considered and discussed the policies. County's energy policies encourage orderly energy development, and protect oil and gas resources, as well as water resources. County's determinations of consistency are entitled to deference, and were reasonable. Petitioner's interpretation of the policies is not reasonable, and would effectively impose a moratorium on all County land use permitting because any impact on water supply by any source would be significant. Substantial evidence supports County's determinations regarding consistency with the general plan policies. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

4. Noise

Petitioner argues the EIR's noise analysis violates CEQA because: (1) the EIR fails to disclose the project's impacts on ambient noise levels, and (2) the EIR fails to mitigate those significant impacts.

Ambient Noise Impact:

Petitioner argues the EIR fails to disclose significant noise impacts by concluding that all increases to ambient noise levels are insignificant if they occur under 65 dB. Petitioner argues, in essence, that the EIR misapplies the thresholds of significance stated in the EIR.

The EIR identified three significance thresholds to evaluate noise impacts from the project. The first threshold evaluated noise impacts based on standards in applicable general plans, which the EIR determined was 65 dB DNL (day/night average sound level). The second threshold evaluated whether the project would create a "substantial temporary or periodic increase" in ambient noise levels. The third threshold evaluated whether the project would create a "substantial permanent increase" in ambient noise levels.[1]

[1] The parties' briefs and the AR are not entirely consistent regarding the order in which the significance thresholds for noise are listed. The DEIR (AR 2002) listed the threshold for

County explained in response to comments:

> The second threshold applies to project construction, and addresses whether the proposed project would create a "substantial temporary or periodic increase in ambient noise levels in the project vicinity above levels existing without the project." The third threshold applies to project operation, and addresses whether the proposed project would create a "substantial *permanent increase in ambient noise levels in the project vicinity above levels existing without the project.*" While these two thresholds *qualitatively* assess temporary or permanent increases over ambient noise without the project, the lead agency – Kern County – maintains discretion to determine the *quantitative* threshold applicable to each project. For this project, the *County applied a quantitative threshold of 65 dB DNL/CNEL*, which represents the exterior noise levels the County has deemed to be acceptable for noise sensitive areas. . . Where a project would exceed 65 dB DNL/CNEL, noise mitigation measures would be required. (Emphasis added.)

Petitioner argues that County's application of the significance thresholds ignores noise increases from existing levels that occur *under* 65 dB. Petitioner argues that County's approach "simply writes the third threshold out of existence." Petitioner cites no authority to suggest that if an EIR has two thresholds of significance, those thresholds may not overlap, or arrive at the same result, or use the same numerical metric, evaluating an impact.

County's "quantitative" measure (65 dB DNL/CNEL) to determine whether an increase in ambient noise was "substantial" is supported by substantial evidence. County's noise study included ambient noise measurements from multiple locations in each of the subareas, with the results expressed using several discreet metrics, including "DNL/CNEL." Substantial evidence explains how noise is measured, the existing noise environment in the project area, how the noise study was conducted in the subareas, the

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"substantial *permanent* increase" (associated with operations) before "substantial *temporary* or periodic increase" (associated with construction). The responses to comments refer to temporary increases as the "second" threshold and "permanent" increases as the "third" threshold, which appears to be consistent with the parties' briefs. This ruling will refer to permanent increases as the "third" threshold to remain consistent with the briefs. The text of the DEIR (AR 2002), however, stated that a "project would normally be considered to have a significant impact if it would result in:

- Exposure of persons to, or generate, noise levels in excess of standards established in the local general plan or noise ordinance or applicable standards of other agencies;

* * * * *

- A substantial permanent increase in ambient noise levels in the project vicinity above levels existing without the project;
- A substantial temporary or periodic increase in ambient noise levels in the project vicinity above levels existing without the project[.]" (Emphasis added.)

results of the study, and applicable regulations. Part of this discussion included: OSHA's noise exposure limit for workers (90 dBA over an 8-hour work shift); California State Dept. of Health "acceptable" noise level for land use compatibility (60 dBA DNL/CNEL); Kern County General Plan limit in noise sensitive areas (65 dBA DNL); Metro Bakersfield General Plan limit (65 dB CNEL). The EIR's noise study expert stated:

> The Noise Element of the Kern County General Plan establishes a land use compatibility criterion of 65 dB DNL for exterior noise levels in outdoor activity areas of residential uses. Additionally, *the 65 dB DNL exterior noise level criterion is commonly applied throughout incorporated areas of Kern County, and therefore should be used to determine project compliance in most instances.* (Emphasis added.)

The record provides substantial evidence to support County's use of "65 dB DNL/CNEL" as a quantitative measure for determining whether an increase in noise was "substantial." County acted within its discretion to make that determination, and was not compelled by CEQA, case law, or experts to do otherwise.

CEQA does not define what constitutes a "substantial" increase in noise. Petitioner cites *Berkeley Keep Jets Over the Bay Committee v. Board of Port Commissioners ("Berkeley Keep Jets") (2001) 91 Cal.App.4th 1344*, a case that demonstrates the fact-dependent nature of the court's evaluation of an EIR's noise impact analysis. In *Berkeley Keep Jets*, the Port Commissioners evaluated an airport expansion, but failed to select an additional significance threshold, beyond the 24-hour weighted average ("CNEL"), to determine if 27,000 additional flights annually—approx. 73/day, mostly at night—would have a significant effect on sleep in neighborhoods. Applying a 65 CNEL average, the Port Commissioners essentially found there would be little or no significant noise impacts from the additional flights. Many people objected. The court in *Berkeley Keep Jets* held the EIR was deficient for failing to specifically evaluate the impact of the increased flights. *Id. at p. 1382.* The court's analysis emphasized the unique circumstance of "the effect on sleep patterns from a proposed increase in overnight flights over noise-sensitive residential areas." *Id. at p. 1379.*

The present case does not involve thousands of additional nighttime flights over noise-sensitive residential areas. Averages are capable of "watering down" or obscuring important facts. That obviously occurred in *Berkeley Keep Jets.* But it did not occur here. The EIR provided more than just the DNL/CNEL weighted average. County's determination to use the 65 dB DNL/CNEL value to assess what increases were "substantial" from a standpoint of land use compatibility was within County's discretion, informed by substantial evidence. County explained why it used its general plan standard to define "substantial." See, *National Parks & Conservation Assn. v. City of Riverside (1999) 71 Cal.App.4th 1341, 1353* [upholding use of 65 dB as noise threshold]; *Oakland Heritage Alliance v. City of Oakland (2011) 195 Cal.App.4th 884, 896* [agency discretion to rely on

adopted standards]. County was not required to accept petitioner's suggestion that *any* "5 dB increase" be deemed "substantial."

County's determination to use 65 dB DNL to define what was "substantial" within the meaning of its stated noise significance threshold is supported substantial evidence. County acted within its discretion to select a quantitative measure. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

Noise Mitigation:

Petitioner argues the noise mitigation violated CEQA because "significant increases" in noise levels below 65 dB were not addressed in the EIR, and thus, not mitigated. The EIR determined that noise impacts would be significant, but would be reduced to a level of less than significant after mitigation. In light of this court's ruling above, and in light of the record, substantial evidence supports County's determination that noise impacts would be less than significant after mitigation. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

5. Recirculation of EIR - Revised Health Risk Assessment

Petitioner argues the EIR should have been recirculated after it had been revised to include an analysis of cumulative health risks from multiple wells in the same area. The DEIR included a health risk assessment ("HRA"). In response to comments by SJVAPCD, the HRA was revised. In response to comments that the first 2 HRAs did not address the combined effects of multiple wells, County prepared a third HRA. KGF argues the third HRA should have been recirculated for comments.

Real parties' contention that the multiple-well HRA was not a "cumulative impact" analysis within the meaning of CEQA is incorrect. "Cumulative impacts" refers to two or more individual *effects* which, when considered together, are considerable or which compound or increase other environmental impacts. *Guideline § 15355.* The "individual effects may be *changes resulting from a single project* or a number of separate projects." (Emphasis added.) *Guideline § 15355(a).*

However, County determined based on substantial evidence that the cumulative HRA confirmed conclusions reached earlier. Those conclusions were presented for review and comment, and petitioner commented on the cumulative HRA. The cumulative HRA presented no significant new information; it amplified an earlier conclusion. The record does not show that the draft EIR was so "fundamentally and basically inadequate and conclusory in nature that public comment on the draft was in effect meaningless." *Center for Biological Diversity v. California Dept. of Forestry and Fire Protection (2014) 197 Cal.App.4th 931, 949.* The decision not to recirculate the EIR is supported by substantial evidence. There was no prejudicial abuse of discretion.

Arvin Petitioners' Issues

1. "Ministerial" v. "Discretionary" Permits

Arvin Petitioners assert a "facial challenge" to the project ordinance. They argue the permit approval process is "inherently discretionary" because "many of the 88 mitigation measures ask the County to make subjective, discretionary decisions...." Arvin Petitioners' complaint seeks a declaratory judgment determining that the project ordinance "[d]oes not, within the meaning of CEQA, establish a ministerial, non-discretionary permitting scheme...." In their opening brief, Arvin Petitioners ask for a declaratory judgment that the "Ordinance's permitting scheme is discretionary, not ministerial, and does not exempt approval of future oil and gas activities from CEQA review." There is no challenge to a particular permit decision or approval.

The project ordinance establishes "Conformity Review" and "Minor Activity Review" permits in designated tier areas. "Conformity Review" permits are generally applicable to major oil and gas development activities, and "Minor Activity Review" permits are applicable to less intensive activities such as replacing tanks and pipelines. County has determined that the permits are ministerial. Applicants for either permit must demonstrate compliance with specified mandatory mitigation measures.

County's determinations regarding the ministerial nature of the permits and the permit approval process are supported by substantial evidence. There was no failure to proceed in a manner required by law. There was no prejudicial abuse of discretion. Declaratory relief is not warranted or appropriate, for several reasons.

First, County's legislative decision to establish a ministerial permit process, and its characterization of the permits as "ministerial," are entitled to deference. CEQA exempts ministerial permits from CEQA review. *Pub. Res. Code § 21080(b)(1).* CEQA Guidelines state, "The determination of what is 'ministerial' can most appropriately be made by the particular public agency involved based upon its analysis of its own laws...." *Guidelines § 15268(a).* Public agencies are urged to make a determination, in advance, what projects, actions and permits are ministerial. *Guidelines §§ 15022(a)(1)(B), 15268(c); Sierra Club v. Napa County Bd. of Supervisors (2012) 205 Cal.App.4th 162, 178.*

Second, the declaratory judgment Arvin Petitioners seek would effectively rewrite the project ordinance and create a new discretionary permitting system that County does not intend. When an agency's determination, finding, or decision does not comply with CEQA, Pub. Res Code § 21168.9 *requires* the court (i.e., "shall") to enter an order that "*includes*" one or more specified "mandates" to the agency, but only those "necessary to achieve [CEQA]compliance." Thus, while the equitable remedy of declaratory relief is expressly *not* precluded by section 21168.9, see *Pub. Res Code § 21168.9(c)*, such relief would seem to have limited value in the present case given the mandates required by section 21168.9. If the court determined that a particular mitigation measure gave County discretion, the

mandate necessary to achieve CEQA compliance might not require re-characterizing all permits issued under the ordinance as discretionary. The court cannot ignore County's determination, based on substantial evidence, that discretionary review of 2,000 plus permits per year is infeasible, or County's legislative judgment that ministerial permits are the most appropriate way to transition from "by-right" oil and gas development, to permits.

Third, just as declaratory relief is not available to review CEQA decisions subject to Pub. Res. Code § 21168, declaratory relief does not appear to be available in this ordinary ("traditional") mandamus proceeding governed by Pub. Res. Code § 21168.5. Judicial review of CEQA decisions that are subject to Pub. Res. Code § 21168 ("adjudicative" decisions) must be brought as administrative mandamus proceedings under CCP § 1094.5, and "[a] party...may not challenge an agency action that is reviewable under section 1094.5 by seeking *declaratory* or injunctive relief, either instead of or in addition to relief by administrative mandamus." *2 Kostka and Zischke, Practice Under the California Environmental Quality Act (2nd ed. 2017), § 23.59.* (Emphasis added.) Adoption of an ordinance is a "legislative" act to which Pub. Res. Code § 21168.5 applies, and related CEQA determinations are reviewed by ordinary mandamus under Code Civ. Proc. § 1085. *Western States Petroleum Assn. v. Superior Court (1995) 9 Cal.4th 559, 566; Friends of Sierra Madre v. City of Sierra Madre (2001) 21 Cal.4th 165, 172 fn.2.*

> An ordinary mandamus proceeding under CCP section 1085 is the method for reviewing a CEQA decision governed by Pub Res C section 21168.5. (Citation omitted). The same limitations on the scope of judicial review that apply in CEQA cases reviewed under CCP section 1094.5 apply in most CEQA cases reviewed under CCP section 1085....*The rule prohibiting other forms of review should apply in those cases as well.* (Emphasis added.) *2, Kostka and Zischke, Practice Under the California Environmental Quality Act (2nd ed. 2017), § 23.59.*

Fourth, the subject mitigation measures are not "inherently discretionary." They contain objective standards, or require compliance with existing regulations, or defer to discretionary decisions of other agencies, all of which confirm the essential "ministerial" nature of the implementation standards and conditions, including the mitigation measures. *See, Guidelines § 15126.4(a)(1)(B); Citizens for a Sustainable Treasure Island v. City and County of San Francisco (2014) 227 Cal.App.4th 1036, 1059; North Coast Rivers Alliance v. Marin Municipal Water Dist. Bd. of Dir. (2013) 216 Cal.App.4th 614, 629-631; Oakland Heritage Alliance v. City of Oakland (2011) 195 Cal.App.4th 884, 906-907; Health First v. March Joint Powers Authority (2009) 174 Cal.App.4th 1135, 1142-1145.* The permit process requires County to determine whether a proposed activity *conforms* to specified standards. County is not given discretion to "shape" the repairs to, or development of, oil or gas wells. Neither the substance of the mitigation measures nor the permit approval process is discretionary to any substantial degree, thus distinguishing the present case from the circumstances involved in *Friends of Westwood, Inc. v. City of Los Angeles ("Westwood")*

(1987) 191 Cal.App.3d 259, and *Natural Resource Defense Council, Inc. v. Arcata Nat. Corp. ("NRDC/Arcata") (1976) 59 Cal.App.3d 959.*

Fifth, Arvin Petitioners have not shown in their facial challenge that "no set of circumstances exists under which the [ordinance] would be valid." See, *Sierra Club v. Napa County Bd. of Supervisors (2012) 205 Cal.App.4th 162, 173.* Arvin Petitioners do not challenge a particular permit, such as the challenges involved in *Westwood, supra, 191 Cal.App.3d 259*, and *NRDC/Arcata, supra, 59 Cal.App.3d 959. Westwood* and *NRDC/Arcata* both emphasize the fact-specific nature of determining whether an act is ministerial or discretionary under CEQA, and *Westwood* carefully avoids finding that the entire regulatory process was discretionary, or that the exercise of *any* discretion renders a particular permit decision discretionary. *Id. at p. 280.* The breadth of possible activities subject to the permit requirement make it very difficult, if not impossible, to know, over time, and in every situation, which mitigation measures will actually apply to a given application, or *how* the measure will be applied. Some activities *may* involve all of the mitigation measures with predictability, while others may not. The parties' briefs pose and analyze hypothetical scenarios, and there are no doubt many scenarios that *could* be envisioned where there is less predictability about the mitigation measures. It is conceivable the mitigation measures with which Arvin Petitioners are concerned will not apply to a particular project activity.

2. Spanish Language Translation.

Arvin Petitioners argue that County unlawfully denied Spanish-speaking residents meaningful participation in the CEQA process.

Neither CEQA nor the CEQA Guidelines require translation or interpretation in the manner suggested by Arvin Petitioners. No reported case has concluded that CEQA requires lead agencies to translate documents or provide interpreters. Public Res. Code § 8 requires CEQA notices, reports, statements and records to be made "in writing in the English language." Pub. Res. Code § 21083.1 precludes courts from interpreting CEQA or the Guidelines "in a manner which imposes procedural or substantive requirements beyond those explicitly stated in [CEQA] or in the [Guidelines]."

The issue in *San Franciscans for Reasonable Growth v. City and County of San Francisco (1987) 193 Cal.App.3d 1544* ("*San Franciscans*"), cited by Arvin Petitioners, was the *comprehensibility* of an EIR. An EIR "must be written and presented in such a way that its message can be understood by . . . members of the public who have reason to be concerned with the impacts which the document studies." *Id. at p. 1549.* CEQA Guidelines contain specific "plain language" requirements. Public Res. Code § 8 contains a specific English-language requirement. The plain meaning of Public Res. Code § 8 is not limited to publication of notices. The statutory language is not ambiguous: "[A]ny notice, report, statement or record [] required by [CEQA] . . . shall be made in writing in the English language." An EIR is a "report" within the meaning of section 8.

Arvin Petitioners argue that Public Res. Code § 8 "does not mean . . . documents governed by [the Public Resources Code] may be published only in English." The issue is whether translation was required, not whether it was *permitted*. Petitioners cite examples in the Public Resources Code where translation is specifically addressed, but these examples demonstrate how clear the Legislature can be when it imposes a translation requirement, e.g., *Pub. Res. Code § 3465* [oil sellers to post recycling signs in languages other than English under specified circumstances]; *Pub. Res. Code § 30315.5* [Coastal Commission "shall" make meeting notices available "in both English and Spanish"]; *Pub. Res. Code § 71113* [environmental working group to provide "guidance for determining when it is appropriate . . . to translate crucial public documents, notices, and hearings . . . for limited-English-speaking populations" by April 2002].

Imposing or implying a requirement to translate and interpret in the manner suggested by Arvin Petitioners would impermissibly add new procedural and substantive requirements that are not explicitly required by CEQA. There was no prejudicial abuse of discretion. Respondent County did not fail to proceed in a manner required by law. Arvin Petitioners have not shown by a preponderance of the evidence, or by the weight of the evidence, that "meaningful participation" was denied. No prejudicial abuse of discretion has been shown.

3. Water Supply Mitigation Measures

Arvin Petitioners argue that MM 4.17-2, MM 4.17-3 and MM 4.17-4 unlawfully defer formulation of mitigation. They argue the EIR defers mitigation to future groundwater plans that will not be completed until years after project approval, while failing to commit the County to measures that will satisfy specific performance criteria articulated at the time of project approval. They argue the Sustainable Groundwater Management Act ("SGMA"), and the 30,000 AF re-use goal for produced water are not sufficiently specific performance criteria under CEQA.

County did not unlawfully defer mitigation in violation of CEQA. County was not precluded from adopting measures that might not be effective in mitigating water supply impacts that County determined were "significant and unavoidable." County approved the project, adopting a statement of overriding economic and other considerations, and acknowledged uncertainty regarding the effectiveness of MM 4.17-2, MM 4.17-3 and MM 4.17-4. That was sufficient. See, *Gray v. County of Madera (2008) 167 Cal.App.4th 1099, 1119 ("*County could have approved the Project even if the Project would cause significant and unavoidable impacts on water despite proposed mitigation measures if the County had adopted a Statement of Overriding Considerations that made such findings," but failed to do so.*); see also, Citizens for Open Government v. City of Lodi (2012) 205 Cal.App.4th 296, 332; 1 Kostka and Zischke, Practice Under the California Environmental Quality Act (2nd ed. 2017), § 14.9.*

Substantial evidence supports County's determination the water supply impacts were significant and unavoidable, the uncertainty regarding the effectiveness of the mitigation measures, and County's statement of overriding considerations approving the project. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

4. Air Quality

Arvin Petitioners argue the EIR inadequately analyzed and inadequately mitigated the project's air quality impacts, in that: (1) MM 4.3-8 violates the CEQA requirement that a project activity not be undertaken without mitigation measures in place; (2) the EIR fails to adequately mitigate PM 2.5 emissions; and (3) the EIR fails to assess the environmental impacts of road paving as mitigation.

MM4.3-8 - Deferral

The EIR discloses the project will cause significant air quality impacts, and mitigation measures were adopted. Among those measures, MM 4.3-8 requires an emission reduction agreement ("ERA") between County and the SJVAPCD whereby County will collect mitigation fees that the SJVAPCD will use for emission reduction projects, or, *alternatively, the applicant may conduct its own emission reduction projects approved by* SJVAPCD.

The legal principles governing deferral of the formulation of mitigation are discussed in *POET, LLC v. California Air Resources Board ("POET") (2013) 218 Cal.App.4th 681, at p. 738:*

> [W]e glean two principles that are important to this case. First, the deferral of the formulation of mitigation measures requires the agency to commit itself to *specific performance criteria* for evaluating the efficacy of the measures implemented. Second, the "activity" constituting the CEQA project may not be undertaken without mitigation measures being in place "to minimize any significant adverse effect on the environment of the activity." (Citation) In other words, the deferral relates only to the *formulation* of mitigation measures, not the mitigation itself. Once the project reaches the point where activity will have a significant adverse effect on the environment, the mitigation measures must be in place.

A project's contribution to an impact is less than cumulatively considerable if the project is required to implement or fund its fair share of a mitigation measure or measures designed to alleviate the cumulative impact. *Guidelines § 15130(a)(3).* CEQA allows a project to mitigate by paying a fee to fund its fair share of a measure designed to mitigate that project's cumulative impact, so long as the funding contributions are part of a reasonable plan of actual mitigation that the responsible agency commits itself to

implementing. See, *Gray v. County of Madera (2008) 167 Cal.App.4t 1099, 1121-1122; Anderson First Coalition v. City of Anderson (2005) 130 Cal.App.4th 1173, 1187; 1 Kostka and Zischke, Practice Under the California Environmental Quality Act (2nd ed. 2017), § 14.14.*

Substantial evidence shows that MM 4.3-8 is one of five measures adopted to reduce emissions to a performance standard of "no net increase." Substantial evidence shows there are a variety of available emission reduction programs that could be completed with fee proceeds which satisfy CEQA requirements for fee-based mitigation, notwithstanding opinions to the contrary. Substantial evidence shows there is a history of funding such emission reduction programs within Kern County and the SJVAPCD. It is presumed that County will comply with its own ordinance and will spend the fees it collects for the required air quality mitigation purposes. *Save Our Peninsula Comm'n v. Monterey County Bd. of Sup. (2001) 87 Cal.App.4th 99, 140-141.* If a fee program is not available, MM 4.3-8 allows the project applicant to undertake its own emission reduction program, verified by SJVAPCD. Substantial evidence shows that if an applicant does not comply with MM 4.3-8, no permit will issue.

The formulation of mitigation under MM4.3-8 was not improperly deferred. Substantial evidence shows that MM 4.3-8 satisfies the requirements for fee-based mitigation, and supports County's determinations regarding MM 4.3-8. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

PM 2.5 Emissions

Arvin Petitioners argue that only respirable particulate matter (PM 10) emissions are mentioned in MM 4.3-8,[2] and that the absence of specific mitigation for fine particulate matter (PM 2.5) in MM 4.3-8 means the EIR's determination the project will "fully offset" emissions is not supported by substantial evidence. The EIR determines the project will make a cumulatively significant contribution of criteria pollutant emissions (NOx, PM 10, PM 2.5, CO and SO2), for which the project region is in nonattainment under applicable federal and state air quality standards. The draft EIR discloses that PM 2.5 was treated as a subset of PM 10. Five measures (MMs 4.3-1 through 4.3-4, and 4.3-8) were implemented

[2] MM 4.3-8 states, in relevant part:

> For Project facilities or equipment that are not required to offset emissions under a District rule as described in MM 4.3-1, and for Project vehicle and other mobile source emissions, the County will enter into emission reduction agreement with the San Joaquin Valley Air Pollution Control District, pursuant to which the Applicant shall pay fees to fully offset Project emissions of oxides of nitrogen, reactive organic gases, and particulate matter of 10 microns or less in diameter (including as applicable mitigating for reactive organic gases by additive reductions of particulate matter of 10 microns or less in diameter) (collectively, "designated criteria emissions") to avoid any net increase in these pollutants.... (Emphasis added)

to mitigate the project's contribution to criteria emissions. The EIR determined that even with implementation of the mitigation measures, the impacts will remain significant and unavoidable.

Substantial shows the air quality mitigation measures are designed to work together to mitigate project emissions, each measure achieving a portion of the required emissions mitigation. MM 4.3-8 requires an emission reduction agreement "[f]or Project facilities or equipment that are not required to offset emissions under a District rule as described in MM 4.3-1, and for Project vehicle and other mobile source emissions." Substantial evidence shows the EIR's "no net increase" standard for NOx, ROG and PM 10 is based on SJVAPCD policy, which can result, and historically has resulted, in direct and indirect reductions of PM 2.5 when viewed as a subset or component of PM 10. PM 2.5 represents approximately 35% of the total estimated particulate matter emissions from the project (PM 2.5 and PM 2.5-10). Substantial evidence shows that NOx generates PM 2.5 through chemical reactions in the atmosphere, that MM 4.3-8 emission reduction agreement programs for diesel vehicles and equipment will reduce PM 2.5 more than PM 10 emissions, and that NOx emission reductions are part of the SJVAPCD's strategy for reducing PM 2.5. Substantial evidence supports the determination that all feasible and reasonable changes or alterations have been required in, or incorporated into, the project that substantially reduce the potentially significant effects of PM 2.5 identified in the EIR.

The EIR does not fail to adequately mitigate PM 2.5 emissions. There may have been some lack of clarity regarding PM 2.5 in the EIR, but absolute perfection is not required. The EIR is adequate as an informational document, and substantial evidence supports the EIR's determinations, as stated, regarding MM 4.3-8. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

Road Paving:

Arvin Petitioners argue the EIR fails to assess the environmental impacts of road paving as mitigation. Arvin Petitioners are correct.

Impacts of mitigation measures must be discussed in the EIR if such measures "would cause one or more significant effects in addition to those that would be caused by the project as proposed." *Guidelines § 15126.4 (a)(1)(D)).* County argues that MM 4.3-8 requires payment of a per-well mitigation fee and that *potential* emission reduction projects, such as road paving, are examples and not commitments concerning mitigation.

As Arvin Petitioners correctly observe, "[I]t is far from speculative that road paving will be proposed and approved."

County adopted a resolution committing County to implementing measures aimed at reducing PM 10 emissions, including road paving. The project applicant requested recognition of paving as an emission reduction measure. The SJVAPCD repeatedly cites

road paving as a pollution reduction option. In the realm of what is merely possible, County's argument might have merit. In the realm of what reasonable decision-makers and informed citizens would have understood from reading the EIR, road paving was and is a reasonably likely air quality mitigation measure under MM 4.3-8. Road paving impacts should have been addressed in the EIR.

County failed to proceed in a manner required by law, and there was a prejudicial abuse of discretion.

5. Biological Resources

Arvin Petitioners argue that: (1) the EIR fails to adequately analyze impacts to special-status species;[3] (2) the EIR's analysis of impacts to habitat adjacent to worksites is inadequate; (3) the EIR unlawfully defers mitigation of impacts to species; and (4) the EIR fails to ensure adequate mitigation of harm to species' habitats.

Analysis of Impacts to Special-Status Species

CEQA guidelines do not compel use of a particular methodology for assessing impacts to special-status species. See, *Save Round Valley Alliance v. County of Inyo (2007) 157 Cal.App.4th 1437, 1468.* CEQA Guideline § 15065 describes the circumstances under which a lead agency "shall find that a project may have a significant effect on the environment *and thereby require an EIR...*" It is a preliminary step, not a mandatory methodology or significance threshold. CEQA Guideline § 15151 states:

> An EIR should be prepared with a sufficient degree of analysis to provide decisionmakers with information which enables them to make a decision which intelligently takes account of environmental consequences. An evaluation of the environmental effects of a proposed project need not be exhaustive, but the sufficiency of an EIR is to be reviewed in the light of what is reasonably feasible. Disagreement among experts does not make an EIR inadequate, but the EIR should summarize the main points of disagreement among the experts. The courts have looked not for perfection but for adequacy, completeness, and a good faith effort at full disclosure.

The EIR divided species into three 3 categories for analysis. Category 1 species included plants and animals known or likely to occur in the project area, and for which one of four types of habitat modeling data was available and used to quantify and analyze potential impacts by subarea and tier. Potential habitat, by tier and subarea, was modeled for nine Category 1 plant species and 28 animal species identified in the project area. Project impacts to high quality and low-to-moderate quality habitat for each Category 1

[3] Arvin Petitioners use the term "sensitive species." The EIR and County use the term "special-status species."

species were estimated. The EIR analysis of habitat impacts to Category 1 species allowed quantification of impacts without knowing the actual occurrence of a species at a particular place, focusing on the importance of habitat to a species rather than occupation levels "that tend to change over time."

Category 2 included species known or likely to occur in the project area but for which no modeling data was available. Impacts to Category 2 species were evaluated by identifying the subarea and tiers where those species could occur and by considering the level of potential new disturbance in each location. The EIR identified 31 Category 2 special-status plant species and 19 special-status animal species, summarized the likelihood of habitat occurrence by species, and analyzed the species on the basis of species-specific occurrence information. This analysis included an assessment of which species could occur in each subarea and tier, and identified key habitat requirements or constraints that could affect the spatial distribution of special-status species.

The EIR's impact analyses for Category 1 and Category 2 species were based on several assumptions: that all new wells will occur on undisturbed land, when that is likely not the case; "potential" land disturbance to poor quality habitat was deemed a potential impact for Category 1 species; the occurrence was considered possible for Category 2 species even if there were only limited historical observations or an extremely low likelihood of species activity in a tier or subarea. The EIR discussed the potential level of habitat modification for each Category 1 species, and assessed the likelihood of occurrence of habitat for every Category 2 species. Potential impacts to modeled special status species were characterized in terms of annual impacts to all identified habitat categories for each species analyzed within the project area, which included urbanized, agricultural, or high-density oil and gas production areas where predicted habitat values have been reduced or eliminated. Potential impacts to non-modeled special status species were analyzed, assuming that impacts would occur even in areas where there was an extremely low likelihood of species impact.

Category 3 included "potentially occurring" species. Category 3 species were identified through literature review, database searches, or by local experts as "potentially occurring" in the vicinity of the project area, and for which suitable habitat is present. Based on the evaluation by County's biologist, a total of 53 plants and 24 wildlife species were included in Category 3 and not further analyzed in the EIR, because they either did not occur in the project area, or had the potential to occur in the project area but lacked official status. The determination that species were Category 3 species if they were absent from the project area was based on a reasonable screening analysis, followed by a biologist's review to determine those warranting further study. Species were screened from further consideration when: no records for a species were found in the project area and suitable habitat was not present or not expected; species occurrence in the project area was migratory or transient, with little or no chance of impact from project activities; and occurrence data for species within project area was found to be erroneous. "Watch list" species were included in Category 3 unless review of their distribution and status indicated

that the portion of the species' distribution within the project area warranted further consideration of impacts. Appendix "N" of the EIR identified and discussed all Category 3 species excluded from further analysis based on County's biologist's review. No Category 3 species were excluded from Category 3 analysis. Category 3 species are part of the project-related preconstruction surveys. All applicable mitigation applies to Category 3 species.

Detailed findings were made regarding each Category 1 and Category 2 species. The EIR determined that without mitigation, the project had the potential to cause substantial adverse effects, either directly or through habitat modification, on identified special-status species. The methodology and scope of analyses for impacts to plant and wildlife special-status species were adequate, complete and a good faith effort at full disclosure. Site-specific or further analysis was not required. See, *Save Round Valley Alliance v. County of Inyo, supra, 157 Cal.App.4th 1437, 1468; Center for Biological Diversity v. Dept. of Fish & Wildlife (2015) 234 Cal.App.4th 214, 234.*

The EIR adequately analyzed impacts to special-status species and mitigated where required. The EIR's methodology, scope of analysis, and determinations regarding impacts to special-status species are supported by substantial evidence. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

Habitat Adjacent to Worksites–Edge Effects

The EIR discusses affected species, their habitat needs and distribution across the *entire project area, existing efforts to conserve species and protect habitat*, and the harmful effects of habitat fragmentation. Potential impacts to plant and wildlife species outside the construction or operations "footprint" are described. Both quantitative and qualitative approaches were utilized. The EIR discussed research specific to the area to analyze impacts, including local studies, that showed wildlife's ability to move across an active oil field was less impeded than with agricultural and urban lands, even where the oil field was moderately developed.

Mitigation measures to avoid or minimize impacts to species both at, and outside of, the development site were discussed and incorporated, including preconstruction surveys that must extend a specified distance beyond the ground disturbance, distance requirements in species-specific survey protocols where adjacent landowner approval is obtained, species-specific setbacks from occupied nests, burrows and other sensitive locales, and setbacks of up to one-half mile from certain active nests. The EIR was not required to quantify the acreage for "edge effects," and represents an adequate, complete and good faith effort at full disclosure.

The EIR specifically and adequately analyzed impacts to habitat outside the "footprint" of project-related development, including in the impact analysis and the formulation of mitigation measures. The EIR's methodology and scope of analysis regarding habitat

adjacent to worksites is supported by substantial evidence. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

MM 4.4-1 – Deferral of Mitigation

The EIR determined that impacts to special-status species were potentially significant, and mitigation measures were identified. MM 4.4-1[4] is part of a comprehensive mitigation plan expressed in fifteen separate measures to which County is committed, and which contain sufficiently specific performance criteria for valid mitigation under CEQA. County stated in response to comments, "When considered as a whole, the mitigation measures for biological resources comprise a comprehensive approach that emphasizes avoidance of impacts and mitigation of the remaining impacts through conservation of species and habitats in a manner that has the greatest likelihood of success."

MM 4.4-1 requires a biological reconnaissance survey to advise on potential project impacts, potential surveying needs, and the need for focused special status surveys. Focused/protocol surveys are conducted to "confirm the presence or absence" of sensitive species and to identify and implement "feasible avoidance and minimization measures for such species." In addition to MM 4.4-1, there are 14 other mandatory measures with which the applicant must comply, and which County considered in determining that impacts *would be mitigated to less than significant. Pre-disturbance surveys are required by* Mitigation Measures 4.4-1 (special status wildlife), 4.4-5 (bats), 4.4-8 (golden eagle nests), 4.4-10 (active birds' nests), 4.4-11 (blunt-nosed leopard lizard), 4.4-12 (protected and sensitive plant species), and 4.4-17 (sensitive natural communities, including waters and wetlands). The mitigation measures specify that surveys must be completed by qualified biologists in accordance with approved protocols. Surveys must be conducted at times that *will provide relevant information regarding the presence of sensitive species at the site.*

MM 4.4-1 is distinguishable from the mitigation measure expressing a "generalized goal" involved in *San Joaquin Raptor Rescue Center v. City of Merced (2007) 149 Cal.App.4th 645, 670.* The reconnaissance surveys required by MM 4.4-1 are part of a series of mandatory measures that work together to impose specific avoidance measures, prohibit the wrongful take of protected species, and require specific mitigation ratios where habitat disturbance is unavoidable. The decision in *Gentry v. City of Murrieta (1995) 36*

[4] MM 4.4-1 states in relevant part: "A qualified biologist shall conduct a biological reconnaissance survey to potential special-status species habitat to advise the project proponent of potential project impacts, potential surveying needs, and advise on the need for focused special status surveys...Based on the information gathered from the biological reconnaissance survey and any informal consultation with United States Fish and Wildlife Service and California Department of Fish and Wildlife, focused/protocol surveys shall be conducted by a qualified or permitted biologist (whichever is applicable) well in advance of ground disturbing activities to determine the presence/absence of sensitive species protected by state and federal Endangered Species Acts and potential project impacts to those species..."

Cal.App.4th 1359, is similarly distinguishable because *Gentry* held the city was required to further analyze mitigation measures to support a negative declaration, applying the "fair argument" standard. *Gentry* stated, however, that, "a condition could validly allow for deferred mitigation, provided other mitigation measures were clearly adequate..." *Gentry, supra, 36 Cal.App.4th at p. 1396*. The mitigation measures, of which MM 4.4-1 forms a part, contain adequate performance criteria.

MM 4.4-1 does not unlawfully defer mitigation of impacts. Substantial evidence supports County's determination that impacts to biological resources will be less than significant after mitigation. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

MM 4.4-16 - Mitigation of Harm to Habitats

Arvin Petitioners argue that MM 4.4-16[5] fails because it does not require that habitat be replaced with habitat of the equivalent type or quality. Arvin Petitioners cite *Preserve Wild Santee v. City of Santee (2012) 210 Cal.App.4th 260*. In *Santee*, which involved the Quino butterfly, the court stated at page 281:

> The absence of standards or guidelines in the EIR for active management of the Quino within the preserve is problematic because the draft habitat plan indicates vegetation management is the key consideration for the Quino's conservation and the City will not be utilizing prescribed burns or grazing in the preserve, the only two methods of vegetation management the draft habitat plan identifies. In addition, the timing and specific details for implementing other Quino management activities discussed in the draft habitat plan are subject to the discretion of the preserve manager based on prevailing environmental conditions. *Consequently, these activities are not guaranteed to occur at any particular time or in any particular manner.* (Emphasis added.)

[5] *MM 4.4-16 states in relevant part: "Ground disturbance shall be mitigated at a 1.0 to 1.0 ratio (one-acre of new disturbance shall require one-acre of mitigation) except in Tier 1 areas that contain existing disturbance of 70% or greater which shall be mitigated at a 1.0 to 0.5 ratio (one-acre of new disturbance shall require one-half acre of mitigation), for the land included in the Site Plan...New disturbance mitigation may be satisfied by one or a combination of the following measures: a. The recordation of a conservation easement or similar permanent, long-term conservation management agreement...b. Acquisition of land preservation credits from a mitigation bank... c. Removal of legacy oil and gas equipment...complete a reseeding effort using native species...d. Enhancement or restoration of existing habitat on lands already subject to a conservation easement or similar agreement, or which become subject to a conservation easement or similar agreement subsequent to the certification of this Environmental Impact Report...e. Payment of a biological resources mitigation fee for the acquisition and management of mitigation lands, legacy equipment removal, and/or land enhancement..."*

Santee does not hold that compensatory habitat must be of the same quality or nature as the habitat destroyed. *Santee* held that the mitigation was deficient because it lacked specific performance criteria regarding vegetation management.

The EIR's evaluation and determination of significance regarding biological resources was based on six separately-stated criteria. Habitat modification, alone, was not identified as a significant impact; replacement of habitat, alone, was not identified as adequate mitigation. County relied on multiple, complementary measures to mitigate impacts, and the entire "suite of measures" constitutes substantial evidence supporting the County's findings. Arvin Petitioners have not shown that the EIR's measures, acting together, will not mitigate the impacts to less than significant.

MM 4.4-16 is part of a comprehensive mitigation plan that adequately ensures mitigation of harm to species' habitats. The EIR's determinations are supported by substantial evidence. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

6. GHG Emissions

Mitigation – MM 4.7-4

County determined that GHG emissions from the project would be potentially significant, and implemented four mitigation measures to reduce impacts to less than significant. The first three measures rely on regulations to mitigate impacts. For emissions not captured by the first three measures, MM 4.7-4[6] applies and requires each applicant to reduce emissions to "no net increase" in one of three ways: (1) applicant reduction of GHG emissions verified by County; (2) acquisition of offset credits; or (3) inclusion in an emission reduction agreement ("ERA"). County determined the project's GHG impacts after mitigation would be less than significant, and determined the project's cumulative GHG impacts would be significant and unavoidable.

Arvin Petitioners argue there is no substantial evidence of the effectiveness of GHG mitigation through offset purchases. Arvin Petitioners specifically argue there is no substantial evidence: (1) that GHG offset programs exist, or that credits are available from

[6] MM 4.7-4 states: "Each Applicant shall offset all greenhouse gas emissions not covered by the Cap-and-Trade program or other mandatory greenhouse gas emission reduction measures through Applicant reductions of greenhouse gas emissions as verified by Kern County, through acquisition of offset credits from the California Air Pollution Control Officers Association Exchange Register or other third party greenhouse gas reductions, with consultation as to the validity of methodology for calculating reductions verified by the San Joaquin Valley Air Pollution Control District and accepted by Kern County, or through inclusion in an Emission Reduction Agreement, to offset Project-related greenhouse gas emissions that are not included in the Cap and Trade program to assure that no net increase in greenhouse gas emissions from the Project." (Emphasis added.)

existing programs; or (2) that offsets will satisfy CEQA's requirement that only GHG reductions "not otherwise required" may be used to offset emissions, i.e., the requirement of "additionality." Regarding ERAs, Arvin Petitioners argue there is no established program to support ERAs for project GHG emissions.

Arvin Petitioners' did not object to the effectiveness of the option under MM 4.7-4 permitting an applicant to directly reduce GHG emissions. That failure renders Arvin Petitioners' substantial evidence challenge to the remaining options academic. There is no reason that direct GHG reductions, verified by County, will not meet the performance standard.

In *San Joaquin Raptor Rescue Center v. County of Merced (2007) 149 Cal.App.4th 645*, the court found a mitigation measure adequate where only one of the two mitigation options available under the measure would be effective. The mitigation measure required mitigation in the form of replacement by either creating wetlands on site, or by offsite purchases of wetland banking credits. There was no wetlands conservation bank in the County, but the court held the mitigation measure was adequate, stating:

> Finally, Petitioners note that in mitigation measure 3.6-2d, if the Project causes loss to functioning and value of vernal pool areas, there must be mitigation in the form of replacement by either creating vernal pools or swales within the conservation area on site, or by off-site purchase of wetland banking credits. Since there are no wetlands conservation banks present in the County of Merced, the latter alternative is unavailable. The FEIR acknowledges this fact, but emphasizes that the other option—i.e., creating new vernal pools in the conservation area onsite—remains a reasonable mitigation measure. And if mitigation credits become available within the watershed, the FEIR further explains, then 'such acquisition would become an additional available measure.' In light of this clarification in the FEIR, petitioners have failed to demonstrate this particular mitigation measure is inadequate or unsubstantiated." *Id. at pp. 671-672.*

Arvin Petitioners' substantial evidence challenge regarding MM 4.7-4 fails on other grounds.

County and real parties in interest argue that during the administrative process, petitioners did not question the availability of offsets or credits, or whether the offsets would satisfy the requirement of GHG reductions "not otherwise required" ("additionality"). Exhaustion of administrative remedies is a jurisdictional prerequisite to maintenance of a CEQA action. *Bakersfield Citizens for Local Control v. City of Bakersfield (2004) 124 Cal.App.4th 1184, 1199.* Arvin Petitioners must show that an objection was made during the administrative process that was sufficiently specific so that County had the opportunity to evaluate and respond. *Citizens for Responsible Equitable Environmental Dev. v. City of San Diego (2011) 196 Cal.App.4th 515, 527.* The petitioners' objections

during the administrative proceeding regarding MM 4.7-4 did not give County the opportunity to evaluate and respond to comments or arguments regarding the availability of offset programs or credits, or the requirement of "additionality." Petitioners failed to exhaust their administrative remedy on those issues.

Nevertheless, substantial evidence supports the EIR's determinations regarding MM 4.7-4. The EIR discloses that the GHG mitigation measures were not intended to individually provide full mitigation for project GHG emissions. The measures were designed as a package, such that mitigating project GHG emissions to a level of "net zero" is achieved by all four of the mitigation measures working in concert. The record shows that lower GHG emission levels through compliance with MM 4.7-1, 4.7-2, and 4.7-3 will require smaller quantities of offsetting emission reductions, but emissions remaining after application of MM 4.7-1, 4.7-2 and 4.7-3 must be offset in accordance with MM 4.7-4. The record shows that at the time of filing an application for conformity review, applicants must specify their expected GHG emissions and identify how those emissions will be mitigated. According to the EIR:

> Emission-reducing measures may include the measures listed by ARB at http://www.arb.ca.gov/cc/non-co2-clearinghouse/non-co2-clearinghouse.htm, but those measures are not required. All reductions will be verified by the County.

In addition to mitigation through direct applicant reductions under MM 4.7-4, the applicant may acquire offset credits through the CAPCOA Exchange or other third party offset programs. Substantial evidence shows that offset programs exist, including Climate Action Reserve, the SoCal Climate Solutions Exchange, CARB-approved Offset Project Registries, and programs outside California. CEQA's "additionality" requirement is adequately addressed in MM 4.7-4. For third party offsets, MM 4.7-4 requires the SJVAPCD to verify, and County to accept, the methodology used to calculate GHG reductions, thus providing the mechanism to ensure that offsets will be reductions "not otherwise required." The court will presume the SJVAPCD and County will properly undertake those responsibilities.

Arvin Petitioners complain that real parties cite "a few passing references to offset programs scattered across an almost random collection of documents." This statement serves to underscore the reason it is necessary to make a sufficiently specific objection during the administrative process. From this court's vantage point, *petitioners* should have brought to this court's attention *all* references to offset programs as part of their "no substantial evidence" argument in the opening brief.

Arvin Petitioners cite *Kings County Farm Bureau v. City of Hanford ("Kings County") (1990) 221 Cal.App.3d 692*, where the appellants challenged an EIR's water impacts analysis that found no significant impact. The project applicant agreed to contribute financially to a water recharge program, but the appellants referred to a memo from the

city public works director stating there was no water available to purchase for a water recharge program. The record did not disclose whether the city relied on the applicant's agreement to help fund the water recharge program in making its "no significant impact" determination. The court stated:

> To the extent the GWF-KCWD agreement was an independent basis for finding no significant impact, the failure to evaluate whether the agreement was feasible and to what extent water would be available for purchase was fatal to a meaningful evaluation by the city council and the public. *Id at p. 728.*

MM 4.7-4's mitigation through direct GHG reduction, verified by County, is not analogous to paying a mitigation fee for a water recharge program where there is no water to buy, or no evidence of it. Moreover, substantial evidence in the present case shows that offset programs exist and that MM 4.7-4 would be effective, unlike the absence of analysis or information in *Kings County*.

MM 4.7-4 specifically refers to the CAPCOA Exchange Register. The EIR refers to emission-reducing measures "listed by ARB at http://www.arb.ca.gov/cc/non-co2-clearinghouse/non-co2-clearinghouse.htm." The administrative record discussed Climate Action Reserve, the SoCal Climate Solutions Exchange, CARB-approved Offset Project Registries and programs outside California.

Substantial evidence supported the effectiveness of offset programs as a method of mitigating GHG impacts. In general, the *effectiveness* of "market-based" solutions such as offsets is embedded in the Global Warming Solutions Act of 2006 ("Act"), and the regulations adopted to achieve that Act's objectives. The legislature specifically authorized the Air Resources Board to adopt regulations which establish market-based compliance mechanisms "in furtherance of achieving the statewide [GHG] emissions limit." *Health & Safety Code §§ 38562(b), 38570(a)* [authorizing regulation for "use of market-based compliance mechanisms to comply with the regulations"]. The Act defines a market-based compliance mechanism, which includes GHG exchanges, banking, credits, and other transactions. *Health & Safety Code § 38505(k).*

More directly, MM 4.7-4 specifically requires the SJVAPCD to validate the methodology for calculating the GHG reductions, and the County to accept it. Decision-makers could reasonably infer from the EIR that MM 4.7-4 would be effective.

County's determinations were supported by substantial evidence. The EIR was adequate as an informational document. There was no failure to proceed in a manner required by law of prejudicial abuse of discretion.

Long-term Impacts

Arvin Petitioners also argue that the EIR failed to adequately disclose and analyze long-term impacts to climate, and specifically, GHG emissions from 2035 through 2050 by: (1) failing to provide "meaningful analysis" of the conflict between the project's "rising emissions over time and the long-term reductions climate scientists and California policymakers deem necessary," including failure to analyze consistency with the Governor's executive order target for 2050; and (2) wrongfully assuming Cap-and-Trade would extend past 2020.

In July 2017, essentially between the second and third days of trial in this case, the California Supreme Court decided *Cleveland National Forest Foundation v. San Diego Association of Governments ("SANGAG") (2017) 3 Cal.5th* 497. The Supreme Court held that the agency considering a regional transportation plan did not abuse its discretion in declining to explicitly analyze the consistency of projected GHG emissions with the statewide GHG goals expressed in executive order. *Id. at p. 517.* The *SANDAG* opinion acknowledged the challenges that agencies face in analyzing GHG emissions in a climate of evolving regulations and science. *Ibid.*

Also in July 2017, AB 398 was passed by the California legislature and signed into law, extending Cap-and-Trade through 2030.

The EIR adequately disclosed and analyzed GHG emissions and long term impacts. The EIR comprehensively analyzed all project-related activities, including all phases of construction and operations. The EIR discussed direct and indirect emissions from all sources. It conservatively assumed for purposes of analysis that more wells would be drilled each year than are authorized under the project ordinance, and provided technical estimates based on the assumption Cap-and-Trade would *end* in 2020. The EIR used mandatory reporting regulation ("MRR") emissions as baseline, even though for some companies MRR-reported emissions include all activities in the San Joaquin Valley, not just the local area. It included these baseline emissions in calculating project emissions. The EIR mitigated the projects GHG emissions to "net zero," which is below the applicable threshold of significance.

The existence and content of the long-term statewide goals expressed in executive order was plainly discussed in the EIR. Nothing was obscured. The EIR included discussion and analysis for informational purposes regarding the project's consistency with the executive orders. County discussed and acknowledged the uncertainty in trying to predict what the oil and gas industry would be required to do in order to achieve statewide 2030 and 2050 targets. The EIR also acknowledged the project's long-term increases in GHG emissions, and discussed project GHG emissions in relation to statewide reduction goals. The EIR estimated the project GHG emissions at full build out in 2035. County determined and disclosed the project's cumulative GHG impacts would be significant and unavoidable. The project was approved based on a statement of overriding considerations.

In addition, County's technical analysis assumed Cap-and Trade would end in 2020 (the law at the time), but at the same time, included mitigation in the EIR based on the continued existence of Cap-and-Trade, as well as measures not covered by Cap-and-Trade. County disclosed its reasons for the EIR's approach, and stated that it believed Cap-and-Trade would "almost certainly" extend beyond 2020. County was correct.

Substantial evidence supports the EIR's determinations regarding GHG thresholds of significance, and Arvin Petitioners clarified in their reply brief that they do *not* contend the EIR should have used different significance thresholds. Substantial evidence supports the EIR's methodology, scope of analysis, and determinations regarding GHG emissions, including County's determination that project-related GHG impacts would be less than significant after mitigation. The EIR was adequate as an informational document. There was no failure to proceed in a manner required by law, and no prejudicial abuse of discretion.

SUPERIOR COURT OF THE STATE OF CALIFORNIA

COUNTY OF KERN

VAQUERO ENERGY, INC., a California corporation; and HUNTER EDISON OIL DEVELOPMENT LIMITED PARTNERSHIP, a California limited partnership; Petitioners and Plaintiffs, vs. COUNTY OF KERN; and KERN COUNTY BOARD OF SUPERVISORS; Respondents and Defendants. CALIFORNIA INDEPENDENT PETROLEUM ASSOCIATION, a California non-profit mutual benefit corporation; INDEPENDENT OIL PRODUCERS' AGENCY, a California corporation; and WESTERN STATES PETROLEUM ASSOCIATION, a California non-profit mutual benefit corporation; Real Parties in Interest.	Case No. BCV-15-101645-EB (Lead case) [Consolidated w/ Case No. BCV-15-101666-EB and Case No. BCV-15-101679-EB] **PEREMPTORY WRIT OF MANDATE**

TO: Respondents COUNTY OF KERN (including its Planning Commission, and Planning and Natural Resources Department) and KERN COUNTY BOARD OF SUPERVISORS (collectively "County"):

The court has entered judgment ordering that a peremptory writ of mandate issue under the seal of the court in the above-referenced consolidated actions [BCV-15-101645-EB (Lead case), consolidated w/ Case Nos. BCV-15-101666-EB and BCV-15-101679-EB] challenging respondent County's decision to approve and adopt Ordinance No. G-8605 and Resolution No. 2015-298, which, together, amended the Kern County Zoning Ordinance governing oil and gas activities (the "Project"), certified the Environmental Impact Report ("EIR") for the Project, and made related findings and determinations. Accordingly,

YOU ARE HEREBY COMMANDED, upon receipt of this writ, to do the following:

1. Within 45 days from service of the this peremptory writ of mandate, County shall transmit to the San Joaquin Valley Air Pollution Control District copies of this peremptory writ of mandate, and the JUDGMENT in Case Nos. BCV-15-101666-EB and BCV-15-101679-EB (the "Judgment"), including a copy of the Ruling attached as Exhibit "A" to said Judgment.

2. Consistent with the Ruling and the procedures set forth in California Environmental Quality Act, Public Resources Code sections 21000 et seq. ("CEQA") and CEQA Guidelines, County shall prepare such analysis as is necessary to address the EIR's deficient analysis of the Project's (i) environmental impacts to rangeland/grazing land, and (ii) environmental impacts from road paving as an air emissions mitigation measure ("Supplemental Analysis"). In the event the Supplemental Analysis determines that any such environmental impacts are potentially significant, the Supplemental Analysis shall identify feasible mitigation measures and/or alternatives to mitigate or avoid such impacts consistent with CEQA's requirements, unless County makes findings of infeasibility and overriding considerations as provided by CEQA.

3. Upon completion of the Supplemental Analysis described in paragraph 2 above, County shall: (a) reconsider its approval of the Project and its Statement of Overriding Considerations adopted in connection with that Project, in light of any new information in the Supplemental Analysis, and (b) take any and all further action that may be necessary to bring the approval of the Project and the related findings and mitigation monitoring and reporting program into compliance with CEQA. County shall file an initial return to this writ not later than 75 days after the service of the writ of mandate, setting forth what it has done to comply with paragraph 1

above. County shall file a supplemental return to the writ of mandate not later than 180 days after the initial return, stating whether it has complied with paragraphs 2 and 3 above, and describing what it has done to do so. County shall thereafter file supplemental returns every 60 days until it has fully complied with paragraphs 2 and 3 above.

4. Nothing in this writ may be construed as an order that County exercise its lawful discretion in a particular way.

5. The court retains jurisdiction in consolidated case nos. BCV-15-101666-EB and BCV-15-101679-EB to ensure compliance with the Judgment, and the writ(s) issued pursuant to the Judgment.

Dated: APR 24 2018



Y. TORRES
CLERK OF THE SUPERIOR COURT

July 2, 2018

Via Email
Lorelei H. Oviatt, AICP, Director
Loreleio@kerncounty.com
Planning@co.kern.ca.us
Kern County Planning and Natural Resources Department
Public Services Building
2700 M Street, Suite 100
Bakersfield, CA 93301-2370

Re: Comments on the Notice of Preparation of a Draft Supplemental Environmental Impact Report for Revisions to the Kern County Zoning Ordinance 2015 C

Dear Ms. Oviatt:

On behalf of the Center for Biological Diversity and its members, I am writing to submit the following comments regarding the scope of the draft Supplemental Environmental Impact Report (SEIR) for Revisions to the Kern County Zoning Ordinance (the Project). Committee for a Better Arvin, Committee for a Better Shafter, Greenfield Walking Group, Center on Race, Poverty & the Environment, Earthjustice, and Sierra Club join these comments.

As we have commented previously, the 2015 Environmental Impact Report (FEIR), which the County offers as a project-level environmental impact report intended to take the place of all environmental review of oil and gas activity in the County for the foreseeable future, is contrary to basic environmental protections and public participation rights. Moreover, substantial, irreversible harm to our air, water, health, and climate will result from these activities. Rather than encourage the expansion of dangerous oil and gas activity through these amendments (written by the industry), the County should begin the transition toward a cleaner, safer, healthier economy.

We also continue to be discouraged by the County's failure to provide notices and hearings regarding the Project in Spanish, the primary language of a substantial portion of Kern County residents who will be disproportionately affected by oil and gas activity. The draft SEIR must be made available in Spanish to provide meaningful notice and disclosure to Spanish-speaking residents.

The Kern County Superior Court ruled that the County violated CEQA by adopting an EIR that did not meet CEQA's requirements in two respects. First, the EIR was deficient due to its inadequate analysis of the impact of decades' worth of oil and gas activity on rangelands. Second, the EIR also failed to analyze the impact of road paving that could be used as mitigation measure. Both of these impacts are potentially significant and require a full and transparent analysis that allows decision-makers and the public to be fully informed about the potential harm that would result from the Project.

I. Impacts to Rangeland

The wholesale approval of thousands of new wells and supporting infrastructure each year for the next 25 years or more will undoubtedly have significant impacts on the 982,166 acres of rangeland within the Project area in Kern County. Consequently, the scope and content of the draft SEIR must address the following impacts:

A. Rangelands will be impacted by soil and water shortages

The oil industry uses a significant amount of surface and groundwater, which will make watering livestock more difficult over the course of the next 25 years.

B. Rangeland will be impacted by water contamination

Ample evidence exists that oil and gas activity in Kern County has resulted in groundwater contamination. Oil spills contaminate soil surrounding well sites. Polluting groundwater as well as soil and making it unusable for rangeland activities will have a significant impact on rangeland.

C. Air/Noise/Light Pollution will impact rangeland

Significant amounts of air, light, and noise pollution from the oil and gas industry are likely to make worksite-adjacent land unsuitable or less productive than other rangelands. The draft SEIR must fully assess and quantify the area of rangelands that will be harmed by various types of oil and gas pollution that travels far from the worksite.

D. The cumulative impacts to Rangeland will be significant

The impact of any loss of rangeland within the project area will be compounded by the loss of rangeland elsewhere in the state. The draft SEIR must fully assess the cumulative impacts of loss of rangeland across the state.

II. Impacts from Road Paving as Mitigation

The Notice of Preparation (Notice) indicates that the County will *not* be analyzing the impacts of road paving as a mitigation measure, based on the County's assertions that the EIR currently does not authorize road paving to mitigate air quality impacts and that any future use of road paving will entail discretionary approvals that will trigger CEQA review. Because road paving has significant, negative environmental impacts and actually worsens air quality—particularly for fine particulate matter air pollution ($PM_{2.5}$)—we support eliminating it as an approved approach to air quality mitigation. (See further discussion *infra.*) However, the Notice includes several incorrect or inadequate statements about road paving that the draft SEIR must address:

- The Notice asserts that there is no need to analyze road paving in the draft SEIR because "[r]oad paving is not an approved air quality mitigation measure in the EIR." To the contrary, Mitigation Measure 4.3-8 includes a non-exclusive list of "example" measures, but provides that specific mitigation decisions ultimately will be addressed by the San Joaquin Valley Air Pollution Control District (Air District) and County pursuant to the Oil and Gas Emissions

Reduction Agreement (OGERA or OG-ERA). (*See* MM 4.3-8; EIR at 7-186.) In turn, the EIR also states that both the County and Air District concur that road paving is "appropriate for inclusion in the OGERA." (FEIR at 7-212.) It is for this reason that the Superior Court concluded that "reasonable decision-makers and informed citizens would have understood from reading the EIR [that] road paving was and is a reasonably likely air quality mitigation measure under MM 4.3-8."

Since the FEIR explicitly states that the County and Air District both regard road paving as "appropriate," despite the FEIR's unlawful failure to analyze the potential impacts of this proposed mitigation approach, the draft SEIR must address the FEIR's discussion at 7-212, and specify that the County no longer recognizes road paving as an appropriate approach to air mitigation unless or until it is subject to review consistent with the requirements of CEQA and the Superior Court's judgment.

- The Notice also asserts that there is no need to analyze road paving in the draft SEIR because the County "confirmed" in a "transmittal letter" to the Air District that road paving will not be allowed unless or until future discretionary decisions are made, subject to CEQA review and public input. Such an informal commitment is wholly inadequate given contrary statements in the FEIR. As noted above, the FEIR—which was certified by the Kern County Board of Supervisors—explicitly recognizes road paving as an "appropriate" approach to mitigating air quality impacts. It therefore is not enough for the County to declare in correspondence with the Air District that road paving is disallowed unless/until future CEQA review is completed. This commitment, which constitutes a departure from the text of the FEIR, must be set forth and adopted in the SEIR, consistent with the Superior Court's judgment.

- The Notice incorrectly states that, under the Project's Mitigation Monitoring and Reporting Program, road paving is merely an option for individual permit applicants. Rather, the FEIR states that both the County and Air District agree that road paving is "appropriate for inclusion in the OG-ERA." (FEIR at 7-212.) "OG-ERA" refers to the overarching "agreement between the Kern County Board of Supervisors and the SJVAPCD Board" to "implement the required mitigation reductions," as distinguished from "an ERA between individual well permittees and the Air District." (FEIR at 4.3-99.) In other words, the OG-ERA not only addresses how the Air District will work with individual permit applicants, but it also authorizes the Air District to spend fees monies collected by the County.

  Consequently, the County's promise that further CEQA review will be required before any approval of "a future applicant request" to undertake road paving wholly fails to address the Air District's separate authority to itself fund and implement road paving under Mitigation Measure 4.3-8. The SEIR therefore must specify that no road paving will be allowed for air quality mitigation whatsoever—whether through the Air District's expenditure of fee monies or undertaken by individual applicants—unless/until CEQA review is completed as required by the Superior Court.

- The Notice's discussion of prospective future CEQA review for road paving is inadequate because it suggests that CEQA review might be conducted at the level of an individual

project applicant's road paving proposal—as opposed to assessing the potential impacts across the breadth of the entire Project (which really is a program). Both for consistency with the underlying FEIR and to comply with CEQA, any future analysis of the potential impacts of road paving must be analyzed it at both the Project-wide and site-specific level. Both levels of analysis are required because, standing alone, an applicant or site-specific analysis might fail to account for cumulative impacts that the FEIR should have addressed but did not.

Separately, the Notice promises that any future CEQA review process for road paving would be "inclusive of public notice and outreach." We agree that the County should and must provide such notice and outreach to comply with CEQA.

If and when the County does assess the impacts of road paving as an air mitigation strategy, it must acknowledge that the impacts are significant and negative. We previously submitted and now reattach an expert report that identifies the potentially significant and counter-productive impacts of road paving, including significant air pollution emissions from road construction and increased traffic. Road paving also poses potentially significant impacts to biological resources, including: mortality during road construction; increased frequency of road kill; spread of invasive plant species; air, water, soil, and noise pollution; soil disturbance and erosion; degradation and fragmentation of habitat; alteration of wildlife movement; and changes in wildlife populations.[1]

In addition to the attached expert report, we provide further elaboration on the following impacts that must be addressed if and when the County undertakes an evaluation of road paving impacts:

A. Creating roads contributes to air pollution

Creating new roads has a direct negative impact on air quality. Vehicle operation does not only create emissions from fossil fuel combustion, it also generates pollutants from "tire wear and re-suspension of particulate matter generated by wheels interaction with road surface and wind erosion."[2] Not only does this happen once, but if the pollutants manage to resettle on the road, every car that goes over will reintroduce old and new particulates to the air. Alternatively, the particulates can be carried long distances through wind and can affect flora and fauna that is not adjacent to the road.[3] These molecules dissipate slowly, and roads are estimated to be the source of at least 20% of all particulates in the air in the US.[4] The impact of creating roads will affect air quality in the surrounding area and it is imperative to understand the cumulative effects across all species to fully understand the impact to the environment.

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[1] Expert Report of Petra Pless (Nov. 9, 2015); see also *Cal. Unions for Reliable Energy v. Mojave Desert Air Quality Management Dist.* (2009) 178 Cal.App.4th 1225, 1235-36, 1245.

[2] Zavala, Miguel et al., Real-world emissions of in-use off-road vehicles in Mexico, 67 Journal of the Air & Waste Management Association 958 (2017).

[3] Forman, Richard T. & Lauren E. Alexander, Roads and Their Major Ecological Effects, 29 Annual Review Ecological System 207 (1998).

[4] Countess, Richard et al., Methodology for Estimating Fugitive Windblown and Mechanically Resuspended Road Dust Emissions Applicable for Regional Air Quality Modeling, Western Regional Air Partnership (2001) *available at*: https://www3.epa.gov/ttn/chief/conference/ei10/fugdust/countess.pdf.

B. Road paving increases runoff

Road runoff can affect ecosystems in three ways: increased drainage and elongated water flow, increased sediment volume, and the facilitated introduction of new potentially dangerous chemicals.[5] These three factors are compounded by the distance water can travel. One study examining road paving impacts found that as much as "11% of land area, 77% of surface water area, 1/3 of the water bodies, and 52% of stream length" may be impacted by road runoff.[6]

Roads are considerably more level and less permeable than the surrounding environment and because water concentrates on the path of least resistance, water concentrates on roads and forms runoff channels which meet up with established water sources.[7] This tends to increase stream discharge rates and affect downstream structures and ecosystems through flooding, increased erosion, and refill rates of lakes and aquifers.[8]

Roads produce sediment through normal wear and tear and this sediment can then be introduced to the environment through wind and water runoff. This sediment is then absorbed into the soil and can lead to changes in the pH and soil chemical structure which can lead to a shift in the natural vegetation. One analysis found that some road-originating elements could be found in the soil up to 200 meters away from the source pavement.[9]

Road runoff can contain chemical pollutants which are not found in nature in such high concentrations. Polycyclic aromatic hydrocarbons (PAHs) that are a classification of chemicals are carcinogenic and can be toxic for the entire biosphere including the bacteria present in soil.[10] These compounds are formed from a variety of sources, including fossil fuel production and combustion. Elevated levels of PAHs are found in areas surrounding roads arising as a product from vehicle emissions[11]. These are not just potentially harmful to bacteria in the soil; they may enter the water supply and can pose a risk to larger wildlife, including humans.

Road runoff must be evaluated as its effects are much larger than the surrounding area and can prove to be detrimental to already threatened species.

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[5] Forman, Richard T. & Lauren E. Alexander, Roads and Their Major Ecological Effects, 29 Annual Review Ecological System 207 (1998).
[6] Regalado, Sean A. & Daniel L. Kelting, Landscape level estimate of lands and waters impacted by road runoff in the Adirondack Park of New York State, 187 Environment Monitoring Assessment 510 (2015).
[7] Montgomery, David R, Road surface drainage, channel initiation, and slope instability, 30 Water Resource Research 1925 (1994).
[8] Forman, Richard T. & Lauren E. Alexander, Roads and Their Major Ecological Effects, 29 Annual Review Ecological System 207 (1998).
[9] Santelmann, Mary V. & Eville Gorham, The influence of airborne road dust on the chemistry of Sphagnum mosses, 76 Journal of Ecology 1219 (1988).
[10] Azah, Edmund et al., Source of polycyclic aromatic hydrocarbon in roadway and stormwater system maintenance residues, 74 Environmental Earth Science 3029 (2015).
[11] Krein, Andreas & Marcel Schorer, Road runoff pollution by polycyclic aromatic hydrocarbons and its contribution to river sediments, 34 Water Resource Reserves 4110 (2000).

C. Roads act as barriers to animal species and lead to habitat fragmentation

The barrier effect of roads is present in every animal species. From wolf spiders to grizzly bears, many animals avoid roads as much as possible.[12] The possibility of small mammals crossing a small road (6-15 m) was less than 10 percent in one study.[13] This "barrier effect," in which avoidance of a road can create smaller populations within one species over time, leads to small and isolated populations. Habitat fragmentation is particularly dangerous as it places affected species at higher risk for extinction because smaller populations have less genetic diversity and less resilience against threats.[14] This is true across all species even when anatomical size and range distance was taken into account.[15] This effect was shown to be especially harmful when the species already had a small population which means special status species will be impacted disproportionately.[16] It is imperative to the ecosystem when building a new road to understand the species that reside there as well as their migration routes.

D. Roads increase mortality to special status species.

Increasing road networks increase animal mortality rates. Though most animals avoid roads, as outlined above, animals will cross out of necessity, such as for migration, foraging and mating behaviors. Small species face a larger mortality rate; one study found that there was only a 2% survival rate for a turtle trying to cross US27.[17] All special status species may face a more threatened lifestyle, however. One study by the Federal Highway Administration discovered road collisions posed a severe threat to the survival of at least twenty one special status species.[18] This study was made up of a variety of different species, including three amphibians, seven reptiles, three bird species and eight mammals, which shows the range of the affected animals. The risk road collisions pose in some areas are so pronounced that the theoretical prevention of roads being built could save entire populations: 1/3 of the Lower Keys marsh rabbit's mortalities are due to road collisions, with some populations being affected so strongly that the theoretical prevention of roads being paved could have "eliminated the chance of extinction."[19] Big mammals seem to fair no better, with an estimated 44% of deaths of the Canada Lynx being due to road collisions.[20]

Road paving thus poses a significant risk to already vulnerable populations and there must be an emphasis on understanding the effect paving roads has in Kern County and mitigation to keep special status species safe.

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[12] Forman, Richard T. & Lauren E. Alexander, Roads and Their Major Ecological Effects, 29 Annual Review Ecological System 207 (1998).
[13] Forman, Richard et al., Road Ecology: Science and Solutions 122, Island Press (2003).
[14] Haddad, Nick et al., Habitat fragmentation and its lasting impact on Earth's ecosystems, 1 Science Advances 1 (2015) *available at*: http://advances.sciencemag.org/content/advances/1/2/e1500052.full.pdf.
[15] Crooks, Kevin R. et al., Quantification of habitat fragmentation reveals extinction risk in terrestrial mammals, 114 PNAS 7635 (2017) *available at:* http://www.pnas.org/content/pnas/114/29/7635.full.pdf.
[16] Ibid.
[17] Aresco, Matthew J., Highway mortality of turtles and other herpetofauna at Lake Jackson, Florida, USA, and the efficacy of a temporary fence/culvert system to reduce roadkills, U.C Davis: Road Ecology Center (2003).
[18] FHWA, Wildlife-Vehicle Collision Reduction Study: Report to Congress, U.S. Department of Transportation (2008) *available at*: https://www.fhwa.dot.gov/publications/research/safety/08034/08034.pdf.
[19] Ibid.
[20] Baigas, Phillip E. et al., Using environmental features to model highway crossing behavior of Canada lynx in the Southern Rocky Mountains, 157 Landscape and Urban Planning 200 (2017).

III. Conclusion

The draft SEIR must provide a fair and thorough evaluation of the direct and indirect environmental impacts described above, and in doing so meaningfully respond to and adopt recommendations from the public.

Respectfully submitted,



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Joined by: Committee for a Better Arvin, Committee for a Better Shafter, Greenfield Walking Group, Center on Race, Poverty and the Environment, Sierra Club, and Earthjustice

IV. References

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https://www3.epa.gov/ttn/chief/conference/ei10/fugdust/countess.pdf

Crooks, Kevin R. et al., Quantification of habitat fragmentation reveals extinction risk in terrestrial mammals, 114 PNAS 7635 (2017) available at:
http://www.pnas.org/content/pnas/114/29/7635.full.pdf

Desert Air Quality Management Dist. (2009) 178 Cal.App.4th 1225, 1235-36, 1245.
Expert Report of Petra Pless (Nov. 9, 2015); see also Cal. Unions for Reliable Energy v. Mojave

Federal Highway Administration, Wildlife-Vehicle Collision Reduction Study: Report to Congress, U.S. Department of Transportation (2008) available at:
https://www.fhwa.dot.gov/publications/research/safety/08034/08034.pdf

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Montgomery, David R, Road surface drainage, channel initiation, and slope instability, 30 Water Resource Research 1925 (1994)

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November 9 2015

Via Email

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Re: Review of Final Environmental Impact Report for Revisions to the Kern County Zoning Ordinance – 2015(C), Focused on Oil and Gas Local Permitting, SCH# 2013081079

Dear Mr. Rostov,

Per your request, I reviewed the Final Environmental Impact Report ("Final EIR") for Revisions to the Kern County Zoning Ordinance – 2015(C) ("Project") released by Kern County Planning and Community Development Department ("County") as the lead agency under the California Environmental Quality Act ("CEQA").[1] As requested, my review focuses on particulate matter emissions ("PM") generated during construction of Project components and the mitigation measures proposed to reduce significant impacts.

I. The Final EIR Fails to Support Emission Estimates and Underestimates Criteria Pollutant Emissions from Project Construction

As discussed below, the Final EIR presents unsupported revised emission estimates which are based on incorrect methodology and fails to estimate emissions from all sources.

A. The Final EIR's Emission Estimates for Project Construction Are Not Supported

The Final EIR provides revised emission estimates for criteria pollutants emitted during construction and operation of new permitted facility equipment (boilers,

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[1] Kern County Planning and Community Development Department, Final Environmental Impact Report for Revisions to the Kern County Zoning Ordinance – 2015(C), Focused on Oil and Gas Local Permitting, November 2015, SCH# 2013081079; http://pcd.kerndsa.com/planning/environmental-documents/421-oil-gas-Draft EIR.

cogeneration, process heaters, internal combustion engines, steam generators, thermally enhanced oil recovery systems, and volatile organic compounds destruction devices (flares), permit exempt equipment (*e.g.*, pressure vessels and piping components) and small production settings, and wells.[2] The Final EIR provides no support for these revised estimates but simply states that the errors in the Draft EIR's emission estimates "were confirmed by the County's experts and SJVAPCD staff" and consist of the following:

> i) in the DEIR, permitted stationary equipment and permitted stationary source emissions are increased by 10% in order to account for the emissions from small oil and gas operators not subject to Title V permit requirements. The 10% factor was incorrectly applied in certain spreadsheets, leading to an overestimate of the forecast of additional equipment needed for the 2035 project build-out; and ii) The number of active wells per year is calculated as the number of new wells drilled, plus the number of wells reworked and placed in service, minus the number of abandoned wells. The number of abandoned wells in the Eastern Subarea was incorrectly applied in the DEIR. [3]

Thus, with the exception of these errors, it can be assumed that the methodology used to derive emissions remains the same as that used for the Draft EIR. Review of the modeling files and Excel spreadsheets provided by the County shows that the methodology contains errors.

For example, for construction of *new permitted facility equipment*, the Draft EIR calculates annual emissions of particulate matter equal to or smaller than 10 micrometers and 2.5 micrometers ("PM10" and "PM2.5") of 572 tons/year and 509 tons/year[4], respectively, based on total emissions over the 21-year Project period (2015-2035) of 12,007 tons and 10,689 tons, respectively.[5] In contrast, review of the Vector Environmental spreadsheets shows that total PM10 and PM2.5 emissions from construction of new permitted facility equipment were estimated at 12,893 tons and 11,479 tons, respectively, as shown in the screenshot below.

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[2] Final EIR, Tables 4.3-12, 4.3-13, 4.3-14, 4,3-15, 4.3-20, 4.3-27, 4.3-28, 4.3-29, 4.3-30, 4.3-31, and 4.3-32, pp. 7-192 through 7-211.

[3] Final EIR, p. 7-190.

[4] Draft EIR, Appx. I, Table AQ-7 Facility Construction, and Draft EIR, Table 4.3-12.

[5] Draft EIR, Table 4.3-13.

Kern County - Baseline Equipment and Projected Build-Out to 2035

2.1 Overall Construction

Unmitigated Construction

Total Kern County	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total
Source Category	tons/yr					
Boiler	2.5	76.6	79.0	0.9	70.6	71.5
Cogeneration	42.8	843.1	885.4	14.1	777.2	790.6
Process Heater	15.0	293.2	307.9	4.9	270.3	275.0
IC Engine (RICE)	57.8	1,229.7	1,286.6	19.3	1,133.6	1,152.3
Steam Generators	218.9	3,502.3	3,718.9	69.4	3,228.4	3,294.8
Production Tanks	312.1	5,844.7	6,153.2	101.7	5,387.6	5,484.5
VOCDD (Flare)	24.9	437.1	461.7	8.0	402.9	410.6
	673.9	12,226.8	12,892.7	218.3	11,270.4	11,479.3

From: "CALEEMOD KCEIR - report SUMMARY226.xlsx," spreadsheet "Summary"

The Vector Environmental emission estimates were derived based on CalEEMod modeling results in tons/year and multiplying them by the number of equipment or systems and a 20-year Project period.[6] Thus, the Draft EIR – and by extension the Final EIR – errs twice: 1) by relying on lower total PM10 and PM2.5 emissions than estimated by Vector Environmental and 2) by dividing total emissions by a 21-year Project period rather than a 20-year Project period. Based on the Vector Environmental spreadsheet, construction of new permitted facility equipment, would result in annual PM10 and PM2.5 emissions of 645 tons/year and 574 tons/year, respectively.[7] Thus, the Draft EIR – and by extension the Final EIR – substantially underestimates PM10 and PM2.5 emissions. (The calculation of all other criteria pollutant emissions, *i.e.*, reactive organic compounds ("ROG"), nitrogen oxides ("NOx"), carbon monoxide ("CO"), and sulfur dioxide ("SO_2"), are affected in the same way.)

B. The Final EIR Fails to Quantify Criteria Pollutant Emissions from All Sources

The Final EIR fails to account for emissions from all sources, specifically, indirect emissions from electricity generation and windblown fugitive dust particulate matter emissions.

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[6] For example, the Vector Environmental workbook "CALEEMOD KCEIR - report SUMMARY226.xlsx," spreadsheet "Summary," calculates total emissions from process heaters in the Central Zone as "='Construction Central'!I8*20*Summary!$B8," where "Construction Central'!I8" are PM10 emissions for boiler construction in tons/year, 20 is the Project period, and "Summary!$B8" is the number of new equipment or systems.

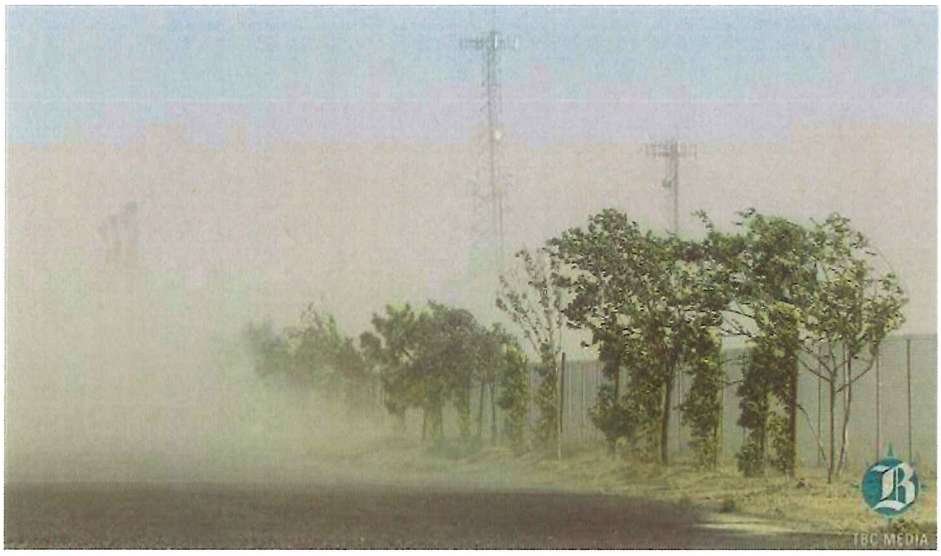
[7] (12,892.7 tons PM10)/(20 years) = **644.6 tons PM10/year**;
(11,479.3 tons PM2.5)/(20 years) = **574.0 tons PM2.5/year.**

1. *Indirect Electricity Generation*

Project construction and operation would use substantial amounts of electricity.[8] The Final EIR fails to quantify indirect emissions of criteria pollutants, including particulate matter, from electricity generation.

2. *Windblown Fugitive Dust*

The Project area experiences frequent high-wind events that can cause substantial emissions of fugitive dust particulate matter, particularly from disturbed surfaces.[9] This is vividly illustrated by a YouTube video of a sandstorm in Inyokern, which shows the comparative impact of these storms on a graded and undisturbed area.[10] The photos below show the effects of typical dust storms in the Project area.



From: Ruth Brown, The Bakersfield Californian, Morning Dust Storm in Kern Delays Traffic, April 30, 2014; http://www.bakersfield.com/news/2014/04/30/morning-dust-storm-in-kern-delays-traffic.html (Exhibit 2)

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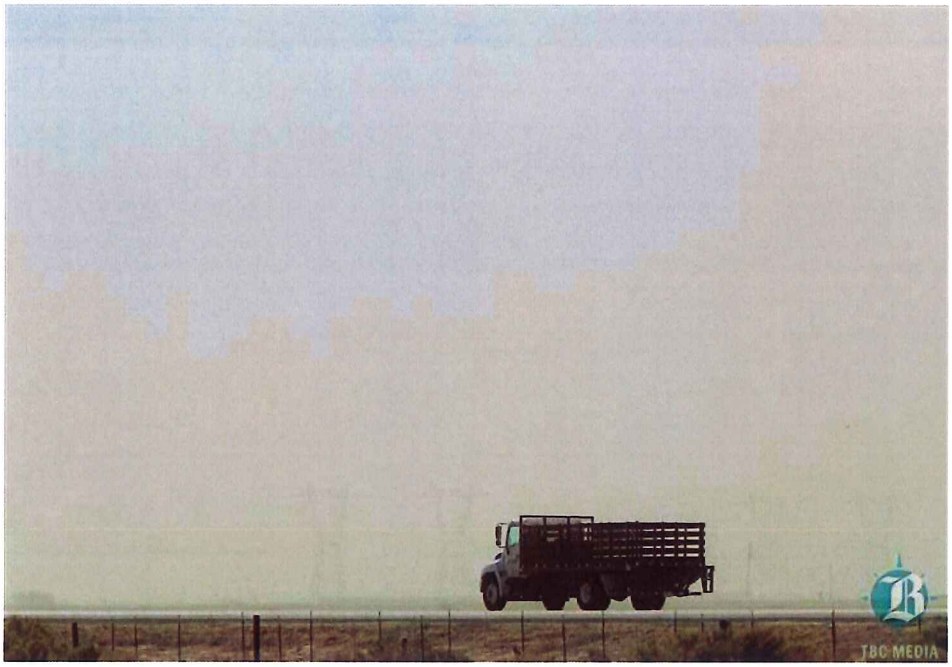
[8] *See* Draft EIR, Table 4.17-23.

[9] Kern County Soil Conservation Committee, Dust Storms, April 1949; http://ucanr.edu/sites/UCCE_LR/files/180706.pdf (Exhibit 1).

[10] 7 Dec 2013 Sandstorm in Inyokern; https://www.youtube.com/watch?v=q-NFAmKHL88; 7 Feb 2014 Dust Storm at Black Mountain Estates, Inyokern, Kern County, CA; https://www.youtube.com/watch?v=yZLv9otHs8k.



The Bakersfield Californian, *op. cit.*

Much of the disturbed area consists of undeveloped land. Grading would increase the surface material available for entrainment and would greatly increase the potential for windblown dust. Wind erosion of the graded surfaces can be expected to be substantial, hindering the progress of the San Joaquin Valley Air Basin ("SJVAB") towards compliance with the federal PM2.5 annual National Ambient Air Quality Standard ("NAAQS").

The CalEEMod model used to estimate Project construction emissions calculates fugitive dust PM10 emissions from material handling, paved roads, and grading, but not from wind erosion of the graded areas:

> Wind-blown fugitive dust is not calculated in CalEEMod because of the number of input parameters required such as soil type, moisture content, wind speed, etc. This limitation could result in underestimated fugitive dust emissions if high wind and loose soil are substantial characteristics for a given land use/construction scenario.[11]

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[11] CalEEMod, Technical Paper, July 2011, p. 4; http://www.aqmd.gov/docs/default-source/caleemod/techpaper.pdf?sfvrsn=2 (Exhibit 3).

Thus, Project construction PM10 and PM2.5 emissions are substantially underestimated and the omitted emissions are not addressed by the Final EIR's proposed mitigation measures. Windblown fugitive dust emissions can be estimated using standard methods, for example, based on methodology developed by Maricopa County Air Quality Department ("MCAQD") in Arizona, another area whose air quality is suffering from the effects of wind erosion.[12]

I estimated emissions of fugitive windblown dust during Project construction based on emission factors for disturbed soil established by MCAQD, the disturbed Project acreage, and information about the amount of time during a year certain wind speeds are exceeded in the area, as shown in Table 1.

Table 1: Fugitive dust PM10 emissions due to wind erosion from disturbed soil

Wind speed bin (mph)	**12-15**	**15-20**	**20-25**	**25-30**	**30-35**	**Total**
Stable soil PM emission factor[a] (ton/acre/5-min)	1.10E-05	2.93E-05	7.68E-05	1.64E-04	3.10E-04	
Disturbed soil PM emission factor[a] (ton/acre/5-min)	5.44E-05	1.69E-04	5.14E-04	1.24E-03	2.57E-03	
Percent of time in wind speed bin[b] (%/year)	11.5%	6.5%	2.0%	0.6%	0.1%	
Count of 3- or 5-minute periods/year in wind speed bin (#/year)[c]	175,200	105,120	105,120	105,120	105,120	
PM10 emissions increase (tons/year)						
350 acres disturbed/151,690 acres stable	3.83	4.18	4.02	2.97	1.04	**16.03**
500 acres disturbed/151,540 acres stable	5.47	5.97	5.74	4.24	1.48	**22.90**
1000 acres disturbed/151,040 acres stable	10.93	11.93	11.49	8.48	2.97	**45.80**
PM2.5 emissions increase (tons/year)[e]						
350 acres disturbed/151,690 acres stable	0.57	0.63	0.60	0.45	0.16	**2.40**
500 acres disturbed/151,540 acres stable	0.82	0.89	0.86	0.64	0.22	**3.44**
1000 acres disturbed/151,040 acres stable	1.64	1.79	1.72	1.27	0.45	**6.87**

a MCAQD, 2008 PM10 Periodic Emissions Inventory, *op. cit.*

b From: Western Regional Climate Center – Desert Research Institute, Wind Speeds for Kettleman Hills, CA, for November 1, 1988 through November 1, 2015; http://www.raws.dri.edu/cgi-bin/rawMAIN.pl?caCKET (Exhibit 5)

c Count of 3- *or* 5-minute periods/year in wind speed bin = (365 days/year) × (24 hours/day) × (60 minutes/hour) / (3 *or* 5)

d PM10 Emissions = {PM10 emissions from stable soil} - {PM10 emissions from disturbed soil} - {PM10 emissions from stable soil for total Project area } = {(stable soil acreage) × (count of 3- *or* 5-minute periods/year in wind speed bin) × (% of time in wind speed bin) × (wind speed bin stable soil PM emission factor) × (PM10/PM: 0.0125)} + {(disturbed soil acreage) × (count of 3- *or* 5-minute periods/year in wind speed bin) × (% of time in wind speed bin) × (wind speed bin disturbed soil PM emission factor) × (PM10/PM: 0.0125)} -

[12] Maricopa County Air Quality Department, 2008 PM10 Periodic Emissions Inventory for the Maricopa County, Arizona, Nonattainment Area, Revised June 2011, Appendix 4. Windblown Dust Emission Estimation Methodology; https://www.maricopa.gov/aq/divisions/planning_analysis/docs/Reports/2008/08_PM10_PEI_Entire.pdf (Exhibit 4).

{(1402 acres) × (count of 3- *or* 5-minute periods/year in wind speed bin) × (% of time in wind speed bin) × (wind speed bin stable soil PM emission factor) × (PM10/PM: 0.0125)}

e PM2.5 emissions increase = PM10 emissions increase × (0.15 PM2.5/PM10 (*see* MCAQD, *op. cit.*, p. A4-21))

Table 1 shows that windblown PM10 emissions from disturbed soil by themselves would exceed the SJVAPCD's 15-tons/year threshold of significance for this pollutant if as few as 350 acres are disturbed throughout the year (16.03 tons/year). Clearly, Project construction would result in much larger disturbed areas throughout much of the 21-year Project period. Thus, the Final EIR substantially underestimates PM10 emissions from Project construction and fails to identify and adequately mitigate a significant impact with respect to PM10 emissions. Windblown fugitive dust would also contribute substantially to emissions of PM2.5.

The Final EIR should be revised to include these emissions, additional mitigation required, and the EIR recirculated for public review.

II. The Final EIR Fails to Require Adequate Mitigation for PM10 and PM2.5 Construction Emissions

The Final EIR recognizes that that construction of *new permitted facility equipment* would generate emissions of PM10 and PM2.5 (as well as ROG, NOx, and CO) in excess of the SJVAPCD's respective significance thresholds for construction. The Final EIR states that construction of these sources would be subject to District Rule 2201, *New and Modified Stationary Source Review Rule*, which would ensure that all emissions would have to be fully offset. Therefore, the Final EIR concludes, there would be no net increase in these emissions.[13] This is incorrect. District Rule 2201, which implements the New Source Review requirements of the federal Clean Air Act ("CAA"), applies to operational emissions from stationary sources; emissions generated during construction of such stationary sources are not covered by the rule.[14] Thus, emissions generated during construction of new permitted facility equipment are significant and remain entirely unmitigated. The Final EIR fails to identify this significant impact.

With respect to *permit exempt equipment, small production settings and wells*, the Final EIR concludes that their construction would exceed the SJVAPCD's significance thresholds[15] and would result in a cumulatively considerable net increase of criteria pollutants for which the Project region is nonattainment and therefore would result in

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[13] Draft EIR, p. 4.3-78.

[14] SJVAPCD, Rule 2201, New and Modified Stationary Source Review Rule, Amended April 21, 2011, Section 2.0: "This rule shall apply to all new stationary sources and all modifications to existing stationary sources which are subject to the District permit requirements and *after construction* emit or may emit one or more affected pollutant." *Emphasis* added; https://www.valleyair.org/rules/currntrules/Rule22010411.pdf (Exhibit 6).

[15] Draft EIR, pp. 4.3-79 and 4.3-82.

significant impacts on air quality.[16] The Final EIR then claims, without any quantitative analysis whatsoever, that implementation of Mitigation Measures MM 4.3-1 through MM 4.3-4 would reduce these impacts to less than significance.[17] This claim is not supported and erroneous.

First, Mitigation Measure MM 4.3-1[18] only addresses emissions from permitted stationary sources and does not address permit exempt equipment, small production settings and wells. Thus, Mitigation Measure 4.3-1 does nothing to reduce significant PM10 and PM2.5 emissions from these sources.

Second, without quantifying the control efficiency and the potential emission reduction of the remaining mitigation measures, MM 4.3-2 through 4.3-4, the Final EIR may not conclude that mitigated emissions would be less than significant.

Third, Mitigation Measure 4.3-2 requires the Applicant to develop and implement a "Fugitive Dust Control Plan" in compliance with SJVAPCD fugitive dust suppression regulations (Rule 8021) and lists 14 specific dust control measures that shall be included.[19] This list does not include all feasible fugitive dust control measures. As the mitigated PM10 and PM2.5 impacts are significant and unavoidable under Impact 4.3-5, all feasible mitigation must be required.

Several agencies have conducted comprehensive studies on fugitive dust control measures to bring their region into compliance with the NAAQS for PM10. For example, the South Coast Air Quality Management District ("SCAQMD") has sponsored research, passed regulations (*e.g.*, Rule 403[20]), and published guidelines that identify best management practices for controlling fugitive dusts at construction sites. The Rule 403 Implementation Handbook[21] contains a comprehensive list of such

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[16] Draft EIR, p. 4.3-82.

[17] Draft EIR, p. 4.3-103, and Final EIR, p. 7-50.

[18] Mitigation Measure MM 4.3-1: "Consistent with the requirements of the San Joaquin Valley Air Pollution Control District Regulation II-Permits, the Applicant shall obtain an Authority to Construct permit and a Permit to Operate for any facility or equipment requiring a permit from the San Joaquin Valley Air Pollution Control District, such as stationary sources required to obtain permits pursuant to District Rule 2010. All emissions increases from permitted equipment shall comply with District Rule 2201."

[19] Draft EIR, pp. 4.3-68 and 4.3-69, and Final EIR pp. 7-49 and 7-50.

[20] SCAQMD, Rule 403 Draft Final Rule 403 Implementation Handbook, April 2004; http://www.capcoa.org/Docs/SCAQMD%20r403%20handbook.doc (Exhibit 7).

[21] SCAQMD, Rule 403, Fugitive Dust, amended June 3, 2005; http://www.aqmd.gov/docs/default-source/rule-book/rule-iv/rule-403.pdf?sfvrsn=4 (Exhibit 8).

measures. The SCAQMD also maintains a list of mitigation measures, including for fugitive dust sources.[22]

Clark County, Nevada, has also sponsored research, passed regulations (Rule 94), and published best management practices for controlling fugitive dust from construction activities.[23] Clark County's *Construction Activities Notebook* contains a comprehensive list of best management practices. Similarly, the Arizona Department of Environmental Quality ("ADEQ") has developed guidance to control fugitive PM10 emissions.[24] Further, additional feasible measures have been developed and required by other air districts for a number of large-scale projects, for example, the Chevron Modernization Project EIR.[25]

Several of the measures included in these agency guidelines and required for other large-scale projects are feasible and much more effective than the 14 mitigation measures proposed by the Final EIR for inclusion in the *Fugitive Dust Control Plan*, which are too generalized to implement and do not require any monitoring to verify. For example, MM 4.3-2(d)(2) requires watering or temporary covering of excavated soil piles to limit dust emissions to less than 20 percent opacity and MM 4.3-2(d)(11) requires suspension of grading when visible dust emissions exceed 20 percent, but none of the measures requires opacity monitoring. Thus, these measures are not enforceable. Further, an on-site construction manager is not required to assure that the proposed measures are implemented. Examples of feasible mitigation measures for construction not required by the Final EIR are listed below:

- For backfilling during earthmoving operations, water backfill material or apply dust palliative to maintain material moisture or to form crust when not actively handling; cover or enclose backfill material when not actively handling; mix backfill soil with water prior to moving; dedicate water truck or large hose to backfilling equipment and apply water as needed; water to form crust on soil immediately following backfilling; and empty loader bucket slowly; minimize drop height from loader bucket. (CCHD)[26] This is

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[22] SCAQMD, Mitigation Measures and Control Efficiencies, Fugitive Dust; http://www.aqmd.gov/home/regulations/ceqa/air-quality-analysis-handbook/mitigation-measures-and-control-efficiencies/fugitive-dust (Exhibits 9a through 9e).

[23] P.M. Fransioli, PM10 Emissions Control Research Sponsored by Clark County, Nevada, Proceedings of the Air &Waste Management Association's 94th Annual Conference & Exhibition, Orlando, FL, June 24-28, 2001.

[24] ADEQ, Air Quality Exceptional and Natural Events Policy PM10 Best Available Control Measures, May 31, 2001; http://www.pima.gov/deq/air/pdf/NEAP/bacmrespsum.PDF (Exhibit 10).

[25] City of Richmond, Chevron Refinery Modernization Project, Final Environmental Impact Report, Chapter 5, Mitigation Measure Monitoring and Reporting Program, June 2014; http://chevronmodernization.com/project-documents/ (Exhibit 11).

[26] The following acronyms are used in this listing of mitigation measures: ADEQ = Arizona Department of Environmental Quality; BCAQMD = Butte County Air Quality Management District; CCHD = Clark

more effective than the Final EIR's measure, which only requires that excavated or graded material will be "sufficiently watered to prevent excessive dust" with watering only occurring "as needed" to limit dust emissions to less than 20% opacity or covered with temporary coverings.[27]

- During clearing and grubbing, prewet surface soils where equipment will be operated; for areas without continuing construction, maintain live perennial vegetation and desert pavement; stabilize surface soil with dust palliative unless immediate construction is to continue; and use water or dust palliative to form crust on soil immediately following clearing/grubbing. (CCHD).
- While clearing forms, use single stage pours where allowed; use water spray to clear forms; use sweeping and water spray to clear forms; use industrial shop vacuum to clear forms; and avoid use of high pressure air to blow soil and debris from the form. (CCHD)
- During cut and fill activities, prewater with sprinklers or wobblers to allow time for penetration; prewater with water trucks or water pulls to allow time for penetration; dig a test hole to depth of cut to determine if soils are moist at depth and continue to prewater if not moist to depth of cut; use water truck/pull to water soils to depth of cut prior to subsequent cuts; and apply water or dust palliative to form crust on soil following fill and compaction. (CCHD)
- For large tracts of disturbed land, prevent access by fencing, ditches, vegetation, berms, or other barrier; install perimeter wind barriers 3 to 5 feet high with low porosity; plant perimeter vegetation early; and for long-term stabilization, stabilize disturbed soil with dust palliative or vegetation or pave or apply surface rock. (CCHD, Chevron) In addition, the Chevron measure requires that the wind breaks be installed on the windward side(s) of actively disturbed area and that wind breaks have 50% porosity.
- In staging areas, limit size of area; apply water to surface soils where support equipment and vehicles are operated; and limit ingress and egress points. (CCHD).
- For stockpiles, maintain at optimum moisture content; remove material from downwind side; avoid steep sides or faces; and stabilize material following stockpile-related activity (CCHD).
- To prevent trackout, pave construction roadways as early as possible; install gravel pads; install wheel shakers or wheel washers, and limit site access. (CCHD). This is much more effective than the Final EIR's proposed

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County (Nevada) Health Department; Chevron = Chevron Refinery Modernization Project; MBUAPCD = Monterey Bay Unified Air Pollution Control District; SBCAPCD = Santa Barbara County Air Pollution Control District; SJVAPCD = San Joaquin Valley Air Pollution Control District; SLOCAPCD = San Luis Obispo County Air Pollution Control District.

[27] Final EIR, Table 7-2, p. 7-49, MM 4.3-2(d)(2).

mitigation measure, which only limits track-out to 50 feet from active operations and subsequent removal.[28]

- Where feasible, use bedliners in bottom-dumping haul vehicles. (Rule 403 Handbook)
- Grade each phase separately, timed to coincide with construction phase or grade entire project. (Rule 403 Handbook)
- All operations shall limit or expeditiously remove the accumulation of mud or dirt from adjacent public streets at least once every 24 hours when operations are occurring. (BAAQMD) *(The use of dry rotary brushes is expressly prohibited except where preceded or accompanied by sufficient wetting to limit the visible dust emissions.) (Use of blower devices is expressly forbidden.).* (SJVAPCD)
- Following the addition of materials to, or the removal of materials from, the surface of outdoor storage piles, said piles shall be effectively stabilized of fugitive dust emissions utilizing sufficient water or chemical stabilizer/suppressant. (SJVAPCD, ADEQ)
- During initial grading, earth moving, or site preparation, projects 5 acres or greater may be required to construct a paved (or dust palliative treated) apron, at least 100 feet in length, onto the project site from the adjacent site if applicable. (BCAQMD)
- Post a publicly visible sign with the telephone number and person to contact regarding dust complaints. This person shall respond and take corrective action within 24 hours. (BCAQMD, MBUAPCD, CCHD, Chevron)
- Prior to final occupancy, the applicant demonstrates that all ground surfaces are covered or treated sufficiently to minimize fugitive dust emissions. (BCAQMD)
- The contractor or builder shall designate a person or persons to monitor the dust control program and to order increased watering and other controls, as necessary, to prevent transport of dust offsite. (SBCAPCD, SLOCAPCD)
- Prior to land use clearance, the applicant shall include, as a note on a separate informational sheet to be recorded with map, these dust control requirements. All requirements shall be shown on grading and building plans. (SBCAPCD, SLOCAPCD)
- All roadways, driveways, sidewalks, etc. to be paved should be completed as soon as possible. In addition, building pads should be laid as soon as possible after grading unless seeding or soil binders are used. (SLOCAPCD)
- Barriers with 50% or less porosity located adjacent to roadways to reduce windblown material leaving a site. (Rule 403 Handbook)

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[28] Final EIR, Table 7-2, p. 7-49, MM 4.3-2(d)(4).

- Limit fugitive dust sources to 20% opacity. (ADEQ)
- All exposed surface shall be watered at a frequency adequate to maintain minimum soil moisture of 12%. Moisture content can be verified by lab samples or moisture probe. (Chevron)
- All excavation, grading, and/or demolition activities shall be superseded when average wind speeds exceed 20 miles per hour. (Chevron). This is more stringent than the Final EIR's requirement to cease construction activities on unpaved surfaces when wind speeds exceed 25 miles per hour, especially since the measure permits continuation of construction activities if dust suppression measures are used to minimize visible dust plumes.[29]
- Vegetative ground cover (*e.g.*, fast-germinating native grass seed) shall be planted in disturbed areas as soon as possible and watered appropriately until vegetation is established. (Chevron) This is more effective than the Final EIR's proposed measure, which does not require watering and only requires that disturbed areas be vegetated once they are no longer needed for oil and gas activities.[30]
- The simultaneous occurrence of excavation, grading, and ground-disturbing construction activities on the same area at any one time shall be limited. Activities shall be phased to reduce the amount of disturbed surface at any one time. (Chevron)
- Site accesses to a distance of 100 feet from the paved road shall be treated with a 6- to 12-inch compacted layer of wood chips, mulch, or gravel. (Chevron)
- Apply non-toxic chemical soil stabilizers according to manufacturer' specifications, to all inactive construction areas (previously graded area inactive for 10 days or more). (SCAQMD). This is more effective than the Final EIR's proposed measure which only requires stabilizers on "on-site unpaved roads".[31]
- Enclose, cover, water twice daily, or apply non-toxic soil binders, according to manufacturer's specifications, to exposed stockpiles (*i.e.*, gravel, sand, dirt) with 5% or greater soil content. (SCAQMD)
- Monitor for particulate emissions according to District-specified procedures. (SCAQMD)
- Apply water three times daily, or non-toxic stabilizer according to manufacturers' specifications to all unpaved parking or staging areas or unpaved road surfaces. (SCAQMD)

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[29] Final EIR Table 7-2, p. 7-49, MM 4.3-2(d)(3).

[30] Final EIR Table 7-2, p. 7-50, MM 4.3-2(d)(14).

[31] Final EIR Table 7-2, p. 7-49, MM 4.3-2(d)(1).

All of these measures are feasible and various combinations of them are routinely required elsewhere to reduce fugitive PM10 emissions. See, for example, the fugitive dust control program for the Big Dig[32], for the El Toro Reuse Draft EIR[33], and for the Padres Ballpark Final EIR[34]. While implementation of all of these measures would substantially reduce fugitive PM10 and PM2.5 emissions compared to the measures proposed by the Final EIR, they likely remain substantially above the respective significance thresholds.

III. Road Paving Is Not Valid CEQA Mitigation

On August 14 and 24, the Applicant submitted a technical report, requesting that the County specifically recognize "paving roads" as a mitigation measure that could be used to comply with the emission reductions required under Mitigation Measure MM 4.3-8.[35] The County accepted this measure as valid mitigation to mitigate particulate matter emissions in the Oil and Gas Emission Reduction Agreement ("OG-ERA") "with appropriate enforcement and prioritization mechanisms."[36] The OG-ERA applies to emissions from stationary equipment that are not required to be offset under a District rule[37] under Mitigation Measure MM 4.3-1, and to vehicle and other mobile source emissions[38], including off-road construction equipment, drill rigs, small equipment, well-related maintenance and treating operations, and routine business travel.[39] This new mitigation measure was not disclosed in the Draft EIR, its impacts have not been analyzed, "appropriate enforcement" mechanisms have not been identified, and it has not been subject to public review.

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[32] A. Kasprak and P.A. Stakutis, A Comprehensive Air Quality Control Program for a Large Roadway Tunnel Project, Proceedings of the Air & Waste Management Association's 93rd Annual Conference & Exhibition, June 18-22, 2000.

[33] County of Orange, Draft Environmental Impact Report No. 573 for the Civilian Reuse of MCAS El Toro and the Airport System Master Plan for John Wayne Airport and Proposed Orange County International Airport, Draft Supplemental Analysis, Volume 1, April 2001, pp. 2-121 to 2-123.

[34] City of San Diego, Final Subsequent Environmental Impact Report to the Final Master Environmental Impact Report for the Centre City Redevelopment Project and Addressing the Centre City Community Plan and Related Documents for the Proposed Ballpark and Ancillary Development Projects, and Associated Plan Amendments, V. IV. Responses to Comments, September 13, 1999, pp. IV-254 to IV-256.

[35] Final EIR, pp. 7-190 and 7-212. Note the that Final EIR includes a typographical error at p. 7-212, mistakenly referring to MM 4.3-5 instead of MM 4.3-8, which is the mitigation measure that addresses offsets.

[36] Final EIR, p. 7-212.

[37] Draft EIR, p. 4.3-83 and Draft EIR, revised Table 4.3-20.

[38] Final EIR, Table 7-2, p. 7-52.

[39] Draft EIR, p. 4.3-63.

The Final EIR fails to explain how this process would work, how road paving particulate matter emission reductions would be calculated, and how road paving emission reduction credits (referred to as "PERCs" in these comments) would be enforced. Further, the Final EIR fails to evaluate and disclose the emissions and impacts that would result from paving roads.

The PM10 and PM2.5 emissions that could be mitigated using road paving offsets consist of combustion exhaust emissions and fugitive dust. The Final EIR does not break out combustion exhaust and fugitive dust emissions separately and the OG-ERA makes no distinction between the two instead only referring to particulate matter.[40] Thus, the Final EIR allows the Applicant to offset PM10 and PM2.5 emissions by reducing entrained road dust PM10 emissions in the District through paving of existing unpaved roads without any prior analysis or notification. These paving emission reduction credits would be used to offset PM10 emissions anywhere in the San Joaquin Valley Air Basin, regardless of the location of the emission source to be offset, the location of the unpaved road, or the physical and chemical composition of PM10 emissions. This leads to a number of problems affecting air quality in the SJVAB and the health of its residents.

In sum, as explained below, there is a reasonable possibility that the generation and use of PERCs to offset the Project's PM10 emissions would not offset PM10 emissions from fuel-fired equipment and would result in significant adverse impacts on the environment. These significant impacts should be analyzed under CEQA before PERCs are accepted to mitigate Project emissions. Alternatively, the Final EIR should be revised to explicitly exclude the use of road paving ERCs to mitigate Project impacts.

A. Road Paving ERCs Are Not Enforceable

Road paving emission reduction credits are a non-traditional source of emission reductions that must be calculated based on the specifics of the selected roads, including vehicle miles traveled and silt content. The calculation of PM10 emission reductions from paving roads is complex and controversial. Significant controversy over the calculation of PM10 emission reductions was generated when the Mojave Desert Air Quality Management District and Imperial County Air Pollution Control District proposed rules to generate ERCs from road paving (MDAQMD Rule 1406[41] and

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[40] Final EIR, Appx. M-3 *Draft Emission Reduction Agreement.*

[41] *See* California Unions for Reliable Energy v. Mojave Desert Air Quality Management District, 178 Cal. App. 4th 1225; 101 Cal. Rptr. 3d 81; 2009 Cal. App., October 30, 2009; http://resources.ca.gov/ceqa/cases/2009/California_Unions_for_Reliable_Energy_v_Mojave_Desert_Air_Quality_Management_District.pdf (Exhibit 12); Petra Pless, Pless Environmental, Inc., Letter to Gloria Smith, Adams Broadwell Joseph and Cardozo, Re: Mojave Desert Air Quality Management District, Comments on Proposed Draft Rule 1406: Emission Reduction Credits for Paving Unpaved Roads, June 1, 2007 (Exhibit 13); David Howecamp, Letter to Gloria Smith, Adams Broadwell Joseph and Cardozo, May 21, 2007 (Exhibit 14); Petra Pless, Pless Environmental, Inc., Letter to Gloria Smith, Adams Broadwell

ICAPCD Rule 214.2[42]) and when the Antelope Valley Air Quality Management District proposed using PERCs to offset operational emissions from a natural gas-fired power plant.[43]

The Final EIR is silent on how this calculation would be made, whether site-specific data would be required (*e.g.*, traffic counts, silt content measurements), and whether distance ratios would be required if the roads are not at the Project site. Further, the Final EIR fails to explain how any party to the OG-ERA could assure compliance would be achieved as no party would have control over public roads. Thus, the feasibility of generating road paving ERCs is speculative at best.

B. Road Paving Does Not Mitigate Particulate Matter Emissions from Combustion Sources

The California Air Resources Board ("CARB") has long opposed using road paving ERCs to offset combustion emissions, writing to all air districts in California in June 2000 as follows:

> I am writing to express our concerns regarding the increasing use of course [sic] particulate matter (PM) emission reductions to offset combustion-generated fine particulate matter increases (e.g., reductions in unpaved road emissions to offset combustion emission increases). Fine particulates, those equal to or smaller than 2.5 microns in diameter (PM2.5), have unique pulmonary dynamics. They selectively penetrate into lung alveoli. Whatever chemicals the particulates have absorbed, either at their source or from ambient air, are also transported into the body. Fine particulate matter emissions are a serious human health concern.
>
> In addition, data from the California Emissions Inventory Development and Reporting System (CEIDARS) illustrates the incongruity of PM size fraction between unpaved road dust and gaseous fuel combustion. CEIDARS data indicates unpaved road dust is approximately 59 percent PM10 and 13 percent PM2.5. Comparatively, 100 percent of PM from gaseous fuel combustion is less than 2.5 microns.

Joseph and Cardozo, Comments on Mojave Desert Air Quality Management District Proposed Amendments to Rule 1406: Generation of Emission Reduction Credits for Paving Unpaved Public Roads, October 15, 2008 (Exhibit 15).

[42] *See* Center for Biological Diversity, Re: Comments on Imperial County APCD Proposed Rule 214.2 Paving Unpaved Public Roads Emission Reduction Credits, Board Hearing Date 5/12/2015, May 6, 2015 (Exhibit 16).

[43] *See* Phyllis Fox, Letter to John Buse, Center for Biological Diversity, Re: Proposed Paving Emission Reduction Credits for Palmdale Hybrid Power Project, July 19, 2010 (Exhibit 17); and Phyllis Fox, Palmdale Hybrid Power Project, Docket 08-AFC-9, Testimony Re: Road Paving Offsets (Exhibit 18).

> We believe there is no technical justification for allowing PM emission reductions from road paving to offset PM increases from natural gas combustion. Any ERC granted for reductions in non-combustion course (sic) particulate matter should contain conditions to limit the use of the ERC to similar-sized non-combustion particulate matter sources. If ERCs have been granted for paving of roads, *those ERCs should not be allowed to be used to mitigate the impacts of combustion particulate."*[44]

1. *PM10 and PM2.5 Size Fractions in Entrained Road Dust and Combustion Emissions Are Significantly Different*

Particulate matter ("PM") is a collective term for very small solid or liquid particles suspended in the atmosphere. Particulate matter can be classified according to physical (size, mode of formation, settling properties and optical qualities), chemical (organic or inorganic composition), and biological (bacteria, viruses, spores, pollens etc.) characteristics. Among the most common categorizations for particulate matter are those with respect to size, referred to as fractions. The notation PM10 is used to describe particles with an aerodynamic diameter of 10 micrometers or less (thoracic fraction) and the notation PM2.5 represents particles with an aerodynamic diameter of 2.5 micrometers or less, the so-called fine particle fraction.[45] (A micrometer, or micron, is one-millionth of a meter.) The remaining fraction of PM10, *i.e.* the size fraction between 2.5 to 10 micrometers, is termed coarse particulate matter or PM2.5-10. The notation PM0.1 represents the ultrafine particle fraction with an aerodynamic diameter of 0.1 micrometers or less. Table 2 below summarizes the various size ranges.

Table 2: Size Ranges of Particulate Matter

Fraction		Size Range
PM0.1	ultrafine	≤0.1 micrometers
PM2.5	fine (respirable)	≤2.5 micrometers
PM2.5-10	coarse	2.5-10 micrometers
PM10	thoracic	≤10 micrometers

Thus, the smaller size fractions are contained within the larger size fractions, as illustrated in Figure 1 below; *i.e.*, the PM2.5 fraction of emissions is contained within the PM10 fraction of emissions and the PM0.1 fraction of emissions is contained within the PM2.5 and PM10 size fractions. The EPA and the State of California have promulgated separate ambient air quality standards for PM10 and PM2.5 based on mass concentrations in ambient air, because their impacts are distinguishable based largely on particle size.

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[44] Letter from Michael P. Kenny, Executive Officer, CARB, to Air Pollution Control Officers, June 16, 2000.

[45] Aerodynamic diameter is a physical property of a particle in a viscous fluid such as air. In general, particles have irregular shapes with actual geometric diameters that are difficult to measure. Aerodynamic diameter is an expression of a particle's aerodynamic behavior as if it were a perfect sphere with unit-density and diameter equal to the aerodynamic diameter.

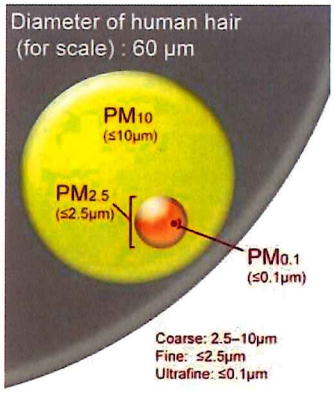

Figure 1: Comparison of PM10, PM2.5, and PM0.1 to Human Hair
(from: Greenfacts, PM10, PM2.5, and PM0.1;
http://www.greenfacts.org/glossary/pqrs/PM10-PM2.5-PM0.1.htm (Exhibit 19))

Speciation profiles developed by CARB for use in modeling[46] indicate that fugitive dust PM10 from unpaved roads consists of about 79% coarse particulate matter, *i.e.* PM2.5-10, and only about 21% fine particulate matter or PM2.5.[47] In contrast, combustion emissions from diesel vehicle exhaust, such as construction equipment and well drilling equipment, are almost entirely composed of very small particulates. PM10 emissions from diesel-fired vehicles (CARB Profiles 425 and 118) are composed of about 2% to 8% PM2.5-10 and 92% to 94% PM2.5.[48] Emissions from gas-fired stationary combustion engines (such as found in equipment in "small production settings" are composed of almost 100% PM2.5.[49] Figure 2 illustrates the fraction of PM2.5 contained

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[46] CARB Speciation Profiles Used in ARB Modeling, February 11, 2015;
http://www.arb.ca.gov/ei/speciate/speciate.htm#specprof.

[47] CARB Speciation Profiles, Particulate Matter Profile Code 394, Unpaved Road Dust;
http://www.arb.ca.gov/ei/speciate/vv10001/profphp/sccpmvv10001_list.php?masterkey=394
(Exhibit 20a); weight fraction PM10/PM = 0.61 and weight fraction PM2.5/PM = 0.13; thus, **PM2.5** = 0.13/0.61 = **0.21** and **PM2.5-10** = 1.00-0.21 = **0.79**.

[48] CARB Speciation Profiles, Particulate Matter Profile Code 425, Diesel Vehicle Exhaust;
http://www.arb.ca.gov/ei/speciate/vv10001/profphp/sccpmvv10001_list.php?masterkey=425
(Exhibit 20b); weight fraction PM10/PM = 1.00 and weight fraction PM2.5/PM = 0.92; thus, **PM2.5** = 0.92/1.00 = **0.92** and **PM2.5-10** = 1.00-0.92 = **0.08**.

CARB Speciation Profiles, Particulate Matter Profile Code 118, Vehicular Sources – Diesel;
http://www.arb.ca.gov/ei/speciate/vv10001/profphp/sccpmvv10001_list.php?masterkey=118
(Exhibit 20c); weight fraction PM10/PM = 0.96 and weight fraction PM2.5/PM = 0.937; thus, **PM2.5** = 0.937/0.96 = **0.976** and **PM2.5-10** = 1.00-0.937 = **0.063**.

[49] CARB Speciation Profiles, Particulate Matter Profile Code 123, Stat. I.C. Engine – Gas;
http://www.arb.ca.gov/ei/speciate/vv10001/profphp/sccpmvv10001_list.php?masterkey=123

in the entrained fugitive dust PM10 emissions from vehicle travel on unpaved roads (left) and combustion emissions from a gas-fired stationary internal combustion engine (right).

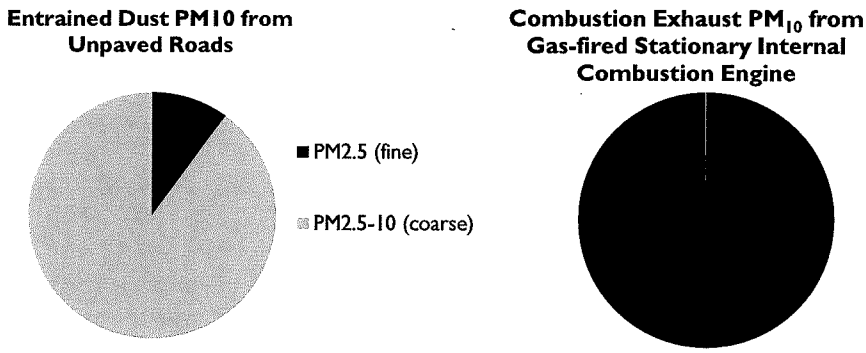

Figure 2: Fraction of PM2.5 (fine) and PM2.5-10 (coarse) in entrained fugitive road dust PM10 emissions from unpaved roads (left) and combustion exhaust from gas-fired stationary internal combustion engines (right)

This is important because it means that trading a pound of PM10 from combustion (which is mostly PM2.5) for a pound of PM10 from road dust would mean that the emitted PM10 would stay in the air longer, spread more widely, and be more likely to cause disease. Further, the very act of road paving would produce still more PM10, mostly made up of PM2.5, while also have adverse biological and growth-inducing impacts, discussed elsewhere.

2. *Use of PERCs Would Increase PM2.5 Emissions, Impeding Compliance with PM2.5 Ambient Air Quality Standards*

The striking difference in the particle sizes contained within PM10 results in significant increases in fine particulate matter, which in turn, results in significant ambient air quality and public health impacts.

In addition to these differences in the composition of particles sizes, the chemical composition also differs. Particles from combustion sources contains chemicals absorbed from the gas stream, unique to the source. Fine particles from diesel exhaust, for example, are permeated with diesel combustion byproducts, such as polynuclear aromatic hydrocarbons from diesel engines, making them a greater health hazard than PM10 from road dust.

(Exhibit 20d); weight fraction PM10/PM = 0.994; and weight fraction PM2.5/PM = 0.992; thus, **PM2.5** = 0.992/0.994 = **0.998** and **PM2.5-10** = 1.00-0.992 = **0.008**.

The PM10 reductions from paving an unpaved road consist of 79% coarse particulate matter, *i.e.* PM2.5-10 and only 21% PM2.5 or fine particulate matter. In comparison, the majority of the particulate matter emissions that would be offset by these PERCs originate from diesel-powered construction equipment and contain only 2% to 8% coarse particulate matter and 92% to 98% PM2.5. Thus, when offsetting, for example, 100 tons per year of PM10 combustion emissions from diesel-fired construction equipment with PERCs, 71 to 77 tons/year of PM2.5 emissions would not be offset,[50] resulting in a significant unmitigated increase in PM2.5 emissions in a PM2.5 nonattainment area.

Thus, while there would be no net increase of PM10 emissions within the District, as intended by the mitigation measure (because PM10 emission increases from construction and operation of new wells would be offset by PM10 emission reductions achieved by paving an unpaved road), the mass quantity of PM2.5 emissions, *i.e.*, the fine particulate fraction of PM10, in the District would increase and the concentration of PM2.5 in ambient air would rise.

Every particle in the fine fraction weighs a lot less than a particle in the coarse fraction, so it takes many more fine particles to make up one ton of PM10 than the number of coarse particles required to make up one ton of PM10. (For example, one particle of 10 micrometers (μm) in diameter has approximately the same mass as 1 million particles of 0.1 μm.) Therefore, the number of fine particles in the air will increase dramatically, not only because more mass (tons/year) of PM2.5 will be emitted but also because it takes many more particles to make up the same mass that was emitted as coarse particles from unpaved roads. (Comment III.B.5 addresses the different health effects of the various particle sizes and the impact of number concentrations versus mass-based concentrations.) Thus, offsetting PM10 emissions from combustion sources with PERCs derived from paving unpaved roads is offsetting apples with oranges, or to keep with the size analogy, apples with orange seeds. Thus, road paving should not be allowed as a mitigation measure for PM10 emissions from any fuel combustion source, including on-road and off-road vehicles and gas- or diesel-fired stationary equipment.

Further, as PERCs from anywhere within the District could be used to offset Project emissions, irrespective of the location of the specific project, emission reductions would not necessarily occur near the emission source, which may result in significant adverse local impacts on air quality.

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[50] (100 tons/year PM2.5 emitted) × (PM2.5 in fugitive dust: 0.92 – PM2.5 in combustion exhaust: 0.21) = **71 tons/year**; (100 tons/year PM2.5 emitted) × (PM2.5 in fugitive dust: 0.98– PM2.5 in combustion exhaust: 0.21) = **77 tons/year**.

3. *Entrained Road Dust and Particulate Matter Emissions from Combustion Sources Experience Different Atmospheric Transport and Distribution*

Local and regional transport of particulate matter is dependent on a number of factors, including particle size, emissions height, wind speed, humidity, and atmospheric stability. Dry deposition, or gravitational settling of particles in the atmosphere, is highly dependent on the particle size. The larger particles do not remain suspended and tend to settle out relatively quickly, in a matter of minutes to hours.

With the exception of dust storm events, coarse particles are transported over only a short distance on the order of less than one to tens of miles. In contrast, smaller particles settle out slowly and are regionally distributed. Ultrafine particles quickly coagulate into fine particles, which have an atmospheric half-life of days to weeks and are transported over hundreds to thousands of miles from the source.[51] As discussed above, most (~80%) of the entrained road dust is composed of coarser particles. Therefore, most of the entrained road dust particulate matter stays in the air for a relatively short period of time and typically spreads only a short distance from the roads.

Conversely, combustion emissions from stationary sources are composed almost exclusively of fine particles, mostly ultrafine particles smaller than 0.1 um. In addition to the longer settling time for fine particulate matter, the long-distance distribution of fine particles from combustion sources like flares and heaters is aided by their emission from tall stacks with high exit velocities. As a result, PM2.5 concentrations in ambient air would increase throughout the District.

4. *Criteria Pollutant Construction Emissions from Road Paving May Be Significant*

The method used to calculate PERCs was not disclosed in the Final EIR, but generally, such reductions are typically calculated as the difference in entrained road dust from vehicle travel before and after paving of an unpaved road. Assuming this is the method that would be used, it fails to account for emissions associated with the paving of existing unpaved roads and with the periodic maintenance of the paved road.

Fugitive dust emissions during road paving for city and county roads result predominantly from site preparation work which may include scraping, grading, loading, digging, compacting, light-duty vehicle travel, and other operations. These emissions are considerable, may result in significant impacts, and should be subtracted from the PERCs that would be generated.

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[51] EPA, Air Quality Criteria for Particulate Matter, October 2004, EPA 600/P-99/002aF-bF; http://cfpub2.epa.gov/ncea/cfm/recordisplay.cfm?deid=87903.

Further, the use of asphalt for paving of roads also results in considerable emissions of ROGs at the asphalt plant and at the construction site. Emissions from asphalt paving occur when asphalt mixtures are applied and as they cure. Emissions of ROGs from asphalt paving have been estimated at 9.2 pounds per barrel ("lb/barrel") applied for emulsified asphalt, 88 lb/barrel applied for cutback asphalt, and 0.9 lb/barrel applied for hot-mix asphalt.[52,53] It takes between 7 and 17 tons of asphalt to pave a mile of road. Assuming the use of hot-mix asphalt, the most commonly type of asphalt, a typical density for hot-mix asphalt of 9 pounds per gallon ("lb/gallon")[54], and the CARB-recommended default factor of 10 tons of asphalt per mile, paving of one mile of road results in ROG emissions of about 48 pounds.[55] The use of even small amounts of cut-back would considerably increase this emissions estimate. For example, using just 2% cutback would triple these emissions.[56] These estimates do not include ROG emissions at the asphalt plant, which are also considerable.[57]

Further, construction equipment and vehicles used to transport asphalt from the asphalt plant, road base from aggregate processing plants, and workers to the construction site would generate exhaust emissions from combustion of diesel and gasoline. Emissions of NOx and ROGs, which are both ozone precursors, have the potential to exceed CEQA significance thresholds for these pollutants and would further exacerbate the District's ozone non-attainment status.

5. *Health Effects of PM2.5 and PM10 and Ambient Air Quality Standards*

From a health perspective, the major difference between entrained road dust and combustion emissions is the size and composition of the particles: combustion particles are very small mostly sulfates particles that are readily dissolved in the lungs while

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[52] Asphalt surfaces and pavements are composed of compacted aggregate and an asphalt binder in the form of either asphalt cement (residue from distillation of crude oils), or liquefied asphalts. To be used for pavement, asphalt cement, which is semisolid, must be heated prior to mixing with aggregate. The resulting hot mix asphalt concrete is generally applied in thicknesses of 2 to 6 inches. Liquefied asphalts are either asphalt cutbacks (asphalt cement thinned with volatile petroleum distillates such as naphtha, kerosene, etc.) or asphalt emulsions (nonflammable liquids produced by combining asphalt and water with an emulsifying agent, such as soap). Liquefied asphalts are used in tack and seal operations, in priming roadbeds for hot mix application, and for paving operations up to several inches thick.

[53] CARB, Asphalt Paving and Roofing; http://arbis.arb.ca.gov/ei/areasrc/ccosmeth/att_c_asphalt.doc (Exhibit 21).

[54] *Ibid.* (Asphalt densities vary between 7 to 9 lb per gallon, with hot-mix asphalts at the heavier end of the scale.)

[55] (10 ton asphalt/mile) × (2,000 lb/ton) / (9 lb/gallon asphalt) / (42 gallons/barrel) × (0.9 lb VOC/barrel asphalt) = **47.6 lb VOC/mile**.

[56] (47.6 lb VOC/mile) × (0.98) + (10 ton asphalt/mile) × (2,000 lb/ton) / (9 lb/gallon asphalt) / (42 gallons/barrel) × (88 lb VOC/barrel cutback asphalt) × 0.02= **139.8 lb VOC/mile;** (139.8 lb VOC/mile) / (47.6 lb VOC/mile) = **2.94**.

[57] CARB, Asphalt Paving and Roofing, *op. cit.*

road dust PM is mostly much larger silica and iron oxides, which are not lung soluble. Any emission reductions used to mitigate impacts of increases in PM10 emissions must have the same qualitative health and environmental impacts as the actual emissions.

The effects of inhaling particulate matter have been widely studied in humans and animals and include asthma, lung cancer, cardiovascular issues, and premature death. The health risk from an inhaled dose of particulate matter depends on the size, composition, and concentration of the particles. The size of the particle is a main determinant of where in the respiratory tract the particle will come to rest when inhaled. Larger particles are generally filtered in the nose and throat and do not cause problems, but particulate matter smaller than about 10 micrometers in diameter, PM10 or the so-called thoracic fraction, can settle in the bronchi and lungs and cause health problems.[58] PM2.5, or the respirable fraction, tends to penetrate into the gas-exchange regions of the lung, and ultrafine particles, PM0.1, may pass through the lungs to affect other organs. Most combustion particulate matter emissions, including diesel exhaust, consist mostly of particles smaller than 0.1 micrometers. Particulates generated during combustion of fossil fuels and entrained road dust particles have fundamentally different physical and chemical properties with larger particles causing less severe health impacts.

Historically, health impacts due to particulate matter were regulated through mass-based PM10 ambient air quality standards. However, a substantial amount of new research has been published, documenting new health impacts at much lower concentrations and for different size fractions of particulate matter than was previously known and reflected in PM10 ambient air quality standards.[59,60] This new research documents that the inhalation of particulate matter, particularly the smallest particles, causes a variety of health effects, including premature mortality, aggravation of respiratory (*e.g.*, cough, shortness of breath, wheezing, bronchitis, asthma attacks) and cardiovascular disease, declines in lung function, changes to lung tissues and structure, altered respiratory defense mechanisms, and cardiopulmonary and lung cancer mortality, among others.[61,62]

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[58] The 10 μm size does not represent a strict boundary between respirable and non-respirable particles, but has been agreed upon for monitoring of airborne particulate matter by most regulatory agencies.

[59] EPA, Air Quality Criteria for Particulate Matter, EPA/600/P-95-001aF through 001cF, April 1996.

[60] EPA, Air Quality Criteria for Particulate Matter, 2004, *op. cit.*

[61] National Ambient Air Quality Standards for Particulate Matter: Proposed Decision, Federal Register, Vol. 61, No. 241, December 13, 1996, pp. 65638-65675.

[62] A.A. Pope III, R.T. Burnett, M.J. Thun, E.E. Calle, D. Krewski, K. Ito, G.D. Thurston, Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution, Journal of the American Medical Association, Vol. 287, No. 9, pp. 1132-1141, 2002; abstract available at: http://www.ncbi.nlm.nih.gov/pubmed/11879110 (Exhibit 22).

Since 1996, more than 2,000 peer-reviewed studies have been published validating earlier epidemiologic studies that link both acute and chronic fine particle pollution with serious morbidity and mortality. This research has also expanded the list of health effects associated with fine particle pollution and has identified health effects at considerably lower exposure levels than previously reported. Overwhelming scientific evidence shows that long-term exposure to fine particulate air pollution contributes to pulmonary and systemic oxidative stress, inflammation, progression of atherosclerosis, and risk of ischemic heart disease and death. A recent study found that an increase in PM2.5 air pollution of 10 micrograms per cubic meter ("$\mu g/m^3$") was associated with approximately a 6% increase in cardiopulmonary mortality and an 8% increase in lung cancer mortality.[63]

Short-term exposure is equally damaging and contributes to complications of atherosclerosis, such as plaque vulnerability, thrombosis, and acute ischemic events. EPA concluded with respect to short-term exposure studies, that epidemiological evidence supported likely causal associations between PM2.5 and both mortality and morbidity from cardiovascular and respiratory diseases."[64] A study of almost 13,000 patients evaluated the role of fine particulate matter exposure in triggering acute ischemic heart disease event. The study found a sharply elevated risk of heart attacks for people with clogged arteries after just a day or two of short-term exposure to fine particulate matter. This study was published in the American Heart Association's peer-reviewed journal *Circulation*.[65] One coauthor of the study stated that the results should prompt heart doctors to advise those with coronary heart disease to stay indoors as much as possible on particularly sooty days and that he was already changing his advice to patients based on these results, even advising in severe cases to move to a less polluted environment.[66]

The EPA and CARB, in their review and analysis of the new information on health impacts of particle pollution, concluded that coarse and fine particles have fundamentally distinct physical and chemical properties and health effects, and thus should be separately regulated and measured so that effective control strategies could be developed. As a result, EPA and CARB promulgated new ambient air quality standards for PM2.5 and the CARB lowered the standards for PM10. The PM2.5

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[63] *Ibid.*

[64] EPA, Provisional Assessment of Recent Studies on Health Effects of Particulate Matter Exposure, EPA/600/R-06/063, July 2006; http://www.epa.gov/pm/pdfs/ord_report_20060720.pdf (Exhibit 23).

[65] Pope A.A. III, Muhlestein J.B., May H.T., Renlund D.G., Anderson J.L., Horne B.D., Ischemic Heart Disease Events Triggered by Short-Term Exposure to Fine Particulate Air Pollution, Circulation, No. 114: 2429, 2006; abstract available at http://circ.ahajournals.org/content/114/23/2443.abstract (Exhibit 24).

[66] Los Angeles Times, Dire Health Effects of Pollution Reported, Diesel Soot from Construction Equipment Is Blamed for Illnesses and Premature Deaths, December 6, 2006; http://articles.latimes.com/2006/dec/06/local/me-dig6 (Exhibit 25).

standards are *not* subsets of the PM10 standards, but new standards for a separate pollutant with distinguishable impacts.

Ultrafine particles, less than 0.1 μm, or PM0.1, may be even more damaging to the cardiovascular system. There is evidence that ultrafine particles can pass through cell membranes and migrate into other organs, including the brain. It has been suggested that particulate matter can cause similar brain damage as that found in Alzheimer patients. Particles emitted from combustion sources are typically in this size range. It is becoming increasingly clear that the ambient air quality standards, which are mass-based, are not a proper measure of health hazards. Proposals for new regulations exist in some countries, with suggestions to limit the particle surface area or the particle number.

Particularly damaging are the ultrafine particles in diesel exhaust, which contain nearly 40 toxic substances and carry carcinogenic components adsorbed to their surface. As early as 1988, the National Institute for Occupational Safety and Health (NIOSH) identified diesel exhaust as a potential occupational carcinogen. In 1998, CARB formally identified the particulate fraction of diesel exhaust as a toxic air contaminant and concluded that exposure to diesel exhaust particulate matter ("DPM") causes cancer and acute respiratory effects.[67] EPA followed suit in 2002 and classified diesel exhaust as a probable human carcinogen. Diesel exhaust is estimated to contribute to more than 75% of the added cancer risk from air toxics in the United States.[68]

The new proposal to allow road paving offset, added to the EIR without any public review, allows PERCs to be used to offset PM10 emissions from diesel-fired stationary sources. In sum, this will result in new significant health impacts not considered in the EIR.

6. *Road Paving May Increase Traffic and Particulate Matter Emissions*

Paved roads are likely to attract more traffic than the previously unpaved roads; traffic speeds would increase, entrained road dust would increase with the number of vehicles on the road and their possibly increasing weight as more trucks would use the

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[67] CARB, Initial Statement of Reasons for Rulemaking, Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant, Staff Report, June 1998; http://www.arb.ca.gov/toxics/dieseltac/staffrpt.pdf (Exhibit 26).

[68] Environmental Defense Fund, Cleaner Diesel Handbook, Bring Cleaner Fuel and Diesel Retrofits into Your Neighborhood, April 2005, p. IV; http://www.environmentaldefense.org/documents/4941_cleanerdieselhandbook.pdf (Exhibit 27).

road. Paved roads may also attract development, which would drastically change the vehicle pattern and weight distribution.

7. *Road Paving Would Result in Adverse Impacts on Biological Resources*

Paving dirt or gravel roads may result in a number of adverse direct and indirect impacts on biological resources. Direct impacts include mortality during road construction and increased frequency of roadkill from vehicle travel on paved roads. In contrast, many indirect effects of roads are cumulative and involve changes in community structure and ecological processes. These indirect impacts include spread of invasive plant species; air, water, soil, and noise pollution; soil disturbance and erosion; and increase of roadway pollutants and associated habitat loss, degradation and fragmentation; alteration of wildlife movement; and changes in wildlife populations.

Paving of unpaved roads in the District would involve improvement of the existing road sub-base including removal of gravel surface layers, widening of the road footprint, and heightening of the road base. Any vegetation along the unimproved road would be removed as well as any organisms living in that vegetation or the unimproved road shoulders. These activities will often result in the loss of sessile or slow-moving organisms in the path of the road.

A number of animals live in or adjacent to road shoulder berms of unimproved roads in the San Joaquin Valley. These include the Western burrowing owl (*Athene cunicularia hypugea*), a state and federal species of concern. Burrowing owls do not dig their own burrows but prefer to adopt vacant tortoise, kit fox, ground squirrel, or other rodent dens or burrows, frequently found in unimproved road shoulders or adjacent vegetation. Burrowing owls are very susceptible to burrow disturbance, particularly during their breeding season from the beginning of February through end of August.[69] Similarly, the desert tortoise (*Gopherus agassizii*), listed as threatened under the federal and state Endangered Species Acts, frequently constructs burrows along the elevated berms of unpaved roads because the topography mimics that formed along the banks of desert washes, a preferred site for burrow construction.[70] Thus, it is likely that construction activities associated with paving roads would impact active burrows of these species and result in direct mortality of individuals. Many other species may also be adversely affected during the construction phase.

Further, animals are attracted to paved roads for a variety of reasons, often to their demise. Dark pavement absorbs radiant heat and releases it at night, creating a

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[69] The California Burrowing Owl Consortium, Burrowing Owl Survey Protocol and Mitigation Measures, April 1993 (Exhibit 28).

[70] Luckenbach R.A., Ecology and Management of the Desert Tortoise (*Gopherus agassizii*) in California. In: Bury R.B. (Ed.), North American Tortoises: Conservation and Ecology, Washington, D.C., U.S. Fish and Wildlife Service Wildlife Research Report 12, pp. 1-39 (Exhibit 29).

"heat island" around roads. This can attract heat-seeking species such as birds and snakes to roads, increasing their mortality by vehicle collision. Paving an unpaved road can elevate the road to higher service levels and may divert traffic from nearby unpaved roads. The increased volume of traffic on the newly paved section of the road would result in increased incidents of wildlife mortality. Further, paving typically increases traffic speed on this section of the road. Traveling at greater speeds reduces the ability of the driver to see animals on the road or on the shoulders, resulting in increased incidents of road kill. Unpaved roads, particularly when "unimproved," are typically less dangerous for wildlife.

Roadkill is the greatest directly human-caused source of wildlife mortality throughout the U.S. with more than a million vertebrates every day. The slow-moving desert tortoise is particularly at risk for collisions with fast-moving vehicles. Vehicle collisions are also the leading cause of mortality in mountain lions (*Puma concolor*)[71] and burrowing owls.

Finally, some species associate roads with negative experiences and are reluctant to cross the barrier presented by roads; other species are physically unable to cross road embankments. For these species, a road effectively cuts the population in half. A network of roads fragments the population further. The remaining small populations are then vulnerable to problems associated with rarity: genetic deterioration from inbreeding and random drift in gene frequencies, environmental catastrophes, fluctuations in habitat conditions, and demographic stochasticity (*i.e.*, chance variation in age and sex ratios). Thus, roads contribute to what many conservation biologists consider the major threat to biological diversity: habitat fragmentation. Such fragmentation may be especially ominous in the face of rapid climate change. If organisms are prevented from migrating to track shifting climatic conditions, and cannot adapt quickly enough because of limited genetic variation, then extinction is inevitable.

Embankments of paved roads are also typically steeper than those of unpaved roads, which for many species, including desert tortoises, increase the difficulty to crossing these roads and, as a result, may lead to habitat fragmentation and the above-discussed associated consequences.

Paving roads also has been found to increase the spread of invasive non-native and opportunistic native plant species. Vehicles carry and distribute seeds on their tires and undercarriages. The establishment of invasive species along roads is promoted by changing habitat by altering conditions; stressing or removing native species during road improvement; and allowing easier movement by wild or human vectors.

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[71] Dickson B.G., Jenness J.S., and Beier P., Influence of Vegetation, Topography, and Roads on Cougar Movement in Southern California, Journal of Wildlife Management, Vo. 69, No. 1, January 2005, pp. 264-276; http://www.jennessent.com/downloads/Dickson_et_al_JWM69_1.pdf (Exhibit 30).

The new edge habitats created by paving roads are often unsuitable for native species, but attract invasive, non-native species or opportunistic native species that can spread into open areas.[72] In general, plant productivity is greater along paved than dirt roads. A study analyzing roads with varying degrees of improvement in a desert ecosystem found that each step of road improvement converted an increasing area of natural habitat to roadside habitat, from which non-native weeds spread into adjacent natural ecosystems. Non-native cheatgrass, for instance, was three times more abundant in verges beside paved roads than in those bordering four-wheel-drive tracks. Verges along improved roads were also wider—about 3 feet on each side of a four-wheel-drive track versus 23 feet on a paved road.[73]

8. *Paving Roads Would Increase Roadside Pollution*

Paved roads typically require considerably increased roadside management compared to unpaved roads. This includes mowing or herbicide application to keep the shoulders of the road clear of vegetation. Chemicals used in the maintenance of roadways contaminate roadside ecosystems. While many state departments of transportation have begun to reduce the use of herbicides and other chemicals, the use of herbicides continues to damage roadside ecosystems. Those chemicals may also promote the invasion of weedy and exotic species, which are resistant to herbicides.

Another source of pollution is direct leaching of polyaromatic hydrocarbons ("PAHs") from the asphalt road itself. In the past, PAHs in roadside runoff were solely attributed to deposition from car exhaust fumes. However, research from Australia indicates that relatively high concentrations of PAHs can be introduced into soils through leaching from asphalt surfaces.[74] PAHs are known to have potential for adverse effects to a large number of animals, including invertebrates, birds, and mammals.

Increased vehicular travel on paved roads would also increase the amount of NOx emissions from exhaust fumes, which has been positively correlated with increased levels of nitrogen in the surrounding soil. Experiments in the Mojave Desert

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[72] Chuck Morton, Caltrans, Presentation at UC Davis, Road Ecology, Integrating Transportation and the Natural Environment, The Roads' Footprint, TTP 289A/B, April 12, 2007 (Exhibit 31).

[73] Matthew L. Brooks and Bridget Lair, United States Geological Survey, Ecological Effects of Vehicular Routes in a Desert Ecosystem, March 2, 2005; http://www.dmg.gov/documents/RPT_Eco_Effects_of_Veh_Routes_in_a_Desert_Ecosystem_USGS_011604.pdf (Exhibit 32).

[74] Sadler R., Delamont C., White P., and Connell D., Contaminants in Soil as a Result of Leaching from Asphalt, Toxicological and Environmental Chemistry, Vol. 68, 1997, pp. 71-81; in: Criley M. and Postelli K., From Gravel to Pavement — The Impacts of Upgrading; The Road-RIPorter, Vol. 5, No. 4, July/August 2000 (Exhibit 33).

suggest that increased soil nitrogen can promote the growth of non-native annual plants and reduce growth and diversity of native annual plants.[75]

C. Mitigation Measure 4.3-8 Fails to Mitigate PM2.5, SO_2, and CO Emissions

The OG-ERAs only mitigate NOx, ROG, and PM10. However, the increase in nonattainment pollutants and their precursor emissions due to the Project are significant due to other criteria pollutants, including PM2.5, SO_2, and CO. Thus, the EIR has failed to mitigate significant impacts of these additional pollutants.

This measure fails to mitigate cumulatively considerable PM2.5 emissions. The Kern County CEQA Implementation Document[76] and Kern County Environmental Checklist[77] relied on in the Final EIR to classify this impact state that a project would have a significant air quality impact if it would "[r]esult in a cumulatively considerable net increase of any criteria pollutant for which the project region is in nonattainment under an applicable federal or state ambient air quality standard ()..."[78] Kern County is in nonattainment for the federal 1-hour ozone standard and the federal annual PM2.5 standard. Thus, this measure should apply to VOCs, NOx, CO, and PM2.5. The EIR omits PM2.5[79] and erroneously includes PM10. Kern County is in attainment with all PM10 standards. The emission tables demonstrate that PM2.5 emissions exceed the threshold of 10 tons/year by huge amounts. Thus, the Final EIR fails to mitigate cumulatively significant PM2.5 impacts.

This is evidentially an error, due to the Final EIR's reliance on outdated guidance. The quoted guidance was published in 2004, before the San Joaquin Valley Air Basin was classified as nonattainment for PM2.5 and at a time when it was nonattainment for PM10. However, currently, the SJVAB is in attainment with PM10 standards, but is not in attainment with the federal annual PM2.5 NAAQS.[80] Thus, Mitigation Measure MM 4.3-8 must be revised to address PM2.5 emissions, not PM10 emissions.

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[75] Brooks and Lair, *op. cit.*

[76] Kern County CEQA Implementation Document, June 2004.

[77] Kern County Environmental Checklist Form, Environmental Factors Potentially Affected, January 2012; https://www.co.kern.ca.us/planning/pdfs/Form122.pdf (Exhibit 34).

[78] Draft EIR, p. 4.3-61.

[79] Final EIR, Table 2-2, p. 7-52.

[80] Final EIR, Table 4.3-2, pp. 4.3-6 and 4.3-7.

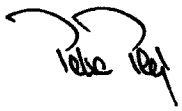
Further compounding the problem, the *Draft Mitigation Agreement*[81] does not require that either PM2.5 or PM10 be mitigated, but rather only particulate matter. Particulate matter is mostly larger particles that do not contribute significantly to the PM2.5 nonattainment impact. The specification of PM, rather than PM2.5, is a setup for road paving, which, as discussed elsewhere in these comments, is invalid mitigation for PM2.5. This essentially allows the Project to aggravate existing violations of the PM2.5 national ambient air quality standard without any valid mitigation.

IV. Recommendation

As discussed, the Final EIR fails to adequately quantify emissions generated by Project construction and operation and fails to require adequate mitigation to reduce significant emissions. As discussed, the proposed use of road paving as a mitigation measure is not valid CEQA mitigation and fails to reduce emissions of PM2.5. I recommend that the County substantially revise and recirculate the Final EIR to address these issues.

Please call me at (415) 492-2131 or e-mail at *petra.pless@gmail.com* if you have any questions about the comments in this letter.

Sincerely,



Petra Pless, D.Env.

[81] Final EIR, Appx. M-3 *Draft Emission Reduction Agreement.*

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Dr. Pless is a court-recognized expert with over 20 years of experience in environmental consulting conducting and managing interdisciplinary environmental research projects and preparing and reviewing environmental permits and other documents for U.S. and European stakeholder groups. Her broad-based experience includes air quality and air pollution control; water quality, water supply, and water pollution control; biological resources; public health and safety; noise studies; California Environmental Quality Act ("CEQA"), Clean Air Act ("CAA"), and National Environmental Policy Act ("NEPA") review; industrial ecology and risk assessment; and use of a wide range of environmental software.

EDUCATION

Doctorate in Environmental Science and Engineering (D.Env.), University of California Los Angeles, 2001

Master of Science (equivalent) in Biology (focus on Limnology), Technical University of Munich, Germany, 1991

PROFESSIONAL HISTORY

Pless Environmental, Inc., Principal, 2008–present

Environmental Consultant, Sole Proprietor, 2006–2008

Leson & Associates (previously Leson Environmental Consulting), Kensington, CA, Environmental Scientist/Project Manager, 1997–2005

University of California Los Angeles, Graduate Research Assistant/Teaching Assistant, 1994–1996

ECON Research and Development, Environmental Scientist, Ingelheim, Germany, 1992–1993

Biocontrol, Environmental Projects Manager, Ingelheim, Germany, 1991–1992

REPRESENTATIVE EXPERIENCE

Air Quality and Pollution Control

Projects include CEQA/NEPA review; CAA attainment and non-attainment new source review; prevention of significant deterioration ("PSD") and Title V permitting; control technology analyses (BACT, LAER, RACT, BARCT, BART, MACT); technology evaluations and cost-effectiveness analyses; criteria and toxic pollutant and greenhouse gas emission inventories; emission offsets; ambient and source monitoring; analysis of emissions estimates and ambient air pollutant concentration modeling. Some typical projects include:

- Provided expert support for intervention in California Energy Commission ("CEC") proceedings for numerous power plants including natural gas-fired, integrated gasification combined-cycle, geothermal (flash and binary) solar (thermal and photovoltaic) facilities with respect to air quality including emission reduction credits, hazards and hazardous materials, public health, noise, and biological resources.
- Critically reviewed and prepared technical comments on the air quality, biology, noise, water quality, and public health and safety sections of CEQA/NEPA documents for numerous commercial, residential, and industrial projects (*e.g.*, power plants, airports, residential developments, retail developments, university expansions, hospitals, refineries, slaughterhouses, asphalt plants, food processing facilities, slaughterhouses, feedlots, printing facilities, mines, quarries, landfills, and recycling facilities) and provided litigation support in a number of cases filed under CEQA.
- Critically reviewed and prepared technical comments on the air quality and public health sections of the Los Angeles Airport Master Plan (Draft, Supplement, and Final Environmental Impact Statement/Environmental Impact Report) for the City of El Segundo. Provided technical comments on the Draft and Final General Conformity Determination for the preferred alternative submitted to the Federal Aviation Administration.
- Prepared comments on proposed PSD and Title V permit best available control technology ("BACT") analysis for greenhouse gas emissions from a proposed direct reduced iron facility in Louisiana.
- Prepared technical comments on U.S. Environmental Protection Agency ("EPA")'s *Inhalation of Fugitive Dust: A Screening Assessment of the Risks Posed by Coal Combustion Waste Landfills* prepared for EPA's proposed coal combustion waste landfill rule.
- Prepared technical comments on the potential air quality impacts of the California Air Resources Board's *Proposed Actions to Further Reduce Particulate Matter at High Priority California Railyards.*
- For several California refineries, evaluated compliance of fired sources with Bay Area Air Quality Management District Rule 9-10. This required evaluation and review of hundreds of source tests to determine if refinery-wide emission caps and compliance monitoring provisions were being met.
- Critically reviewed and prepared technical comments on draft Title V permits for several refineries and other industrial facilities in California.
- Evaluated the public health impacts of locating big-box retail developments in densely populated areas in California and Hawaii. Monitored and evaluated impacts of diesel exhaust emissions and noise on surrounding residential communities.
- In conjunction with the permitting of several residential and commercial developments, conducted studies to determine baseline concentrations of diesel exhaust particulate matter using an aethalometer.
- For an Indiana steel mill, evaluated technology to control NOx and CO emissions from fired sources, including electric arc furnaces and reheat furnaces, to establish BACT. This required a comprehensive review of U.S. and European operating experience. The lowest emission levels were being achieved by steel mills using selective catalytic reduction ("SCR") and selective non-catalytic reduction ("SNCR") in Sweden and The Netherlands.

- For a California petroleum coke calciner, evaluated technology to control NOx, CO, VOCs, and PM10 emissions from the kiln and pyroscrubbers to establish BACT and LAER. This required a review of state and federal clearinghouses, working with regulatory agencies and pollution control vendors, and obtaining and reviewing permits and emissions data from other similar facilities. The best-controlled facilities were located in the South Coast Air Quality Management District.
- For a Kentucky coal-fired power plant, identified the lowest NOx levels that had been permitted and demonstrated in practice to establish BACT. Reviewed operating experience of European, Japanese, and U.S. facilities and evaluated continuous emission monitoring data. The lowest NOx levels had been permitted and achieved in Denmark and in the U.S. in Texas and New York.
- In support of efforts to lower the CO BACT level for power plant emissions, evaluated the contribution of CO emissions to tropospheric ozone formation and co-authored report on same.
- Critically reviewed and prepared technical comments on applications for certification ("AFCs") for numerous natural-gas fired, solar, biomass, and geothermal power plants in California permitted by the California Energy Commission. The comments addressed construction and operational emissions inventories and dispersion modeling, BACT determinations for combustion turbine generators, fluidized bed combustors, diesel emergency generators, etc.
- Critically reviewed and prepared technical comments on draft PSD permits for several natural gas-fired power plants in California, Indiana, and Oregon. The comments addressed emission inventories, greenhouse gas emissions, BACT, case-by-case MACT, compliance monitoring, cost-effectiveness analyses, and enforceability of permit limits.
- For a California refinery, evaluated technology to control NOx and CO emissions from CO Boilers to establish RACT/BARCT to comply with BAAQMD Rule 9-10. This required a review of BACT/RACT/LAER clearinghouses, working with regulatory agencies across the U.S., and reviewing federal and state regulations and State Implementation Plans ("SIPs"). The lowest levels were required in a South Coast Air Quality Management District rule and in the Texas SIP.
- In support of several federal lawsuits filed under the federal Clean Air Act, prepared cost-effectiveness analyses for SCR and oxidation catalysts for simple cycle gas turbines and evaluated opacity data.
- Provided litigation support for a CEQA lawsuit addressing the adequacy of pollution control equipment at a biomass cogeneration plant.
- Prepared comments and provided litigation support on several proposed regulations including the Mojave Desert Air Quality Management District Rule 1406 (fugitive dust emission reduction credits for road paving); South Coast Air Quality Management District Rule 1316, San Joaquin Valley Air Pollution Control District Rule 2201, Antelope Valley Air Quality Management District Regulation XIII, and Mojave Desert Air Quality Management District Regulation XIII (implementation of December 2002 amendments to the federal Clean Air Act).
- Critically reviewed draft permits for several ethanol plants in California, Indiana, Ohio, and Illinois and prepared technical comments.

- Reviewed state-wide average emissions, state-of-the-art control devices, and emissions standards for construction equipment and developed recommendations for mitigation measures for numerous large construction projects.
- Researched sustainable building concepts and alternative energy and determined their feasibility for residential and commercial developments, *e.g.*, regional shopping malls and hospitals.
- Provided comprehensive environmental and regulatory services for an industrial laundry chain. Facilitated permit process with the South Coast Air Quality Management District. Developed test protocol for VOC emissions, conducted field tests, and used mass balance methods to estimate emissions. Reduced disposal costs for solvent-containing waste streams by identifying alternative disposal options. Performed health risk screening for air toxics emissions. Provided permitting support. Renegotiated sewer surcharges with wastewater treatment plant. Identified new customers for shop-towel recycling services.
- Designed computer model to predict performance of biological air pollution control (biofilters) as part of a collaborative technology assessment project, co-funded by several major chemical manufacturers.
- Experience using a wide range of environmental software, including air dispersion models, air emission modeling software, database programs, and geographic information systems.

Water Quality and Pollution Control

Experience in water quality and pollution control, including surface water and ground water quality and supply studies, evaluating water and wastewater treatment technologies, and identifying, evaluating and implementing pollution controls. Some typical projects include:

- Evaluated impacts of on-shore oil drilling activities on large-scale coastal erosion in Nigeria.
- For a 500-MW combined-cycle power plant, prepared a study to evaluate the impact of proposed groundwater pumping on local water quality and supply, including a nearby stream, springs, and a spring-fed waterfall. The study was docketed with the California Energy Commission.
- For a 500-MW combined-cycle power plant, identified and evaluated methods to reduce water use and water quality impacts. These included the use of zero-liquid-discharge systems and alternative cooling technologies, including dry and parallel wet-dry cooling. Prepared cost analyses and evaluated impact of options on water resources. This work led to a settlement in which parallel wet dry cooling and a crystallizer were selected, replacing 100 percent groundwater pumping and wastewater disposal to evaporation ponds.
- For a homeowner's association, reviewed a California Coastal Commission staff report on the replacement of 12,000 linear feet of wooden bulkhead with PVC sheet pile armor. Researched and evaluated impact of proposed project on lagoon water quality, including sediment resuspension, potential leaching of additives and sealants, and long-term stability. Summarized results in technical report.

Applied Ecology, Industrial Ecology and Risk Assessment

Experience in applied ecology, industrial ecology and risk assessment, including human and ecological risk assessments, life cycle assessment, evaluation and licensing of new chemicals, and fate and transport studies of contaminants. Experienced in botanical, phytoplankton, and intertidal species identification and water chemistry analyses. Some typical projects include:

- Conducted technical, ecological, and economic assessments of product lines from agricultural fiber crops for European equipment manufacturer; co-authored proprietary client reports.
- Developed life cycle assessment methodology for industrial products, including agricultural fiber crops and mineral fibers; analyzed technical feasibility and markets for thermal insulation materials from natural plant fibers and conducted comparative life cycle assessments.
- For the California Coastal Conservancy, San Francisco Estuary Institute, Invasive Spartina Project, evaluated the potential use of a new aquatic pesticide for eradication of non-native, invasive cordgrass (*Spartina spp.*) species in the San Francisco Estuary with respect to water quality, biological resources, and human health and safety. Assisted staff in preparing an amendment to the Final EIR.
- Evaluated likelihood that organochlorine pesticide concentrations detected at a U.S. naval air station are residuals from past applications of these pesticides consistent with manufacturers' recommendations. Retained as expert witness in federal court case.
- Prepared human health risk assessments of air pollutant emissions from several industrial and commercial establishments, including power plants, refineries, and commercial laundries.
- Managed and conducted laboratory studies to license pesticides. This work included the evaluation of the adequacy and identification of deficiencies in existing physical/chemical and health effects data sets, initiating and supervising studies to fill data gaps, conducting environmental fate and transport studies, and QA/QC compliance at subcontractor laboratories. Prepared licensing applications and coordinated the registration process with German environmental protection agencies. This work led to regulatory approval of several pesticide applications in less than six months.
- Designed and implemented database on physical/chemical properties, environmental fate, and health impacts of pesticides for a major multi-national pesticide manufacturer.
- Designed and managed experimental toxicological study on potential interference of delta-9-tetrahydrocannabinol in food products with U.S. employee drug testing; co-authored peer-reviewed publication.
- Critically reviewed and prepared technical comments on applications for certification for several natural-gas fired, solar, and geothermal power plants and transmission lines in California permitted by the California Energy Commission. The comments addressed avian collisions and electrocution, construction and operational noise impacts on wildlife, risks from brine ponds, and impacts on endangered species.
- For a 180-MW geothermal power plant, evaluated the impacts of plant construction and operation on the fragile desert ecosystem in the Salton Sea area. This work included baseline noise monitoring and assessing the impact of noise, brine handling and disposal, and air emissions on local biota, public health, and welfare.

- Designed research protocols for a coastal ecological inventory in Southern California; developed sampling methodologies, coordinated field sampling, determined species abundance and distribution in intertidal zone, and conducted statistical data analyses.
- Designed and conducted limnological study on effects of physical/chemical parameters on phytoplankton succession; performed water chemistry analyses and identified phytoplankton species; co-authored two journal articles on results.

PRO BONO ACTIVITIES

Founding member of "SecondAid," a non-profit organization providing tsunami relief for the recovery of small family businesses in Sri Lanka. (www.secondaid.org.)

PUBLICATIONS & RECOMMENDATIONS

Available upon request.

159206

HIGHWAY MORTALITY OF TURTLES AND OTHER HERPETOFAUNA AT LAKE JACKSON, FLORIDA, USA, AND THE EFFICACY OF A TEMPORARY FENCE/CULVERT SYSTEM TO REDUCE ROADKILLS

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Abstract: I investigated highway mortality and the attempted crossings of turtles and other herpetofauna from 2000-2003 on a 1.2-km-section of a four-lane highway crossing Lake Jackson, Florida. U.S. Highway 27 was built directly through the northwest arm of Lake Jackson, separating a 21-ha portion of the lake to the west (now known as "Little Lake Jackson"). U.S. Highway 27 is a virtually impassable barrier to wildlife (21,500 vehicles per day) and prevents normal movements, dispersal, and migration of most species both during non-drought periods and periodic natural drydowns (on average every 12 yrs). During periods of drought, Little Lake Jackson maintains water and is the destination for large numbers of migrating turtles and other wildlife that leave the drying lake until it refills. The objectives of this study were to: (1) determine the level of road mortality and attempted crossings of turtles and other herpetofauna, (2) examine the potential effects of road mortality on turtle demography including sex ratios and female population size, and (3) design and evaluate the effectiveness of a temporary drift fence-culvert system to both reduce road mortality and facilitate migration. Two drift fences (885 and 600m) were constructed to divert animals away from the north and southbound lanes and direct them into an existing 3.5-m-diameter culvert. Monitoring of road kills and attempted crossings consisted of multiple daily surveys for 43 months (5558 h) including a pre-fence (40 d) and post-fence (1274 d) survey during a drought migration and non-drought conditions.

A total of 10,180 reptiles and amphibians of 44 species were found either road killed or alive behind drift fences: 8,833 turtles, 825 frogs, 344 snakes, 145 lizards, 31 alligators, and 2 salamanders. Diversity among taxonomic groups included 10 species of turtles, 15 species of snakes, 10 species of anurans, 6 species of lizards, 2 salamander species, and 1 crocodilian. Drift fences combined with intensive monitoring greatly reduced turtle road kills and facilitated the use of an under-highway culvert. Pre-fence turtle mortality (9.7/km/day) was significantly greater than post-fence mortality (0.08/km/day), and only 84 of 8,466 turtles climbed or penetrated the temporary fences. Pre-fence data provided strong evidence that turtles cannot successfully cross all four lanes of U.S. Highway 27, with 95 percent of 343 turtles killed as they first entered the highway adjacent to the shoulder and the remaining five percent killed in the first two traffic lanes. I used the equation, $P_{killed} = 1 - e^{-Na/v}$, to estimate the probability of being struck in one attempted crossing of U.S. Highway 27, where N is traffic rate in vehicles/lane/sec during 80 percent of daily volume, a = width of the kill zone (2 tire widths per lane plus 2 times weighted average shell length of 5 species), and v = turtle velocity (m/sec). Solving this equation results in a 98 percent probability of a turtle being killed in one attempted crossing, closely matching my direct observations. Using this model and historic traffic data, the probability of a turtle successfully crossing U.S. Highway 27 decreased from 32 percent in 1977 to only two percent in 2001. Therefore, at least 98 percent of turtles diverted by the fences would have been killed on U.S. Highway 27 during this study if fences were not in place, and the road kill rate is estimated at 1,294/km/yr. Based on a literature survey, this is the highest attempted crossing rate ever documented for turtles. Sex ratios (M:F) of *Pseudemys floridana* (4:1), *Trachemys scripta* (3:1), and *Sternotherus odoratus* (2:1) were significantly male-biased and low numbers of mature females are likely due to 5-10 percent annual road mortality during attempted nesting forays. Because of demographic and life history constraints, turtle populations cannot compensate for the combined effects of annual road mortality (5-10%) and periodic mass road mortality (95-99%) during lake dry-downs.

Introduction

Highways can be detrimental to wildlife populations by causing significant levels of direct mortality and habitat fragmentation. Differential road mortality within populations can affect the demography and the dynamics of populations (Mumme et al. 2000). Highways can create impassable barriers to migration, dispersal, and genetic exchange within populations (Wilkins 1982, Reh and Seitz 1990; Vos and Chardon 1998). In addition, population and community-level effects can alter how adjacent ecosystems function. Thus, understanding the ecological consequences of highways and developing ways to mitigate their effects has become an important field of conservation biology (Oxley et al. 1974, Mader 1984, Rodda 1990, Rosen and Lowe 1994, Groot Bruinderink and Hazebroek 1996, Forman and Alexander 1998, Trombulak and Frissell 2000).

Before current wetland protection laws were enacted, thousands of miles of roads constructed through wetlands caused direct habitat loss, habitat fragmentation, and habitat degradation via dredging and filling and alteration of hydrologic regimes (Evink 1980, Johnston 1994, Mitsch and Gosselink 2000). Prior to the mid-1970's, highways were planned and constructed without consideration of their ecological damage (Adamus 1983, Forman et al. 1997).

Reptiles and amphibians are among the fauna most negatively affected by poor transportation planning associated with wetlands and their mortality can be significant (Ehmann and Cogger 1985, Fahrig et al. 1995, Ashley and Robinson 1996, Clevenger et al. 2001, Smith and Dodd 2003). Highways can be significant barriers to breeding migrations, seasonal and/or drought migrations due to water level fluctuations, and normal foraging forays and dispersal of reptiles and amphibians (Bernadino and Dalrymple 1992, Gibbs 1998, Carr and Fahrig 2001). The "road-effect zone," the maximum distance from a road at which significant ecological effects can be detected, varies depending on the maximum movement distance and frequency

(from <200m for sedentary species to >2.0km for turtles, crocodilians, and some frogs (Forman and Alexander 1998, Forman 2000, Carr and Fahrig 2001). Thus, road mortality can reduce the densities of reptiles and amphibians in wetlands for substantial distances from highways and can cause population declines and other negative demographic effects, such as altered sex ratios (Kuslan 1988, Fahrig et al. 1995).

The objectives of this study were to: (1) determine the level of road mortality and attempted crossings of turtles and other herpetofauna on a highway built through a northern Florida lake, (2) examine the potential effects of road mortality on the sex ratios and female population sizes of turtles, and (3) design and evaluate the effectiveness of a temporary drift fence-culvert system to reduce road mortality and to facilitate migration. The design of the temporary ecopassage used vinyl fencing as a guiding structure to divert animals through an existing under-highway drainage culvert. The overall goals were to document road mortality and attempted crossing rates of reptiles and amphibians and to conserve these species until a permanent ecopassage is constructed.

Methods

This study was conducted at Lake Jackson, a 1,620ha lake 11km north of Tallahassee in northwestern Florida, USA. Lake Jackson is a closed basin, and the water depth fluctuates widely. Water level is controlled naturally by variation in rainfall and by two sinkholes. During drought conditions, a lowering of the water table causes leakage into the groundwater through the sinkholes and most of the lake bottom dries, an event that has occurred nine times during the last 100 years (1907, 1909, 1932, 1935, 1936, 1957, 1982, 1999, 2002), drying on average every 12 years (Hughes 1967, Wagner 1984, Carr 1994). Lake Jackson is designated as an Aquatic Preserve by the State of Florida.

From 1963-1965, U.S. Highway 27 was rebuilt as a four-lane, divided highway on a raised road-bed (2.1m above normal high water) directly across a 300m part of Lake Jackson and on 1,000m of the lake shoreline, completely isolating a 21ha portion of the lake to the west (now known as "Little Lake Jackson") (fig. 1). A 3.5m diameter x 46.6m-long round, corrugated metal drainage culvert under U.S. Highway 27 is now the only connection between Lake Jackson and Little Lake Jackson. Presently, U.S. Highway 27 receives an average traffic flow of 21,500 vehicles per day (224 vehicles/lane/hour) and is a major truck route connecting Interstate 10 to destinations in Georgia and Alabama (FDOT 2002).

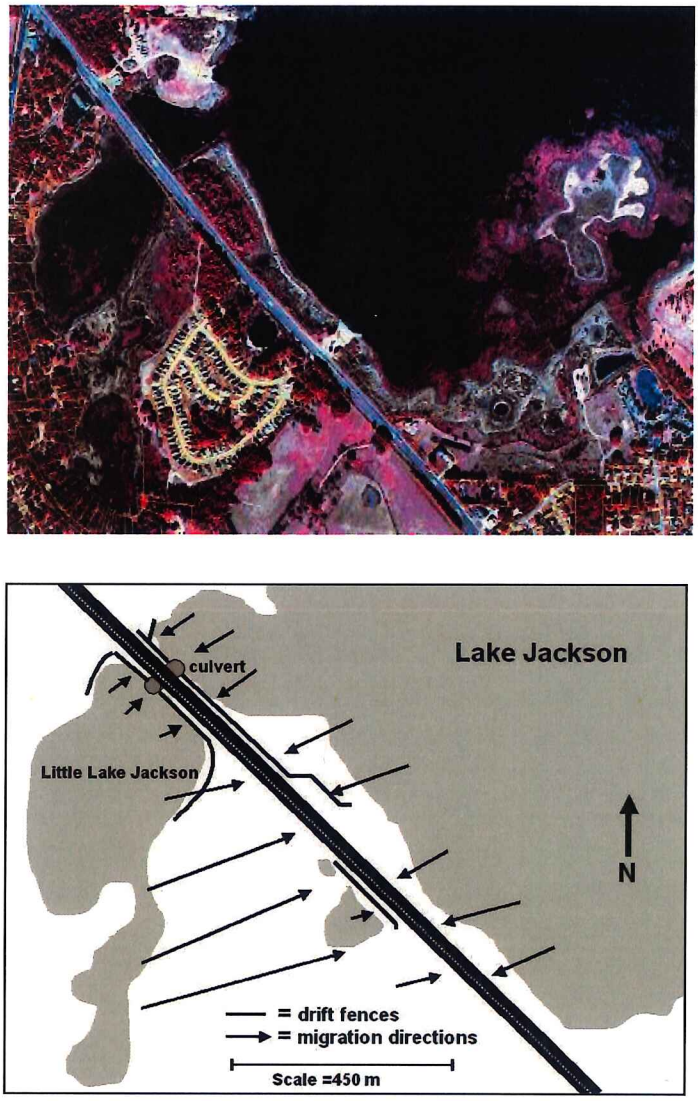

Fig. 1. Aerial photo (above) showing U.S. Highway 27 (center), Lake Jackson (right), and Little Lake Jackson (left) and study area map showing the location of temporary fences and culvert. Arrows indicate direction of migrations by turtles and other herpetofauna.

A large migration of turtles occurred during this study in response to the natural dry down of Lake Jackson in 2000 and the subsequent refilling of the lake in 2001. As Lake Jackson dried, turtles and other herpetofauna emigrated to the west towards Little Lake Jackson, which held water throughout the drought. Heavy rain associated with two tropical storms caused Lake Jackson to refill in 2001, and turtles migrated back from Little Lake Jackson. In 2002-2003, both Lake Jackson and Little Lake Jackson held water.

Monitoring and Fence Design

My daily surveying consisted of two intervals: a pre-fence survey of road kills (22 February - 3 April 2000) and a post-fence survey of the highway and fences (4 April 2000 - 8 September 2003). In the pre-fence survey, I searched the highway, right-of-way, and grassy median of both the north and southbound lanes for live and dead animals two to four times daily between 22 February and 3 April 2000.

Because of the high number of road-killed animals found during the pre-fence survey, I designed and constructed a temporary barrier consisting of 0.6m high woven vinyl erosion control fencing with pre-attached

wooden stakes. The fence was installed at the edge of the mowed right-of-way along 885m of U.S. Highway 27N during 31 March - 4 April 2000. The bottom edge was buried ca. 20cm so that the above-ground height of the fence was ca. 0.4m. The barrier was designed to work as a drift fence and divert animals away from the highway and direct them into the under-highway culvert (fig. 1). The north and south ends of the fences were turned back gradually towards the lake at least 80-100 m to prevent animals from simply wandering around the ends and onto the highway (fig .1). From 8-11 September 2000, a 600m fence of the same design was installed along the right-of-way and shore of Little Lake Jackson on the west side of U.S. Highway 27 (fig. 1). On 26-27 April 2002, I constructed a 118m fence along the roadside margin of a 0.6ha pond located on the west side of U.S. Highway 27 opposite Lake Jackson.

All fences were monitored for migrating animals daily from the date of construction to 8 September 2003. I walked along the inside edge of the entire length of each fence. I monitored the fences four times daily in 2000 and 2001 (0900-1100h, 1200-1400h, 1600-1700h, 1800h-2000h) and two times daily in 2002-2003 (1100-1200h and 1600-1700h). In addition, both the culvert and roadway were monitored for live and dead animals. Total sampling effort was 1,314 days and a total of 5,558h. The identity and number of tracks observed on the sand and mud in the culvert were recorded whenever possible. From November-February, daily monitoring of fences was reduced to once per day during months of reduced activity of herpetofauna, and the fences were not monitored when the maximum daytime temperature fell below 14° C.

I recorded the identity and number of all species observed, captured, or found dead. The location of each road kill on the highway was also recorded. All road kills were removed from the highway to assure that they were counted only once. I collected all animals along each fence, placed them in large plastic containers, and transported and released them on the opposite side of the highway (in the direction that they were traveling) at the edge of the water. Terrestrial species (e.g., black racer, *Coluber constrictor*, five-lined skink, *Eumeces fasciatus)* and some semi-aquatic species (e.g., leopard frog, *Rana sphenocephala*) observed along the fences were not transported across the highway unless they were obviously attempting to cross the fence and move directly towards the road. Green anoles (*Anolis carolinensis*) were abundant on the fences and in the adjacent vegetation, and numbers of this species were not counted. Nesting females, gravid females searching for nest sites (i.e., voiding large volume of bladder-fluid when handled; or post-nesting females, (i.e., soil on rear margin of shell and rear legs) were left alone and not transported across the highway.

Animals found alive or dead along the fences or on the highway were placed into one of five categories: (1) alive at fence (LAF), (2) alive on road (AOR), (3) alive on drying lake bottom adjacent to fences (LOB), (4) dead at fence (DAF), or (5) dead on road (DOR). Animals classified as LOB were primarily turtles that were collected as they left drying pools and began migrating towards the highway.

Sex Ratios and Estimates of Numbers of Mature Females

In most studies of freshwater turtles, sex ratios of individual species and female population size are difficult to assess accurately because of sampling biases, variation in local conditions, and differences in habitat preference (Bury 1979, Lovich and Gibbons 1990). However, because of the unique situation at Lake Jackson (i.e., all individuals of all species were migrating from the drying lake in one direction in 2000), I was able to obtain nearly complete data on absolute abundance and population structure including sex ratios and total number of mature females of individual species. In order to examine possible demographic effects of long-term road mortality, I determined if sex ratios of five turtle species differed from 1:1. For inclusion in this analysis, I only included adult turtles (of the known minimum size at maturity for each sex) captured during the initial migration in 2000. Sex ratios were tested for significant deviation from 1:1 with Chi-square tests at an alpha level of 0.05. The road shoulder and fences were monitored for nesting female turtles and depredated turtle nests. Nesting females, gravid females searching for nest sites (i.e., voiding large volume of bladder-fluid when handled; Jackson and Walker 1997), or post-nesting females (i.e., soil on rear margin of shell and rear legs) were left alone and not transported across the highway.

Mark-Recapture of Turtles and Estimating Number of Individual Crossings

I measured and sexed all turtles and individually marked 16 percent of Florida cooters (*Pseudemys floridana*), 10 percent of yellow-bellied sliders (*Trachemys scripta*), and 34 percent of eastern mud turtles (*Kinosternon subrubrum*). In 2001, all captured Florida softshells (*Apalone ferox*) (n=95) were individually marked using specially engraved Monel cattle-ear tags attached to the rear margin of the carapace.

In order to estimate the proportion of turtles that moved from Little Lake Jackson to Lake Jackson that were already counted when migrating earlier from Lake Jackson to Little Lake Jackson, I used recapture rates of marked turtles to estimate the total number of turtles encountered (number of individuals = total captures - (total post-fence captures x proportion of marked individuals recaptured). I did not use a standard mark-

recapture method to estimate population size (e.g., Jolly-Seber method) because I did not initially mark all captured individuals migrating from Lake Jackson in 2000.

Funnel Trapping
In order to determine the number and species of reptiles and amphibians that may not be encountered during daylight monitoring of fences and highway, I sampled these species with single-entrance screen funnel traps in October-November 2002. Seven traps were placed every 10 m on the inside of the Little Lake Jackson fence along 10 percent of the fence adjacent to the southbound lane of U.S. Highway 27 and checked twice daily.

Evaluating the Effectiveness of Temporary Fences
I evaluated the effectiveness of the temporary fences in reducing road mortality of turtles by comparing the rate of DOR+AOR turtles (turtles/km/day) found on the 885m stretch of highway before and after fences were installed. I also compared the number of DOR+AOR turtles found on the highway adjacent to the fences to those found on the 300m stretch of highway south of the fences during the post-fence period (4 April 2000 – 8 September 2003). I used Chi-square tests for both comparisons.

Results

Summary of Highway Monitoring
In 43 consecutive months, a total of 10,180 reptiles and amphibians of 44 different species was found either behind the fences or on the highway (Appendix 1). In total, I recorded 8,833 turtles (86.8% of captures), 825 frogs (8.1%), 344 snakes (3.4%), 145 lizards (1.4%), 31 alligators (0.3%), and 2 salamanders (fig. 2). Diversity among taxonomic groups included 10 species of turtles, 15 species of snakes, 10 species of anurans, 6 species of lizards, 2 salamander species, and 1 crocodilian (American alligator, *Alligator mississippiensis*) (Appendix 1).

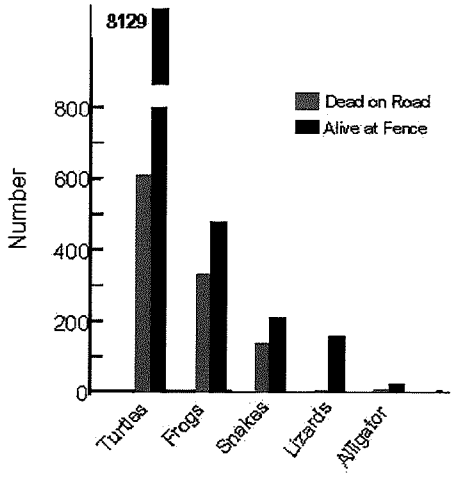

Fig. 2. Number of individuals of each taxon of reptiles and amphibians recorded alive at fences or dead on U.S. Highway 27, Lake Jackson, Florida.

Turtle road mortality and number of attempted crossings
From Feb 2000 - Sept 2003, 4,920 turtles (56%) were found along the Lake Jackson side of U.S. Highway 27 and 3,913 (44%) along the Little Lake Jackson side. Ninety-nine percent of turtles were recorded from March-September. Prior to the construction of the temporary fences, 343 turtles were found DOR on U.S. Highway 27 in 40 days (22 Feb - 3 April 2000) and 24 turtles DOR on U.S. Highway 27 along Little Lake Jackson in 4 days (8-11 September 2000). Following construction of the temporary fences, 8,466 turtles were found along the 1220m on or along the north and southbound lanes of U.S. Highway 27. This total includes 7,526 LAF, 548 LOB, 242 DOR, 95 DAF, and 55 AOR (table 1).

Table 1
Summary data of 10 turtle species found alive behind the fences or on U.S. Highway 27 at Lake Jackson from 22 February 2000 – 8 September 2003. Each individual was classified as alive at fence (LAF), dead on road (DOR), alive on road (AOR), dead behind fence (DAF), or alive on drying lake bottom adjacent to fences (LOB).

Species	*Total*	*LAF*	*DOR*	*AOR*	*DAF*	*LOB*
Apalone ferox	250	206	25	9	1	9
Chelydra serpentina	17	6	5	1	1	4
Deirochelys reticularia	2	2	0	0	0	0
Gopherus polyphemus	4	0	2	2	0	0
Kinosternon subrubrum	95	75	20	0	0	0
Pseudemys concinna	3	2	0	0	0	1
Pseudemys floridana	3695	3303	276	10	68	38
Sternotherus odoratus	775	449	61	7	4	254
Terrapene carolina	18	15	2	1	0	0
Trachemys scripta	3974	3468	218	25	21	242
Total	8833	7526	609	55	95	548

Overall, from 22 Feb - 7 Sept 2000, 4,177 turtles were transported alive across U.S. Highway 27 from Lake Jackson to Little Lake Jackson. Turtles began migrating back to Lake Jackson following heavy rain in early September and a tropical storm on 22 September 2000. From March-June 2001, turtles migrated from Little Lake Jackson back to Lake Jackson as it refilled following heavy early spring rains and a tropical storm (11 June 2001).

Many of the same individuals that were transported across U.S. Highway 27 during the initial migration in 2000 (n=4177) were probably captured again during the return migration in September 2000 and in 2001. Thus, the total number of turtles counted (n=8833) probably represents more than one attempted crossing by many individuals. I used recapture rates of marked turtles to estimate the total number of individual turtles encountered while attempting to cross U.S. Highway 27. Of the 572 *P. floridana* marked during the initial migration from Lake Jackson in 2000, 48 percent (n=236) were recaptured in 2001 during the return migration. Except for *P. floridana*, no other turtle species were marked during the 2000 migration. However, in late 2000 - early 2001, 384 *T. scripta* were marked and released at Little Lake Jackson, and 31 percent (n=119) were later recaptured at the Little Lake Jackson fence as they migrated back to Lake Jackson. In addition, 32 *K. subrubrum* were marked in 2001 with 7 recaptures and 95 *A. ferox* were marked in 2001 with 13 recaptures. In total, 1,185 of 8,466 post-fence turtles were marked, and 33 percent (n=389) were recaptured. Based on the total recapture rate of 33 percent, I estimated that 2794 turtles were captured twice (during both the initial and return migrations), and thus the total number of individual turtles encountered including pre-fence DOR turtles was approximately 5,672.

Efficacy of the Drift Fences for Turtles

The road mortality rate of turtles was significantly less after fences (0.08 DOR/km/day) were installed compared to before (9.7 DOR/km/day) (Chi-square 9.46; P = 0.002). After the fences were constructed, significantly fewer turtles were found DOR at the fences than on the road south of the fences. In total, 84 turtles were found DOR+AOR at the fence array and 213 DOR+AOR on the highway to the south of the fences (Table 2) (Chi-square = 56.1; P < 0.0001). Thus, only 84 of 8466 (<1%) turtles found post-fence construction actually accessed the highway by climbing or penetrating the temporary fences.

Table 2.
Pre-fence (40 days) and post-fence (1,274 days) comparisons of DOR+AOR turtles on U.S. Highway 27 at Lake Jackson. The location of post-fence turtles was classified as either "At fence" (on U.S. Highway 27 next to the fences) or "Not at fence" (on the 300m stretch of highway south of the fence array).

Species	Pre-fence	Post-fence		Total
		At fence	Not at fence	DOR+AOR
Apalone ferox	0	5	29	34
Chelydra serpentina	1	2	3	6
Kinosternon subrubrum	16	0	4	20
Gopherus polyphemus	0	0	4	4
Pseudemys floridana	217	21	48	286
Sternotherus odoratus	19	39	10	68
Terrapene carolina	0	0	3	3
Trachemys scripta	114	17	112	243
Total	367(55%)	84(13%)	213 (32%)	664

The two most abundant turtle species at U.S. Highway 27 were *T. scripta* and *P. floridana* (table 1). Of 3,974 *T. scripta*, 243 were found DOR+AOR, 114 found pre-fence construction (40 d) and 129 found post-fence construction (1274 d) (tables 1 and 2). Of 3,695 *P. floridana*, 286 were found DOR+AOR, including 76 percent pre-fence and 24 percent post-fence construction (tables 1 and 2). The common musk turtle, *Sternotherus odoratus* represented 8.8 percent of all turtles (n=775) and 68 were found DOR+AOR (table 1). *S. odoratus* demonstrated the greatest ability to climb the fences and represented 46% (n=39) of all turtles found DOR+AOR at the fences after construction. In contrast, *T. scripta* and *P. floridana* combined were 10 times more abundant than *S. odoratus* but represented the same percent of DOR+AOR turtles. Of 220 *A. ferox*, 34 were found DOR+AOR including 5 individuals that climbed over the fences and 29 that attempted to cross on the 300m stretch of highway south of the fence array (tables 1 and 2). *K. subrubrum* exhibited the greatest level of road mortality relative to their abundance. Twenty of 93 *K. subrubrum* were found DOR, 16 pre-fence construction and four that walked around the end of the fence array (tables 1 and 2). Although they represented only 1.1 percent of all turtles, their relative abundance among DOR turtles was 3.3 percent.

Sex Ratios of Turtles and Numbers of Nesting Females and Hatchlings on the Highway

Sex ratios of *P. floridana*, *T. scripta*, and *S. odoratus* were significantly male-biased (Table 3). Number of mature females of *P. floridana* and *T. scripta* represented only 25% and 36% of the total adult population, respectively.

Table 3
Sex ratios and numbers of mature females of five turtle species encountered during the 2000 migration at northwest Lake Jackson and U.S. Highway 27. *P*-values < 0.05 indicate adult male-female ratios that are significantly different from 1:1.

Species	Males	Females	M:F ratio	*P*
Trachemys scripta	1478	539	2.7	<0.0001
Pseudemys floridana	1386	350	4.0	<0.0001
Sternotherus odoratus	293	156	1.9	<0.0001
Apalone ferox	29	23	1.3	NS
Kinosternon subrubrum	14	16	1.0	NS

I observed 221 female turtles nesting directly behind the fences on the road shoulder in 2001-2003. Based on the numbers of adult females counted during the mass migration from Lake Jackson, I estimated that the number of females of each species nesting annually along U.S. Highway 27 represented the following proportions of reproductive females in each population: 6 percent of *P. floridana*, 7 percent of *T. scripta*, 6 percent of *S. odoratus*, and 13 percent of *A. ferox*. Table 4 shows the number of adult males and females

found at the fences or on the highway during non-drought years. The observed numbers of females are significantly greater than that expected if turtles were moving on land in numbers equal to the actual population sex ratios (table 4). These data indicate that during non-drought years, female turtles move overland more frequently than males and, thus, have a greater probability of being killed by vehicles, and this may explain the observed male-biased sex ratios.

Table 4
Comparison of the observed and expected number adults of each sex found on land adjacent to or on U.S. Highway 27 at Lake Jackson, Florida in 2002-2003. P-values < 0.05 indicate adult male-female ratios that are significantly different from expected ratios based on population sex ratios.

Species	Observed	Expected	Actual Sex Ratio	*P*
T. scripta				
Male	53	135	2.7:1	<0.0001
Female	132	50		(chi-square=185)
P. floridana				
Male	50	94	4:1	<0.0001
Female	67	23		(chi-square=105)
S. odoratus				
Male	18	39	2:1	<0.0001
Female	42	21		(chi-square=32.3)
A. ferox				
Male	10	22	1.3:1	<0.0001
Female	30	18		(chi-square=14.5)

From 2000-2003, 93 hatchling turtles were found on or along U.S. Highway 27, including 50 *T. scripta*, 34 *P. floridana*, 4 *S. odoratus*, 3 *A. ferox*, and 2 common snapping turtles, *Chelydra serpentina*. Of these 93 hatchlings, 37 percent were DOR.

Road Mortality and Attempted Crossings of Other Herpetofauna and Efficacy of Drift Fences
Other than turtles, 1,064 of 1,346 (79%) of the reptile and amphibian species observed at the fences or on the highway were terrestrial (e.g., *C. constrictor*, corn snake, *Elaphe guttata*, southern toad, *Bufo terrestris*) and semi-aquatic species (e.g., *R. sphenocephala*, cottonmouth, *Agkistrodon piscivorus*, cricket frog, *Acris gryllus*). The upland and semi-aquatic species were often observed foraging or basking in the vegetation at the fences. In total, of the 1,064 upland and semi-aquatic species observed, 26 percent were DOR and 74 percent were LAF. Therefore, three-quarters of the upland and semi-aquatic species either remained at the fences or were diverted from the highway. In contrast, aquatic species had higher road mortality rates. I recorded 282 individuals of aquatic species (e.g., pig frog, *Rana grylio*, water snakes, *Nerodia* spp.), with 76 percent DOR, 22 percent LAF, and 2 percent DAF. Not including turtles, the temporary fences were able to prevent only one-quarter of the aquatic species from being killed on the highway. All of the aquatic, semi-aquatic, and terrestrial species were able to climb or scale the temporary silt fence barrier and access the highway (except for the two-toed amphiuma, *Amphiuma means*, Aresco 2002). The temporary fences apparently diverted some species and may have reduced the overall road-kill rate, especially of small anurans (e.g., *B. terrestris*, eastern narrowmouth toad, *Gastrophryne carolinensis*). Alternatively, many small frogs are difficult to find and count after being killed on the highway (e.g., *Acris* and *Gastrophryne*), as they are either completely obliterated or stick to tires and/or vehicles and are carried away from the study site. Therefore, exact numbers of small frogs actually killed on the highway are difficult to obtain and are probably significantly underestimated (see Funnel Trapping below). Ninety-one percent of non-turtle herpetofauna were recorded from March-September.

Funnel Trapping
A total of 211 reptiles and amphibians from 10 species was captured in 7 trap nights for a catch per unit effort (CPUE) of 4.3 animals/trap night in October-November 2002. Trapped animals are not included in the total numbers in Appendix 1. The two most common species trapped were *G. carolinensis* (n=116) and *A. gryllus dorsalis* (n=71). Two species trapped were not previously encountered at fences or DOR, the central newt, *Notophthalmus viridescens louisianensis*, and the greenhouse frog, *Eleutherodactylus planirostris*.

Culvert Use
I observed *T. scripta* (n=6), *P. floridana* (n=8) and *A. ferox* (n=1) moving into or out of the 3.5m diameter culvert. In addition to direct observations, I recaptured two marked turtles at the Little Lake Jackson fence that were previously marked and released on the Lake Jackson side. These turtles probably moved through the culvert back to Little Lake Jackson. Furthermore, in 2000 and 2001, sets of tracks from >200 individual turtles (primarily *T. scripta* and *P. floridana*) were observed on the sand and mud in the culvert, indicating

that these turtles walked through the culvert. I also observed juvenile and adult *A. mississippiensis* (n=5), numerous *R. sphenocephala, R. catesbeiana, R. grylio,* and an *E. guttata* moving through the culvert. Alligator tracks were also frequently observed (>25 sets of tracks). I did not observe any direct predation on turtles by mammals or alligators in or near the culvert, nor did I find any evidence (e.g., turtle carcasses) of predation by mammals at the culvert.

Discussion

Factors Influencing Frequent Highway Crossings

This study documented that U.S. Highway 27 at Lake Jackson, Florida, is a significant source of mortality for reptiles and amphibians, especially turtles, which attempt to cross the highway in both drought and non-drought years. During the 43-month monitoring period, 10,180 individuals of 44 species of reptiles and amphibians were either found dead on U.S. Highway 27 or intercepted by temporary fences before they accessed the highway. The species encountered represented nearly all reptiles and amphibians known to occur in Lake Jackson and adjacent upland habitats. The frequency of attempted crossings and high levels of road mortality are primarily due to two factors. First, the construction of U.S. Highway 27 along the shore and directly across northwest Lake Jackson created a virtually impassable 1,220m barrier to wildlife that prevents normal terrestrial and aquatic movements, such as dispersal, migration, and nesting activities. Second, the water level of Lake Jackson fluctuates widely in a natural pattern that is typical of shallow, sinkhole lakes in northern Florida (Brenner et al. 1990). Variation in rainfall causes both annual fluctuations and periodic partial and complete drying events during drought conditions (every 12 yrs on average). Little Lake Jackson to the west of the main lake has never dried and is the migration destination for large numbers of migrating turtles and other wildlife when Lake Jackson partially or completely dries. This pattern of emigration and immigration during both normal and drought conditions requires wildlife to attempt to cross U.S. Highway 27, resulting in high road mortality, especially of turtles and other herpetofauna.

Road mortality and attempted crossings of turtles on U.S. Highway 27 is clearly greatest when drought conditions cause Lake Jackson to dry and during subsequent return migrations when the lake refills. In this study, 4,818 turtles were found migrating from Lake Jackson during the dry down in 2000 and 3,783 returning from Little Lake Jackson when the lake refilled in early 2001. I estimated that the fence along U.S. Highway 27 intercepted most of the turtles from a 405ha area of the northwest part of Lake Jackson, as well as many turtles that had migrated to the northern part of the lake in 1999 when the southern part dried. During this study, turtles did not move randomly in all directions from the drying lake and demonstrated the ability to detect water from >1km (Gibbons et al. 1983). Turtle tracks in wet mud on the drying lake bottom were easily visible and indicated that almost all individuals moved directly towards U.S. Highway 27. An aerial photograph taken 150m above drying Lime Sink at Lake Jackson on 17 May 2000 shows a distinct line of hundreds of turtle tracks heading to the northwest in the general direction of Little Lake Jackson approximately 2.1km away (Thomas Scott, Florida Geological Survey, pers. comm.). Therefore, turtles were apparently moving nonrandomly towards Little Lake Jackson, the largest remaining body of water to west. These observations indicate that during mass migrations, a large percentage of the Lake Jackson turtle population will attempt to migrate across U.S. Highway 27.

Probability of Road Mortality in an Attempted Crossing

My observations provide strong evidence that few turtles can successfully cross all four lanes of U.S. Highway 27. Pre-fence data indicated that 95 percent of 343 turtles were killed as they first entered the highway adjacent to the shoulder, and the remaining 5 percent were killed in the first two traffic lanes. In February-March 2000, turtles were observed migrating only from Lake Jackson to Little Lake Jackson (east to west) as Lake Jackson was drying and no DOR or AOR turtles were found west of the median. Based on these observations, traffic volume on the four-lane highway (21,500 vehicles per day; 3.7 vehicles/lane/minute), and turtle movements that correspond with 80 percent of daily traffic volume (0700-2000h), these data demonstrate that virtually no turtles can successfully traverse all four lanes. Further, I used the equation of Gibbs and Shriver (2002) modified from Hels and Buchwald (2001) to estimate the probability that a turtle will be killed in one attempted crossing of U.S. Highway 27:

$$P_{killed} = 1 - e^{-Na/v},$$

where N is traffic rate in vehicles/lane/sec during 80 percent of daily volume, a = width of the kill zone (2 tire widths per lane plus 2 times weighted average shell length of 5 species), and v = turtle velocity (m/sec). I estimated average turtle velocity (v) from direct observations of individuals on U.S. Highway at 0.05m/sec and an average kill zone/lane of 2.4m. Solving this equation for 2001 traffic volume gives a 98 percent probability of a turtle being killed in one attempted crossing which closely matches my direct observations (fig.

3). Therefore, it is reasonable to estimate that at least 98 percent of turtles diverted by the fences (5,558 individuals at a rate of 1,294 road kills/km/yr) would have been killed on U.S. Highway 27 during this study if fences were not in place and turtles were allowed to access the highway. Thus, mass migration events in response to periodic natural dry-downs can potentially decimate the entire populations of six turtle species: *T. scripta, P. floridana, S. odoratus, A. ferox, K. subrubrum, and C. serpentina*.

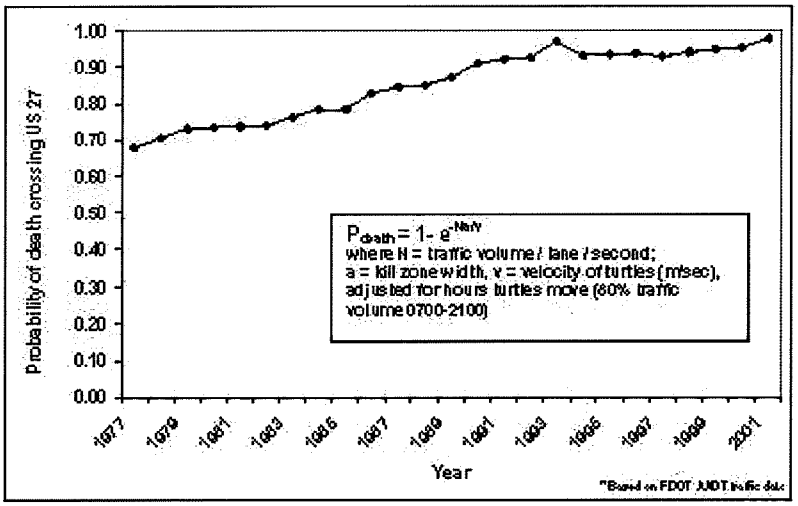

Fig. 3. Annual change in probability of a turtle being killed by a vehicle while attempting to cross U.S. Highway 27 at Lake Jackson as a function of traffic volume (vehicles/lane/second) from 1977-2001 (FDOT 2002). Probability of being killed is calculated using the equation from Gibbs and Shriver (2002) modified from Hels and Buchwald (2001).

Road Mortality Effects on Turtle Population Viability and Demography

Large numbers of turtles are road killed during both periodic dry-downs and in normal years. The mass migration and mortality at U.S. Highway 27 represent turtles from at least 25 percent of the total lake area (400ha northwest sub-basin) and the loss of 25 percent of the entire turtle population every 12 years due to traffic mortality is a severe bottleneck event and a population sink (Pulliam 1988). This mortality alone will likely cause long-term declines that cannot be overcome by immigration from other areas of the lake (Congdon et al. 1993). However, in addition to losses during periodic dry-downs, traffic deaths are also a significant source of mortality for turtles during non-drought years. Frequent terrestrial activity of freshwater turtles is well documented for several species, including *T. scripta, P. floridana, A. ferox, K. subrubrum, C. serpentina*, and the chicken turtle (*Deirochelys reticularia*) (Carr 1952; Bennett et al. 1970; Gibbons 1970; Wygoda 1979; Obbard and Brooks 1980; Gibbons et al. 1983; Buhlmann 1995). Such movements are associated with nesting in spring and summer, annual local migration patterns that correspond to hormone cycles (e.g., movements of male turtles over land in late summer and early spring in search of mates), dispersal of juveniles and subadults, and newly emerging hatchlings searching for water. I found 510 turtles DOR or LAF during non-drought years (2002-2003). These turtles included nesting females, migrating males and juveniles, and hatchlings leaving nests. The high rate of terrestrial recaptures (33%) of turtles in this study demonstrates that aquatic turtles move over land frequently at Lake Jackson. These data suggest that even if a turtle successfully crosses the highway one time, it is likely that it will emigrate back across the highway, with a high probability of being killed by vehicles.

In this study, I found strong evidence of demographic effects of long-term road mortality on female population size and sex ratios of three turtle species. For example, only 25 percent of the adult population of *P. floridana* consisted of mature females (table 3). Previous studies of freshwater turtle populations indicate that normal sex ratios are typically 1:1 to 2:1 ratios of males:females in emydid turtle species with earlier maturing males (Bury 1979; Lovich and Gibbons 1990; Gibbons 1990). In this study, the observed sex ratios are not likely due to habitat-related nest temperatures, as *P. floridana* and *T. scripta* have a different pattern of temperature sex determination (TSD) than *S. odoratus* (Ewert and Nelson 1991), yet all three species showed male-biased ratios. Furthermore, it is also unlikely that differential mortality due to predation by alligators would cause the observed male dominated populations, as alligators prey more heavily on males of *T. scripta* and *P. floridana*, as they are significantly smaller than females (Gibbons et al. 1979). Lastly, differential predation on nesting females by mammalian predators (e.g., raccoons) could reduce the number of adult females, but no nesting

females were found killed by predators on land during three nesting seasons at Lake Jackson (2001-2003). Therefore, significantly male-biased sex ratios of *P. floridana, T. scripta*, and *S. odoratus* at Lake Jackson may be the result of differential mortality of females due to road kills during annual nesting forays. In 2001-2003, 221 nesting females were observed directly along U.S. Highway 27. In non-drought years (2002-2003) significantly more females than males of *T. scripta, P. floridana, S. odoratus,* and *A. ferox* were found on land along the fences adjacent to the highway (table 4). If 5-10 percent of females are killed annually along the highway during nesting season, this level of mortality by itself could be sufficient to cause long-term population declines when combined with relatively slow growth to maturity and low levels of recruitment (e.g., 10-12 yrs for *P. floridana)* (Congdon et al. 1994, Aresco unpubl. data). Hence, it is unlikely that turtle populations at Lake Jackson can compensate for the combined effects of annual road mortality (5-10%) and periodic mass mortality events (95-99%) during lake dry-downs.

Without appropriate baseline data, it may be difficult to detect if turtle populations have already undergone historic declines in population size. In this case, low, but consistent annual road mortality rates may be causing a long-term population decline that will eventually lead to extinction of local populations. Alternatively, recently abundant species may be experiencing dramatic reductions in population size and alterations in demography due to increased traffic volume and greater road kill probability (Gibbs and Shriver 2002). This scenario best fits the case of U.S. Highway 27 and likely many other highways in North America where formerly rural roads that historically allowed successful crossing of some turtles have experienced a 100-200 percent increase in traffic volume over the last two decades (e.g., 162% increase from 1977-2001 at U.S. Highway 27) (National Research Council 1997, FDOT 2002). For example, the probability of a turtle successfully crossing U.S. Highway 27 decreased from 32 percent in 1977 to only 2 percent in 2001 (fig. 4). Lastly, for new road construction, long-lived species with long generation times may exhibit a lag time between current road mortality rates and observable population declines (Doak 1995, Findlay and Bourdages 2000).

Road mortality is an increasingly significant threat to population viability of turtles (Gibbons et al. 2000, Gibbs and Shriver 2002). Recent studies provide strong evidence that local populations of freshwater and terrestrial turtles are reduced along highways by direct traffic mortality and the effects of habitat fragmentation (Mitchell and Klemens 2000). For example, road mortality of five species of turtles on the 3.6km Long Point Causeway on Lake Erie was 716 in four years (50/km/yr) (Ashley and Robinson 1996). On the Cape May peninsula in southern New Jersey, northern diamondback terrapins *(Malaclemys terrapin*) attempt to find nest sites on shoulders of raised roadways built across salt marshes, resulting in high annual road mortality of females (Wood and Herlands 1997). In a seven-year census between 1989-1995, they counted 4020 roadkilled females (23/km/yr). In central Ontario, a three-year study found 31 percent (86 of 279) of *C. serpentina* observed on roads were killed during the nesting season (Haxton 2000). In Montana, large numbers of painted turtles *(C. picta)* are killed while crossing between pothole ponds located on either side of U.S. Highway 93 (e.g., 345 in 2002 on 6.5km) (Fowle 1996, K. Griffin, Univ. of Montana, pers. comm.). During a one-year study of wildlife mortality on a 3.2km stretch of U.S. Highway 441 crossing Paynes Prairie, Florida, 187 turtles were found DOR (58/km/yr) (Smith and Dodd 2003). In the present study at Lake Jackson, Florida, I counted 8,833 turtles either DOR or attempting to cross 1.2km of U.S. Highway 27 in 3.6 years (2056/km/yr). After adjusting for >one capture for some individuals the road-kill rate is estimated at 1,294/km/yr. Although road kill rates of turtles could be greater in some areas, the rate of attempted crossing by turtles at Lake Jackson is presently the highest ever recorded worldwide. Clearly, additional studies should be initiated throughout North America to carefully quantify both direct mortality and demographic effects.

Efficacy of Temporary Fences and Existing Culvert

The temporary fences installed along the right-of-ways at U.S. Highway 27 combined with daily monitoring almost completely eliminated road mortality of turtles. Prior to construction of the fences, the road mortality rate of turtles was 9.7km/day but this rate was reduced to only 0.08km/day after fences were installed. In 43 months, only 84 of 8,466 (<1%) turtles found post-fence construction actually accessed the highway by climbing or penetrating the temporary fences. The fences directed some animals towards the pre-existing 3.5m diameter culvert, and turtles (*P. floridana, T. scripta, A. ferox*), alligators, and frogs (*R. grylio, R. catesbeiana. R. sphenocephala*) were directly observed to use the culvert as a crossing under the highway. Turtles did not hesitate to use the culvert that has sufficient light visible from the opposite side and a natural sand/silt substrate. In addition, configuration of the north and south ends of the fence by turning the turtles gradually back towards the lake bottom for several hundred meters was successful in preventing most turtles from accessing the highway from around the ends. However, most turtles were capable of climbing the fencing, especially *A. ferox, S. odoratus, C. serpentina*, and juvenile *P. floridana* and *T. scripta.* Therefore, the temporary fences required vigilant daily monitoring to remove turtles from behind the fences and transport them across the highway before they could climb over. The low rate of trespass of turtles at the fences (<1%) would have undoubtedly been much greater if the array was not intensively patrolled. Although the climbing

ability of turtles is not well documented, it must be considered for any permanent barrier, including such design features as a smooth, vertical surface (1m tall) and an overhanging, inward lip.

Most mortality of turtles behind the fences was due to predation. Of 95 turtles found dead behind the fences, 92 were killed by predators, and three apparently overheated. Nocturnal mammalian predators killed turtles that left the water in the early evening (1700-2000h) and were diverted by the fences but failed to locate the culvert before nightfall. *P. lotor* were the primary predators, but I also observed a gray fox (*Urocyon cinereoargenteus*) at dusk carrying a live *T. scripta*. Most DAF turtles were found concentrated in a wooded area 235-300m south of the under-highway culvert. These turtles were primarily adult *P. floridana* and *T. scripta* attempting to migrate from drying Lake Jackson to Little Lake Jackson in May-June 2000. In addition, several hatchling and small juvenile turtles were found being attacked by imported red fire ants (*Solenopsis invicta*) and later died. Several turtles were observed being taken by humans at the fences, either for pets (*P. floridana, T. scripta*) or meat *(A. ferox).* These observations demonstrate that simply installing barriers along a roadway without a sufficient number of culverts will result in high rates of depredation if the barriers are not monitored daily. Clearly, a single culvert along a 1.2-km stretch of road, in this case, is not sufficient to facilitate migration, and additional underpasses must be available (Yanes et al., 1995). Therefore, because of potentially high rates of mammalian predation and the slow walking speed of turtles, under-highway culverts should be installed at least every 200-300m to facilitate relatively rapid migration. Thus, at least three-four additional culverts are required at U.S. Highway 27.

Although the temporary drift fences prevented most turtles from accessing the highway, they were only partially successful in diverting other herpetofauna. The drift fences were only able to prevent about one-half of all herpetofauna (other than turtles) from being killed on the highway. Aquatic, semi-aquatic, and terrestrial species were able to climb, scale, or jump over the temporary fence and access the highway. The fences were not monitored at night, so the sampling method underestimated the presence of nocturnal, secretive animals at the fences. In addition, the ability to detect road kills of small frogs, such as *A. gryllus* and *G. carolinensis* is very difficult after they are killed by vehicles, as carcasses are quickly obliterated (Fahrig et al. 1995, Hels and Buchwald 2001). Thus, it is likely that these common species were killed on U.S. Highway 27 in significantly greater numbers than actually observed. Captures in funnel traps confirm that these species were much more common than observed during daylight monitoring. Animals captured in traps were primarily nocturnal species that were not normally encountered, and, thus, numbers of some species are significantly underestimated, and others are completely missed, by simply walking the fences and highway only during daylight hours.

Despite some problems with animal trespass, maintenance, and depredation, the use of vinyl erosion control fencing is recommended for temporary use in diverting turtles towards existing culverts until a more permanent design can be constructed. The design and construction of wildlife crossings is a challenge to both ecologists and highway engineers (Evink et al. 1996, Clevenger and Waltho 2000, Clevenger et al. 2001, Little et al. 2002). Ideally, ecopassages should be designed to mitigate the effects of highway mortality and habitat fragmentation on the full diversity of fauna affected by a particular highway, including reptiles and amphibians. Therefore, a multi-species approach that seeks to restore the ecological connectivity of fragmented areas should be the primary goal, rather than a single-species or single-group approach. An ideal prototype for a multi-species ecopassage design for reptiles, amphibians, and mammals was recently constructed by the Florida Department of Transportation at the Paynes Prairie State Preserve along 3.2-km of U.S. Highway 441 south of Gainesville, Florida. This design consists of a lipped, 1.1-m high concrete guide wall and a series of underpasses. This system has proven effective in diverting wildlife from the highway, reducing mortality, and facilitating under-highway movements (Barichivich and Dodd 2002).

Implications for Prioritization of Wildlife-Highway Problem Areas for Mitigation

Current wildlife-transportation mitigation planning in many states is based primarily on decision-based prioritization models (Smith et al. 1998, Harris and Smith 1999; Schaefer and Smith 2000, Gilbert et al. 2002). Many states use such models to prioritize funding and rank sites for wildlife-highway mitigation projects, and these are based primarily on the presence of threatened and endangered species. However, in cases such as Lake Jackson where there is severe road mortality of non-listed species that affects viability of local populations, we need a better method of identifying and integrating these sites into GIS-based prioritization models. Prioritization algorithms should account for differential vulnerability to high levels of road mortality of long-lived reptiles, such as turtles, that have unique demographic constraints and are unable to compensate for significant losses of adults (Gilpin and Soulé 1986, Congdon et al. 1994, Doak et al. 1994). It is imperative that such sites are identified and mortality rates documented in order to yield a more complete inventory for statewide transportation planning and ranking for environmental mitigation.

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Appendix 1

44 species of reptiles and amphibians found either behind the fences or on U.S. Highway (dead or alive) at Lake Jackson, Leon County, Florida from 22 February 2000 - 8 September 2003. "Alive" includes number alive at fence (LAF) or alive on the road (AOR) and "Dead" is number found dead on road (DOR) or number in parentheses is dead at fence (DAF). An asterisk indicates a State of Florida Species of Special Concern.

Species	Alive	Dead	Total
Salamanders (n=2)			
Two-toed amphiuma, *Amphiuma means*	0	0 (1)	1
Central newt, *Notophthalmus viridescens*	1	0	1
Anurans (n=825)			
Bullfrog, *Rana catesbeiana*	1	34	35
Cricket frog, *Acris gryllus*	309	2	311
Eastern spadefoot toad, *Scaphiopus holbrookii*	1	4	5
Greenhouse frog, *Eleutherodactylus planirostris*	0	1	1
Green tree frog, *Hyla cinerea*	2	36	38
Leopard frog, *Rana sphenocephala*	68	198	266
Narrowmouth toad, *Gastrophryne carolinensis*	5	0	5
Pig frog, *Rana grylio*	7	52	59
Southern toad, *Bufo terrestris*	84	18	102
Squirrel tree frog, *Hyla squirella*	2	1	3
Turtles (n=8833)			
Box turtle, *Terrapene carolina*	16	2	18
Chicken turtle, *Deirochelys reticularia*	2	0	2
Common musk turtle, *Sternotherus odoratus*	710	61(4)	775
Common snapping turtle, *Chelydra serpentina*	11	5 (1)	17
Eastern mud turtle, *Kinosternon subrubrum*	75	20	95
Florida cooter, *Pseudemys floridana*	3351	276 (68)	3695
Florida softshell, *Apalone ferox*	224	25 (1)	250
Gopher tortoise, *Gopherus polyphemus**	2	2	4
Suwannee cooter, *Pseudemys concinna**	3	0	3
Yellow-bellied slider, *Trachemys scripta*	3735	218 (21)	3974
Snakes (n=344)			
Banded water snake, *Nerodia fasciata*	19	43	62
Black racer, *Coluber constrictor*	96	3	99
Black swamp snake, *Seminatrix pygaea*	1	6	7
Corn snake, *Elaphe guttata*	10	4	14
Cottonmouth, *Agkistrodon piscivorus*	31	8	39
Eastern kingsnake, *Lampropeltis getulus getulus*	7	1	8
Florida green water snake, *Nerodia floridana*	13	55	68
Garter snake, *Thamnophis sirtalis*	12	5	17
Gray rat snake, *Elaphe obsoleta spiloides*	11	4	15
Mud snake, *Farancia abacura*	0	3	3
Red-bellied snake, *Storeria occipitomaculata*	1	0	1
Ribbon snake, *Thamnophis sauritus*	3	1	4
Ringneck snake, *Diadophis punctatus*	1	0	1
Rough green snake, *Opheodrys aestivus*	3	0(2)	5
Scarlet snake, *Cemophora coccinea*	0	1	1
Lizards (n=145)			
Broadhead skink, *Eumeces laticeps*	4	0	4
Eastern glass lizard, *Ophisaurus ventralis*	11	0	11
Five-lined skink, *Eumeces fasciatus*	122	0	122
Green anole, *Anolis carolinensis*	NA	NA	NA
Ground skink, *Scincella lateralis*	7	0	7
Six-lined racerunner, *Cnemidophorus sexlineatus*	0	1	1
Crocodilians (n=31)			
Alligator, *Alligator mississippiensis*	24	7	30
Total	8985	1195	10180

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ORIGINAL ARTICLE

Source of polycyclic aromatic hydrocarbon in roadway and stormwater system maintenance residues

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Abstract Soil and sediments adjacent to roadways often contain elevated concentrations of polycyclic aromatic hydrocarbons (PAHs). The sources of these PAH compounds include atmospheric deposition from automobile emissions and abraded bituminous asphalt particles from paved roads. Research was conducted to evaluate the relative contribution of each source on PAH concentrations in roadway-impacted soil and sediments by examining size fractionation and associated PAH content in roadway and stormwater system residuals. Analysis of five fractions (<75, 75–150, 150–212, 212–425 and >425 μm) of roadway and storm system residuals yielded varied results among the samples. The total PAH concentrations in the fractions ranged from 45 to 24,800 μg/kg with PAHs being most often encountered in the fine (<75 μm) and medium coarse (75–150 and 150–212 μm) fractions. The total PAH concentrations in the <75, 75–150, 150–212, 212–425 and >425 μm size fractions were 1070–21,100, 609–24,800, 185–22,500, 110–16,900, and 45–7730 μg/kg, respectively. The highest concentration of individual PAH detected in the size fractions was benzo(g,h,i)perylene (6050 μg/kg) in one catch basin sediment sample. Although abraded asphalt particles from roadways were likely a source of PAHs in the coarse fractions, the predominance of PAH in the fine or median coarse size fractions suggests that other pathways such as atmospheric deposition from vehicle emissions are the major contributor. Additionally, calculated ratios between selected PAH analogs with molecular masses 178, 202, 228 and 276 also support the inference that atmospheric deposition from combustion is a major source of PAHs.

Keywords Polycyclic aromatic hydrocarbons · Soil · Sediment · Stormwater · Roadway: asphalt particles

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Introduction

Polycyclic aromatic hydrocarbons (PAHs) are organic chemicals composed of fused benzene rings. They are ever-present environmental contaminants that consist of more than 100 chemicals (Ramesh et al. 2004). The United States Environmental Protection Agency has listed 16 of these compounds on its list of priority pollutants, which are regulated (Bojes and Pope 2007). A number of PAHs have been shown to be acutely toxic. However, the major concern about PAHs is their metabolic transformation into mutagenic, carcinogenic, and teratogenic agents such as dihydrodiol epoxide. These metabolites bind to and disrupt DNA and RNA, which is the basis for tumor formation (Wild and Jones 1995). Sources of PAH compounds are both natural and anthropogenic and include combustion of fossil fuel and forest fire. PAH compounds from environmental sources rapidly become associated with sediments where they may become buried and persist until degraded, resuspended, bioaccumulated, or removed, for example, by desilting roadside ditches (Cerniglia 1992). The possible fates of PAHs in the environment include microbial degradation, volatilization, bioaccumulation, adsorption to soil particle leaching (Cerniglia 1992).

Elevated concentrations of polycyclic aromatic hydrocarbons (PAHs) are frequently encountered in soils

adjacent to roadways, with concentrations ranging from 9.1 to 23,000 μg/kg reported in studies conducted in the United Kingdom, Korea, and Germany (Smith et al. 1995; Glaser et al. 2005; Dong and Lee 2009). A potential source of PAHs in roadway-impacted soils is atmospheric deposition from vehicle emission (Harvey 1991; Lim et al. 1999; Khan et al. 2008). A number of maintenance practices associated with roadways and ancillary stormwater infrastructure (e.g., street sweeping, snow plowing, cleaning of stormwater conveyance and control structures) result in the generation of residues that must be managed appropriately. These residues, which contain large amounts of soil, often have elevated PAH concentrations.

High PAH concentration in roadway and stormwater system can result in leaching of these compounds to contaminate groundwater during waste management practices. In addition, there is direct human exposure risk through ingestion and dermal absorption. Due to concern about potential leaching of these high PAH to contaminate groundwater, beneficial use of these wastes is limited. These possible beneficial uses include landfill cover; fill for potholes and deicing material. Since potential leaching PAH out of asphalt particle is unlikely or low compared to other fractions of the waste matrix, knowledge of the source of PAH in the waste will aid in the management of large amount of waste generated. For example, fine size waste fractions can be screened out and the larger fractions used beneficially, freeing landfill space. Previous research on the management of roadway and stormwater system maintenance residues found that the beneficial use of some of these wastes may be limited by elevated PAH concentrations (Jang et al. 2009, 2010). An issue raised from studies was whether in addition to the atmospheric deposition source, abraded asphalt particles might also be a contributor to the elevated PAH concentrations observed. PAHs are known components of asphalt and bitumen with total PAH concentrations ranging from 67 to 710 μg/kg reported literature (Birgisdottir et al. 2007); PAH leaching from asphalt and asphalt pavements was also studied and reported (Brandt and De Groot 2001; Legret et al. 2005; Birgisdottir et al. 2007). The potential for abraded asphalt particles as a major PAH source was assessed via analyzing the total concentration of PAHs in soils, which involve extraction with an organic solvent, any asphalt particles contained in a sample, along with their PAH content, will likely be dissolved thereby elevating PAH concentrations in the sample.

Although a few studies have examined source of PAH in sediments mostly from rivers (Krein and Schorer 2000; Wang et al. 2001; Ahrens and Depree 2004), in general, there is limited data on the source of PAH in roadway and stormwater system maintenance residue and management of these waste. Information on the source of PAH, coupled with better a understanding of relative contribution of each source on PAH concentrations in roadway and stormwater system maintenance residue, will enhance development of management practices to isolate contaminated fractions and boost reuse options.

The research presented here was designed to assess the fractions of roadway-impacted soils and sediments for abraded asphalt particles, in addition to determination of whether abraded asphalt particles were the major source of PAHs in the samples. This was examined by assessment of whether PAH concentrations were elevated in sample size fractions where asphalt particles were notably present. Microscopic inspection was carried out to examine the samples for asphalt particles. Additionally, ratios of PAHs were used to infer the source of PAHs found in media.

Materials and methods

Sample collection

A total of eight samples were collected and investigated in this study. Two samples of each street sweeping (SS1 and SS2), catch basin sediments (CB1 and CB2), stormwater sediments (SW1 and SW2), and ditch cleaning samples (DC1 and DC2) were collected from seven cities in Florida, USA (Table 1) over a period of 1 week. Samples were collected in the field and from stockpiled residuals with a stainless scoop. Field samples were collected using random grid sampling technique. Piled-up samples were sectioned into quarters; random samples collected from each quarter and pooled together to generate composite samples. 30 cm surface depth was removed before sampling. The collected samples were transferred into glass jars and stored below 4 °C in ice chests. The samples were transferred to the laboratory for storage below 4 °C prior to analysis. Samples were wet sieved into five size fractions (<75, 75–150, 150–212, 212–425, >425 μm), which correspond to US standard mesh numbers 200, 150, 70, 40 and 25, respectively. The finest particle size fraction (<75 μm) was separated from the aqueous phase by centrifuging (3000 gravitational force for 20 min) the water collected during

Table 1 Sample type and sampling locations

Sample ID	Sample type	Sampling location
SW1	Stormwater pond sediments	Pensacola, FL
SW2		Gainesville, FL
SS1	Street sweeping samples	Pensacola, FL
SS2		Boynton Beach, FL
CB1	Catch basin sediments	Miami Beach, FL
CB2		Orlando, FL
DC1	Ditch cleaning samples	Port St. Lucie, FL
DC2		Daytona Beach, FL

the sieving process. The fractions (fine size fraction: <75 μm; medium size fractions: 75–150 and 150–212 μm; coarse fraction: 212–425 μm and large size fraction: >425 μm) were dried to a constant weight in an oven at 60 °C (Wang et al. 2001).

Determination of PAH concentration

A dried and homogenized sediment sample (2 g) of each size fraction was weighed into 50 mL beakers. Prior to extraction, the sediments were spiked with 100 μL benzo(b)chrysene surrogate (5 mg/L). The sediments were then extracted three times with 30 mL methylene chloride using a sonicator (Heat System-Ultrasonics W-375, USA) for 3 min at 100 % power output, 50 % duty cycle, and pulsing energy. The combined extract was concentrated to 5 mL using the nitrogen blow-down method; the solvent exchanged to acetonitrile and concentrated to 1 mL using a Kuderna Danish (KD) apparatus. To separate PAH from other residual organic compounds, the crude extract was cleaned using a C18 cartridge (Supelco, USA). The crude extract unavoidably contained a large amount of substances other than PAHs which could interfere with analytical measurements. The cartridge was loaded with 0.25 g copper powder, then cleaned and activated by passing through 3 mL of methanol, followed by 3 mL of distilled water. The 1 mL crude sample was then loaded into the cartridge, mixed with 2 mL distilled water, and pulled through a column via vacuum. The cartridge was dried for 20 min under vacuum and the PAH was then eluted with 3 mL of solvent mixture that consisted of 50 % dichloromethane, 47 % hexane and 3 % acetonitrile. The solvent in the extract was changed to acetonitrile using a Kuderna Danish apparatus and the volume reduced to 1 mL.

The analysis of the extracted samples for PAHs was conducted with a reverse-phase, high-performance chromatography system (Hitachi D7000, Japan) equipped with a Brownlee Analytical PAH 5 μm (250 mm × 2.1 mm, 110 Å) column (Perkin Elmer, USA) and UV detector. The chromatographic separation of PAHs was performed using a 60-min gradient elution at 0.7 mL/min (from 60 % acetonitrile in water to 100 % acetonitrile), followed by another 60-min isocratic elution at the same flow rate. Quantitative determination of PAHs was achieved using the external standard calibration curve method. Method detection limits, percent recoveries, and precision of the method were determined.

Total organic carbon analysis and microscopic studies

The dried sediment of each size fraction was homogenized using a ball mill, and the total organic carbon (TOC) of the fractions was measured using a total organic carbon analyzer (Shimadzu SSM-5000A, Japan) (Wang et al. 2001). In addition, each size fraction was inspected with an electron microscope (Carl Zeiss Inc., New York) to evaluate whether asphalt particles were present in the different size fractions of the samples.

Results and discussion

Quality control/quality assurance (QA/QC)

A quality assurance/quality control (QA/QC) plan involved analysis of spikes, duplicates, and blanks. A reagent blank was prepared and analyzed with every batch of samples. Replicate samples were fortified with identical concentrations of PAH standards. A duplicate fortified sample was analyzed after every 20 samples. Table 2 shows the recoveries and detection limits of PAHs in the roadway and storm system residues. With the exception of a few compounds [naphthalene, acenaphthene and benzo(a)anthracene], the PAHs recovery from the fortified samples ranged between 72 and 103 %. Sample blanks extracted under the same conditions as the roadway and storm system sediments were below the detection limit.

Total organic carbon content distribution in size fractions and microscopic inspection

The TOC of the two ditch cleaning samples ranged from 0.4 to 15.5 and 2.3 to 18.4 % in the five fractions. The two

Table 2 Recoveries of PAH compounds determined in roadway and storm system residues

Compounds	Detection limit (μg/kg)	Mean recovery (%)
Naphthalene	2.5	66.3
Acenaphthylene	2.5	73.1
Acenaphthene	4.9	62.3
Fluorene	0.50	76.3
Phenanthrene	0.20	72.8
Anthracene	0.10	92.3
Fluoranthene	0.20	102.9
Pyrene	0.50	87.7
Benzo(k)fluoranthene	0.10	73.6
Chrysene	0.20	83.8
Benzo(g,h,i)perylene	0.40	90.4
Benzo(a)pyrene	0.20	80.7
Benzo(a)anthracene	0.20	66.9
Dibenzo(a,h)anthracene	1.0	72.1
Benzo(b)fluoranthene	0.10	87.1
Indeno(1,2,3-cd)pyrene	0.20	98.3

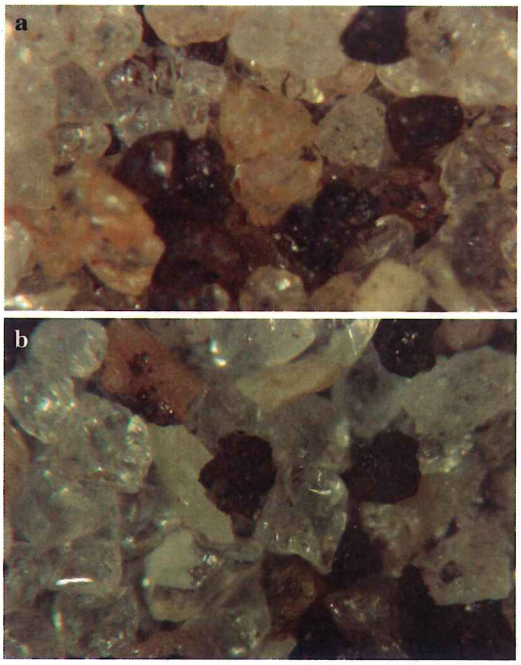

Fig. 1 Pictures show identified asphalt particles in selected roadway-impacted soils and sediments. The pictures are, **a** street sweeping sample, **b** stormwater sample

stormwater sediment TOC values ranged from 1.4 to 6.5 and 0.7 to 9.7 %, while those of the catch basin sediments ranged from 0.9 to 14 and 1.4 to 14 %. The street sweeping TOC values in the five fractions ranged from 1.0 to 15 and 1.5 to 7.4 %. With the exception of one ditch cleaning sample, the TOC was highest in the fine size fractions (<75 μm) of all the sample types. The coarse fraction (75–150 μm) of ditch cleaning DC1 recorded the highest TOC. TOC values measured in the fine fractions of the ditch cleanings were generally higher than corresponding TOC values in street sweepings, stormwater pond sediments, and catch basin sediments. This may be due to the fact that ditch cleaning samples are mostly made up of soil material. Plant growth and subsequent humification of dead plant material in the soil could result in high organic carbon content observed in the ditch cleaning samples. Microscopic inspection of the fractions revealed the presence of dark-colored particles that are likely asphalt pavement debris (Fig. 1).

Distribution of PAH in size fractions

Distribution of the total PAHs (ΣPAH) concentrations in various size fractions were generally similar (Fig. 2) and it indicated accumulation of PAHs in the fines fractions. Examination of association between ΣPAH and total organic carbon (TOC) showed positive correlation in four (DC2, CB1, SS2 and CB2) out of the eight samples (r^2 are 0.93, 0.92, 0.89, and 0.69); though one of the four was not very strong (Fig. 3).

Comparison of the ΣPAH concentration in different size fractions of various waste types revealed a high concentration of PAHs mostly in finer sized fractions (<150 μm) (Fig. 2). Three (SS2, CB2 and DC2) out of the eight samples had high PAHs concentration in <75 μm fraction; two other samples (SW1 and SS1) had high PAHs concentration in both fine <75 μm and 75–150 μm fractions. Elevated PAHs concentrations were observed in medium sized fractions (75–150 and 150–212 μm) of two samples (SW2 and CB1). Lastly, one sample (DC1) had an elevated PAHs concentration in the lower size <75 μm and 75–150 μm fractions and coarse (212–425 μm) fraction. Three samples (CB2, DC2, and SS2) with positive a correlation between TOC and ΣPAH, all had high TOC and PAHs concentration in <75 μm fraction. This suggests that PAHs present were bound to organic carbon fractions of these samples. Wang et al. (2001) reported high PAH concentration in larger size fractions (>250 μm) of marine sediments; a positive correlation between PAHs and TOC was reported in that study. Wang et al. (2001) suggested a pyrogenic source as a possible input of PAHs into the sediments. Two samples (SW2 and SS1) had high PAHs concentration in both fine <75 μm and 75–150 μm fractions did not show a correlation between ΣPAH and TOC; however, TOC observed accumulated mainly in the lower size fractions of <75 μm and 75–150 μm (Figs. 2 and 3). Another pair of samples (SW1 and CB1) with high PAHs concentration in the medium size fractions (75–150 and 150–212 μm) showed mixed relationship between ΣPAH and TOC; one sample showed strong correlation while the other showed a poor correlation. Finally, one sample (DC1) with high PAHs concentration in <75, 75–150 and <212–425 μm fractions did not show a correlation between ΣPAH and TOC.

Overall ΣPAH was not clearly correlated with TOC of all samples. It implies that other organic sources would be involved in TOC of the surface sediment samples, or hydrophobicity of the organic matter accumulated in surface sediment may be relatively weak to hold PAH. Unlike the marine sediments that exhibit high PAH in large size fractions (Wang et al. 2001), relatively high total organic carbon and ΣPAH are observed in small fractions of most samples. It indicates that numerous lumps of organic matter are included in small fraction of the surface sediment samples, or more organic matter may be bound on the fine particles because of their relatively large surface area.

In terms of sampling location, sample from Miami Beach, FL (CB1), recorded the highest PAHs concentration in the fractions while the least PAH concentration was detected in sample from Port St. Lucie, FL (DC2) (Table 1; Figs. 4 and 5). The high PAH concentration in CB1 is

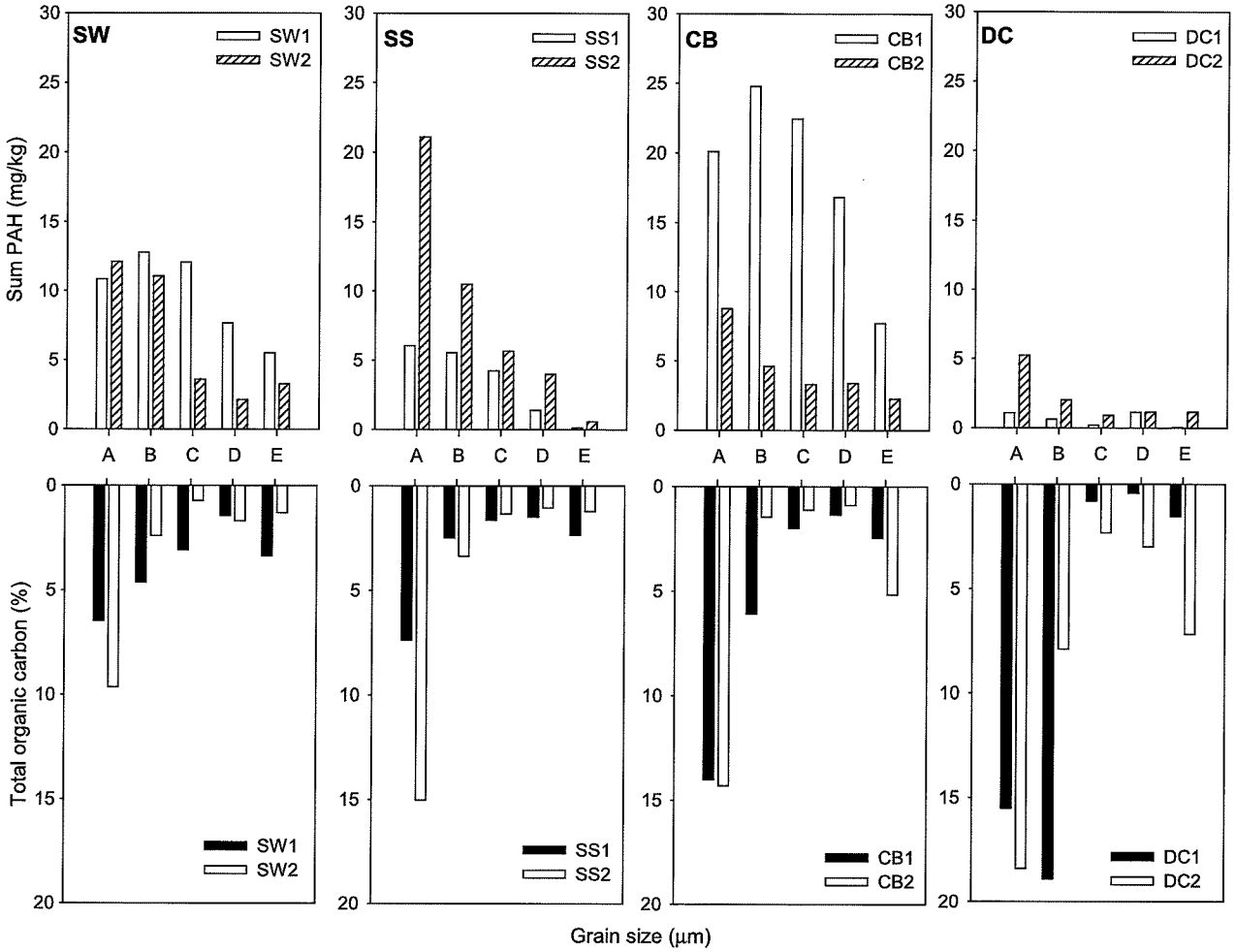

Fig. 2 Distribution of summed PAH and total organic carbon in size fractions (grain size **a** <75 μm, **b** 75–150 μm, **c** 150–212 μm, **d** 212–425 μm, **e** >425 μm)

likely due to the larger population and heavier traffic in the Miami area resulting in more combustion of fossil fuel and release of PAHs into environmental matrices. Furthermore, abraded asphalt particles from roadways could be another source of the high PAH concentration observed. In the case of the sample from Port St. Lucie (DC2), the low PAH concentration observed is likely due to the waste type. Ditch cleaning samples are mostly made up of soil material and hence with potentially lower PAH content compared to material such as street sweeping samples, which are swept directly off the road surface.

The individual PAHs showed distribution patterns similar to the one shown by ΣPAH (Figs. 4 and 5). Among all the samples studied, the highest concentration of individual PAH was benzo(g,h,i)perylene (6050 μg/kg) (CB1) (Figs. 4 and 5). Elevated concentrations of naphthalene (3611 μg/kg) (SS2), fluoranthene (2301 μg/kg) (CB1), chrysene (2000 μg/kg) (CB1), pyrene (2819 μg/kg) (CB1), benzo(a)pyrene (2337 μg/kg) (CB1) and indeno(1,2,3-cd)pyrene (1833 μg/kg) (CB1) were also observed. With the exception of the two ring structure compound naphthalene, which was considerably high in four samples (SS2, CB2, SW1 and SW2), all the PAHs detected with high concentrations consisted of four or more ring structures: pyrene (4-rings), chrysene (4-rings), fluoranthene (4-rings), benzo(a)pyrene (5-rings), benzo(g,h,i)perylene (6-rings), and indeno(1,2,3-cd)pyrene (6-rings). This may be due to the larger molecular sizes of the 4–6 ring compounds coupled with their low water solubility, resulting in the 4–6 ring compounds being partitioned into organic carbon found in roadway-impacted soils and sediments. The management of large volume of waste generated during maintenance practices involving roadway-impacted soil such as cleaning of stormwater system, sweeping of streets and cleaning of ditch is a challenge due to elevated PAH concentrations in the waste. Numerous regulatory agencies

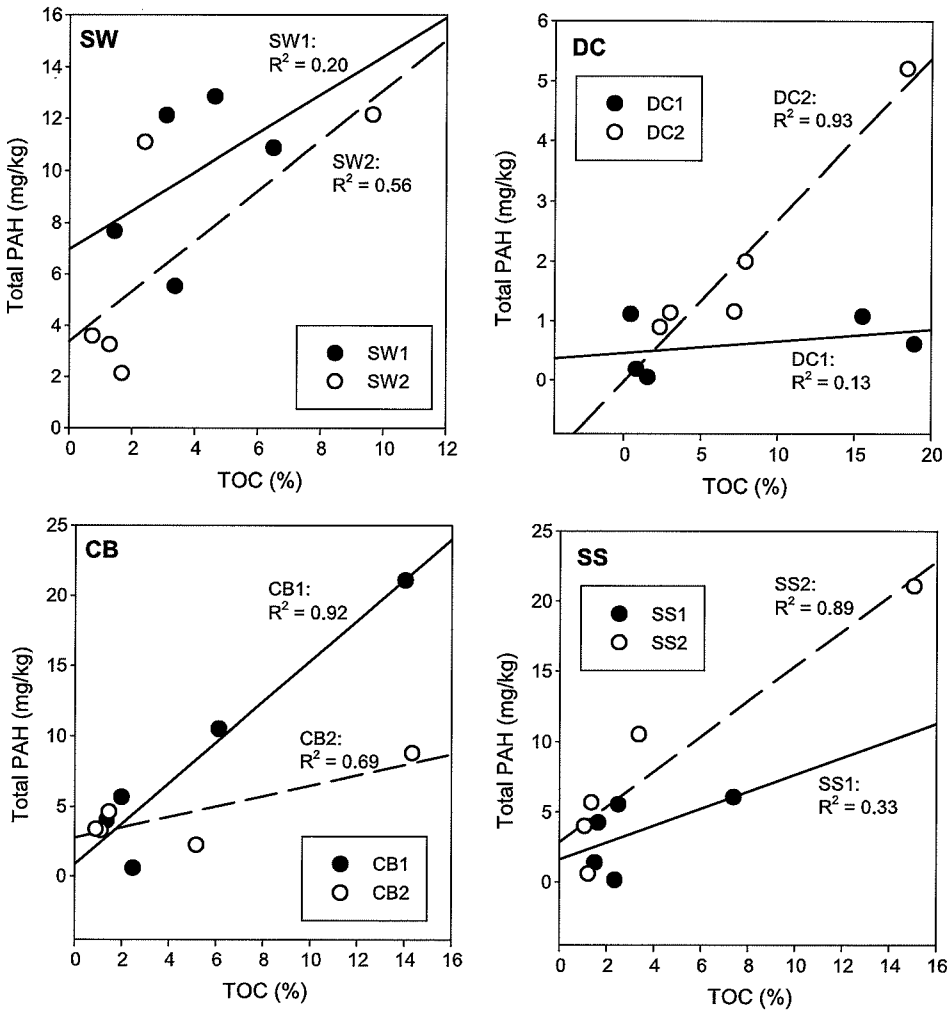

Fig. 3 Correlation between total PAH and total organic carbon in various samples

have set regulatory threshold values for PAH compounds to prevent groundwater and soil contamination. Soil cleanup target level (SCTL) developed by Florida Department of Environmental Protection (FDEP) serves as a guide to assess direct human exposure risk before waste can be land-applied in Florida (FDEP 2005). SCTLs for PAH range from 5.5×10^4 to 3.2×10^6 μg/kg for residential areas and 3×10^5 to 3×10^8 μg/kg for industrial areas, except for benzo(a)pyrene. Benzo(a)pyrene, a five-ring compound, is one of the most potent carcinogenic PAHs and hence has lower regulatory threshold value compared to other PAH compounds. The SCTLs for benzo(a)pyrene in residential and industrial areas are 100 and 700 μg/kg, respectively. The individual PAH measured in the fractions were 3–7 orders of magnitude lower than their corresponding residential and industrial SCTLs except for benzo(a)pyrene. Conversely, measured concentration of benzo(a)pyrene in the fractions ranged from 25 μg/kg (DC1) to 2337 μg/kg (CB1) (Figs. 4 and 5) and these were mostly 2–20 times higher than the residential SCTL with few exceptions in DC1 and DC2. The measured benzo(a)pyrene values, however, were mostly lower than industrial SCTL for benzo(a)pyrene except for CB1 and fine fractions of four samples (SW1, SW2, SS2 and CB2). This implies that these wastes will pose exposure risk to human health if land-applied in residential areas but will pose minimal direct exposure risks if the lower fraction (<75 and 75–150 μm) is screened out.

PAH source using ratios

Part of the motivation for this study was to assess the potential for abraded asphalt particles to represent a major source of PAH concentrations in roadway-impacted soils. Asphalt is a petroleum-based material that has been shown to contain PAHs. If a soil or sediment sample was to contain large particles of asphalt abraded from the pavement, the dissolution of the asphalt as part of the solvent extraction procedure for PAH in soil could plausibly contribute a major source of PAH content. PAHs were

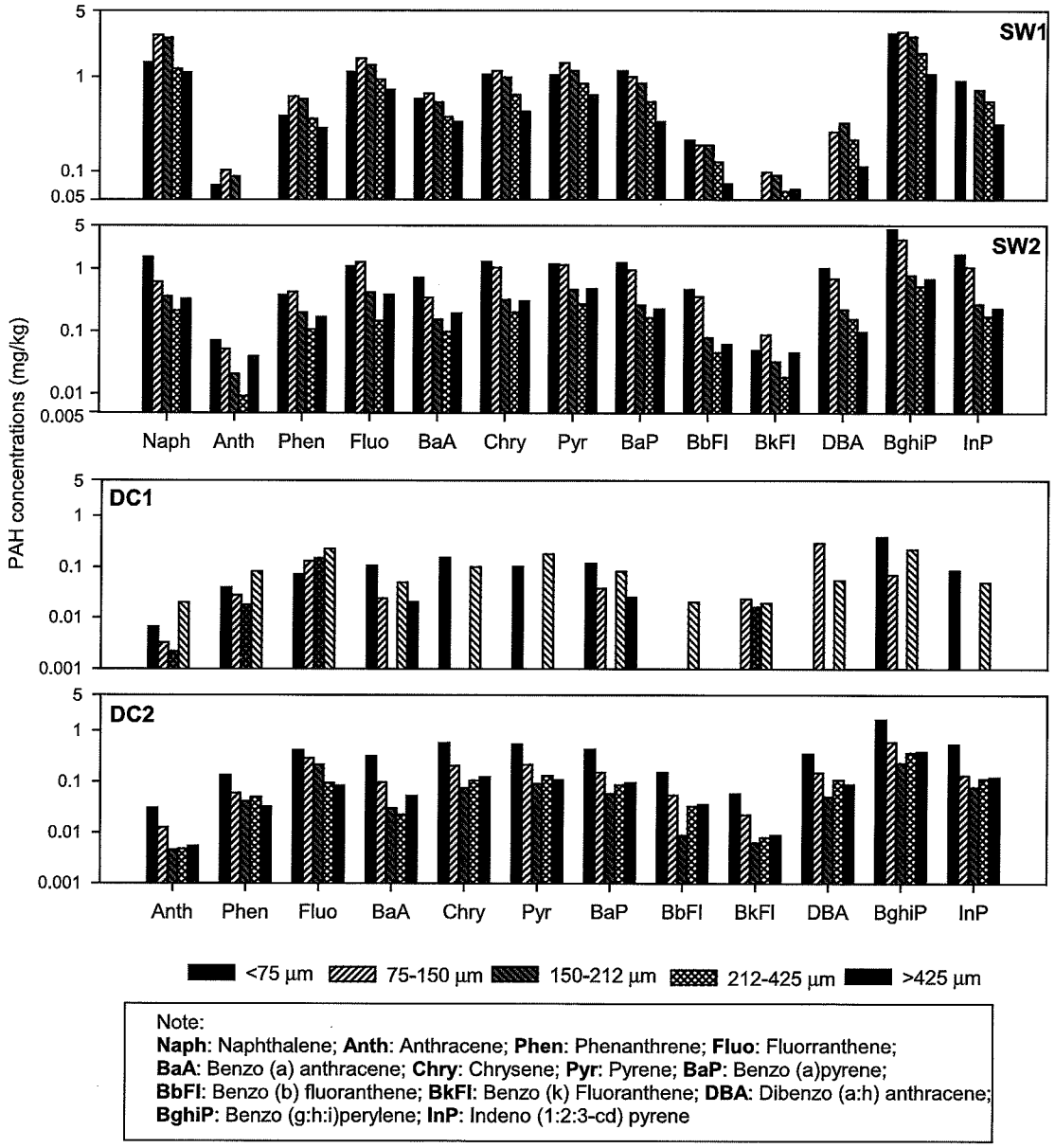

Fig. 4 PAH concentrations in stormwater pond sediments (SW) and ditch cleaning (DC) samples

encountered in various size fractions, but more commonly in the finer (<75 µm) and medium size fractions (75–150 and 150–212 µm), or in some cases, bimodally distributed in the fine (75 µm) and coarse (212–425 µm) fractions. Assuming that abraded asphalt would have a more pronounced effect when present as large particles, the data gathered do not suggest that abraded asphalt represents the dominant contributor to PAH concentrations. The results suggest that variable input sources were responsible for PAH concentrations in roadway-impacted soils.

The use of calculated ratios of selected PAHs with masses 178 (anthracene and phenanthrene), 202 (fluoranthene and pyrene), 228 (benz[a]anthracene and chrysene), and 276 (indeno[1,2,3-cd]pyrene and benzo[g,h,i]perylene) to indicate source of PAHs have been reported (Gschwend and Hites 1981; Sicre et al. 1987; Lipiatou and Saliot 1991; Budzinski et al. 1997; Soclo et al. 2000; Yunker et al. 1996, 2002a; Tay and Biney 2013). These ratios have been used to differentiate between petroleum and combustion sources (Yunker et al. 2002a, b; Hu et al. 2010; Tay and Biney 2013). To limit the effect of factors such as volatility and water solubility, the ratio calculations are limited to PAHs with similar molar masses (Readman et al. 1987; McVeety and Hites 1988). For example, fluoranthene to fluoranthene plus pyrene (Fluo/202) ratios less than about 0.40 usually indicate petroleum (oil, diesel, coal, etc.),

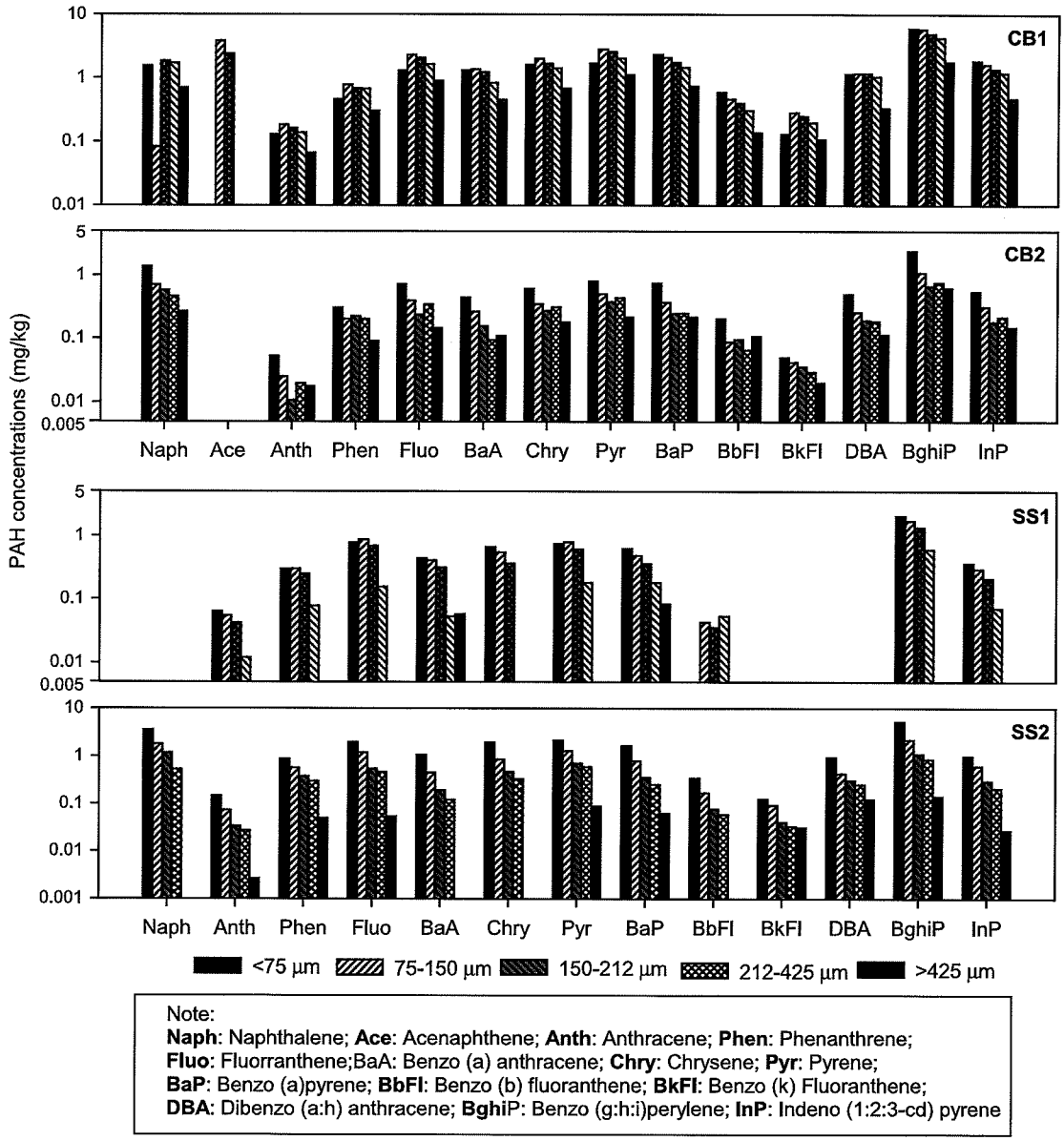

Fig. 5 PAH concentrations in catch basin sediments (CB) and street sweeping samples (SS)

Fluo/202 ratios 0.40 between 0.50 indicate liquid fossil fuel (vehicle and crude oil) combustion while Fluo/202 ratios over 0.50 are attributable to grass, wood or coal combustion (Yunker et al. 2002a, b). For indeno[1,2,3-cd]pyrene to indeno[1,2,3-cd]pyrene plus benzo[g,h,i]perylene (InP/276) ratios, values less than approximately 0.20 imply petroleum, InP/276 ratios between 0.20 and 0.50 signify liquid fossil fuel combustion, and ratios greater than 0.50 indicate grass, wood and coal combustion (Yunker et al. 2002a, b). Anthracene to anthracene plus phenanthrene (Anth/178) ratios less than 0.10 usually are taken as an indication of petroleum while ratios greater than 0.10 indicate combustion (Budzinski et al. 1997; Yunker et al. 2002a, b). Benz[a]anthracene to benz[a]anthracene plus chrysene (BaA/228) ratios less than 0.20 imply petroleum, BaA/228 ratios between 0.20 and 0.35 indicate either petroleum or combustion, while BaA/228 ratios greater than 0.35 imply combustion (Yunker et al. 2002a, b).

The Fluo/202 ratios calculated in this study fall within the ranges indicating petroleum combustion and combustion of grass, wood and coal. However, the majority of Fluo/202 ratios (58 %) lie within petroleum combustion range (Fig. 6). The Anth/178 and BaA/228 ratios both showed predominance of combustion over petroleum origin (Fig. 6). In the case of InP/276 ratios, a third was

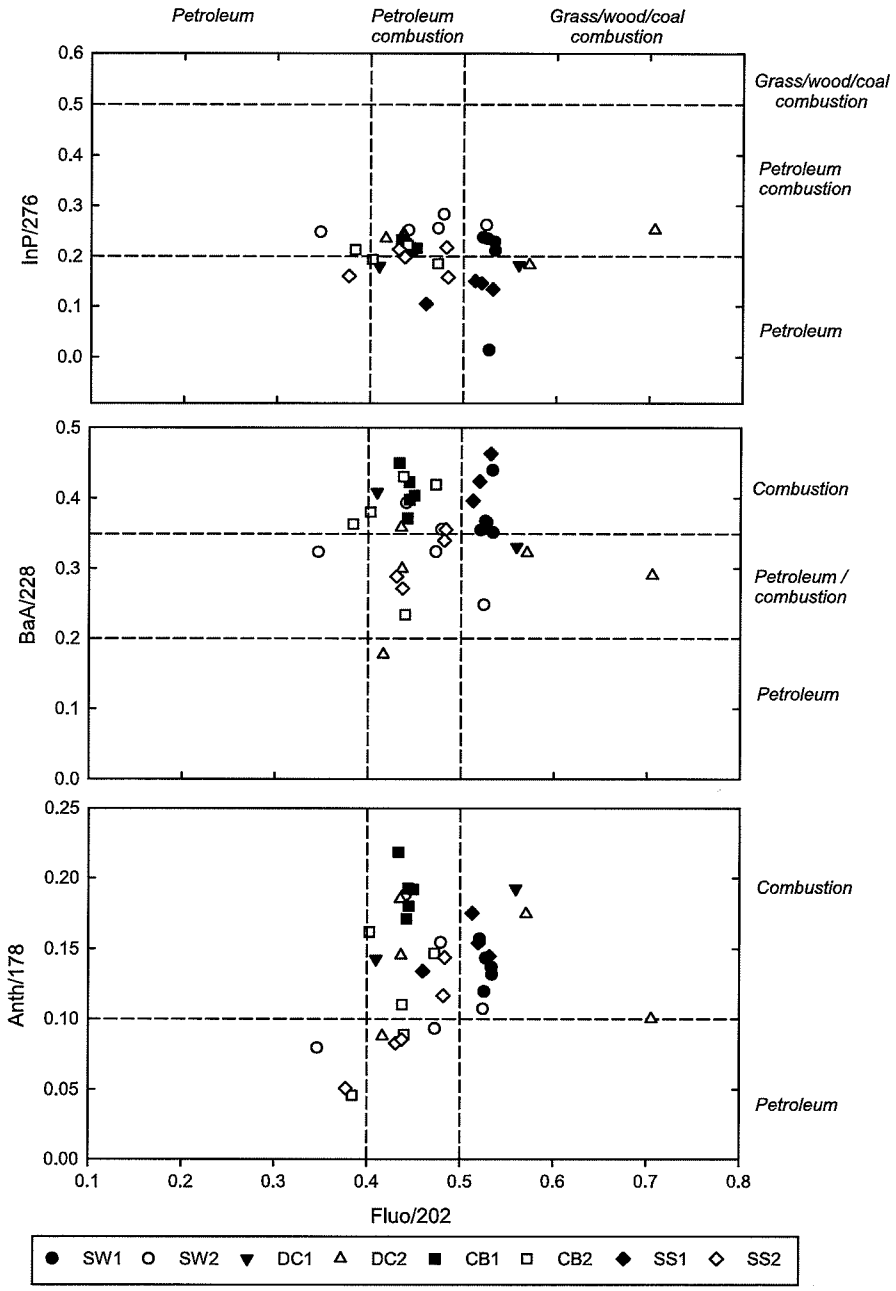

Fig. 6 Cross plot of PAH ratios fluoranthene to fluoranthene plus pyrene (Fluo/202) versus InP/276, indeno[1,2,3-cd]pyrene to indeno[1,2,3-cd]pyrene plus benzo[g,h,i]perylene (InP/276), benz[a]anthracene to benz[a]anthracene plus chrysene (BaA/228), and anthracene to anthracene plus phenanthrene (Anth/178)

characterized as being of petroleum origin whilst majority of InP/276 (67 %) indicated petroleum combustion. Based on the above ratios, the main source of PAHs is consistent with petroleum combustion origin.

Summary and conclusion

This research set out to examine the source of PAHs in stormwater system maintenance residues through the relationship between PAH concentration and particle size fraction. Four common residuals generated through the maintenance of roadways and associated stormwater systems were evaluated. The results were not uniform among all samples; several samples exhibited the greatest concentration of PAH in the finer fractions, while in other samples, PAH concentrations were more uniform among fractions. For example, in the street sweepings samples, PAH concentrations were greatest in the finer size fractions (<75 μm; 75–150 μm). Similar results were observed in one catch basin sample, one stormwater pond sample, and one ditch cleaning sample. PAH concentrations were greater in the intermediate sizes of the second samples of catch basin and stormwater pond sediments. Correlations

were observed between TOC and ΣPAH in four of the roadway and storm system residuals studied, suggesting that PAHs are associated with organic matter present in the samples. The measured TOCs were highest in the fine fractions of the studied samples. Observation of an association between PAHs and TOC suggests that PAHs in fine fractions of the samples are from combustion products coming from motor vehicles. PAHs found accumulated in the coarse size fractions could have originated from abraded asphalt particles from roadways. Microscopic studies of the fractionated samples confirmed the presence of asphalt particles in the samples. Calculated ratios between selected PAH analogs point to combustion fossil fuel, grass, wood and coal as the major source of PAH in the samples. Since elevated concentration of PAH was mostly measured in lower size fractions (<75 μm; 75–150 μm), screening method can be used to isolate fractions with elevated PAH concentration to enhance recycling of these waste. In general, this work suggests that while abraded asphalt particles may be a source of some elevated PAH concentrations in stormwater system maintenance residues, this is not the dominant source, and rather atmospheric deposition from emissions is a major contributor.

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Research paper

Using environmental features to model highway crossing behavior of Canada lynx in the Southern Rocky Mountains

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HIGHLIGHTS

- Lynx crossed two-lane paved highways an average of 0.6 times per day.
- Lynx crossed roads more at dusk and night, coincident with lower traffic volumes.
- Forest cover was predictive of lynx highway crossings at fine and landscape scales.
- Predictions from remotely-sensed covariates validate well with independent data.

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ABSTRACT

Carnivores are particularly sensitive to reductions in population connectivity caused by human disturbance and habitat fragmentation. Permeability of transportation corridors to carnivore movements is central to species conservation given the large spatial extent of transportation networks and the high mobility of many carnivore species. We investigated the degree to which two-lane highways were permeable to movements of resident Canada lynx in the Southern Rocky Mountains based on highway crossings (n = 593) documented with GPS telemetry. All lynx crossed highways when present in home ranges at an average rate of 0.6 crossings per day. Lynx mostly crossed highways during the night and early dawn when traffic volumes were low. Five of 13 lynx crossed highways less frequently than expected when compared to random expectation, but even these individuals crossed highways frequently in parts of their home range. We developed fine- and landscape-scale resource selection function (RSF) models with field and remotely sensed data, respectively. At the fine scale, lynx selected crossings with low distances to vegetative cover and higher tree basal area; we found no support that topography or road infrastructure affected lynx crossing. At the landscape scale, lynx crossed highways in areas with high forest canopy cover in drainages on primarily north-facing aspects. The predicted crossing probabilities generated from the landscape-scale RSF model across western Colorado, USA, were successful in identifying known lynx crossing sites as documented with independent snow-tracking and road-mortality data. We discuss effective mitigation based on model results.

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1. Introduction

Road distribution and density can have a significant impact on the connectivity of wildlife populations (Andrews, 1990; Forman & Alexander, 1998). Increased human activity, vehicle-related mortality, and behavioral avoidance of roads can all contribute to changes in movement, survival, and reproductive success of individuals and populations (Forman & Alexander, 1998; Ferreras, Aldama, Beltran, & Delibes, 1992; Trombulak & Frissell, 2000). Roads may also reduce gene flow for some species (Jackson & Fahrig, 2011; Riley et al., 2006). In particular, carnivores are susceptible to reduced population connectivity due to roads given their large home ranges, long-distance movements, and low recruitment rates

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(Noss, Quigley, Hornocker, Merrill, & Paquet, 1996; Woodroffe & Ginsberg, 2000).

Actions that promote highway permeability for carnivores require an empirical basis so that highway mitigation is most effective. Methods used to site animal-crossing structures and to identify animal crossing zones include expert opinion (Clevenger, Wierzchowski, Chruszcz, & Gunson, 2002), wildlife-vehicle collision patterns (Clevenger, Chruszcz, & Gunson, 2003; Malo, Suarez, & Diez, 2004), remote cameras (Cain, Tuovila, Hewitta, & Tewes, 2003), track surveys (Clevenger & Waltho, 2005; Grilo, Bissonette, & Santos-Reis, 2009), and telemetry (Dodd, Gagnon, Boe, & Schweinsburg, 2007; Tigas, Van Vuren, & Sauvajot, 2002). However, the use of actual crossing locations to determine attributes that carnivores select at highway crossings ensures that already limited funds are expended on conservation measures that truly enhance highway permeability and reduce carnivore mortality. Physical structures that increase permeability of highways to carnivores, such as underpasses and overpasses, must be placed in areas that are consistent with the species' resource-use (Clevenger & Waltho, 2000).

For many species, crossing zones and vehicle-related mortalities tend to be spatially clustered, an indication that animals may cross highways non-randomly in response to habitat or road characteristics (Malo et al., 2004; Neumann et al., 2012; Ramp, Caldwell, Edwards, Warton, & Croft, 2005). The types and spatial distribution of these characteristics vary by species, depending on life history and habitat preferences (Chetkiewicz & Boyce, 2009; Ramp, Wilson, & Croft, 2006). Vegetation characteristics tend to be important for many species. For instance, Seiler (2005) found that moose (*Alces alces*) and vehicle collisions were more likely to occur in areas with greater forest cover and proximity to forest edge. Clevenger et al. (2003) found that small mammal vehicle collisions tended to occur along roads near vegetative cover, and Finder, Roseberry, and Woolf (1999) showed that white-tail deer (*Odocoileus virginianus*) collisions were more likely in areas nearer to forest cover, gullies, or riparian zones. Lewis et al. (2011) modeled black bear (*Ursus americanus*) road-crossing probability and found that bears were more likely to cross in areas with less human development and greater forest cover. Thus, species-specific models that predict highway crossing zones should provide more accurate information on the likelihood of a given area to be used as a crossing, and therefore increase our ability to manage highway permeability and reduce direct vehicle-related mortality of rare carnivores.

The need for connectivity may be particularly important for reintroduced species at their range periphery, given low density and high degree of geographic isolation (Devineau, Shenk, Lukacs, & Kahn, 2010). Populations that are small and geographically isolated from their core range are generally vulnerable to local extinctions (Harrison, 1991; Lawton, 1993) that may be exacerbated by collision-mortality of dispersers and road avoidance (Forman et al., 2003). This concern is particularly acute for reintroduced populations of Canada lynx (*Lynx canadensis*) at their southern range periphery. Canada lynx are a medium-sized felid that generally occupy spatially distinct home ranges, but are also capable of long-distance exploratory or dispersal movements (Aubry, Koehler, & Squires, 2000; Squires & Oakleaf, 2005). Canada lynx are specialist predators of snowshoe hare (*Lepus americanus*) and are associated with moist, high-elevation spruce-fir forests in the Rocky Mountains of North America (McKelvey, Aubry, & Ortega, 2000). Vehicle collisions accounted for nearly half of mortalities for reintroduced lynx in the Adirondack Mountains, New York (McKelvey et al., 2000). Vehicle collision was also an important mortality factor for reintroduced lynx in Colorado (20% of mortalities; Devineau et al., 2010) and 45% of Eurasian lynx (*Lynx lynx*) mortalities in Germany (Kramer-Schadt, Revilla, & Wiegand, 2005).

Here we examine the road crossing characteristics of a reintroduced population of Canada lynx in the Southern Rocky Mountains of Colorado, USA. We first evaluated highway-crossing behavior of Canada lynx in terms of diel timing and road avoidance. We then evaluated the extent to which environmental variables at two spatial scales (fine scale and landscape scale) could be used to predict the probability of highway crossings by lynx. At lynx highway crossings, we quantified fine-scale environmental covariates in the field to evaluate crossings using variables not easily evaluated with remote sensing, such as forest structure and composition, presence of highway guard rails and barriers, and the distance that oncoming traffic was visible. Next, given that lynx are highly mobile (Devineau et al., 2010), our landscape-scale analysis evaluated if environmental heterogeneity quantified with remotely-sensed data could be used to predict highway crossings throughout western Colorado for region-wide planning. Given that lynx generally prefer spruce-fir forests with high horizontal cover (Fuller & Harrison, 2010; Koehler et al., 2008; Squires, DeCesare, Kolbe, & Ruggiero, 2010), we predicted that lynx at both fine and landscape scales would preferentially select forested crossing zones and generally avoid open habitat types.

2. Material and methods

2.1. Study area

Our study areas were in western Colorado, USA and included portions of the San Juan National Forest (37.6°N, 108.0°W) (referred to as SJNF hereafter) in Ouray, San Miguel, and Dolores counties, and the White River National Forest (39.5°N, 106.2°W) (referred to as WRNF hereafter), in Summit County (Fig. 1). The SJNF area occurred within the western San Juan Mountains and encompassed portions of the upper Animas, Dolores, and San Miguel River watersheds. The San Juan Mountain range was the core area in which the Colorado Division of Wildlife reintroduced lynx between 1999 and 2006 (Devineau et al., 2010). The SJNF included portions of two-lane U.S. Highway 550 and State Highway 145, with average daily traffic volumes between 2000 and 2500 vehicles per day (Colorado Department of Transportation, 2014). In the WRNF, the primary highways included Interstate 70 (I-70; 23,000 vehicles/day), a four-lane highway, and two-lane State Highway 91 (4000 vehicles/day; Colorado Department of Transportation, 2014).

Study areas were typical of the Southern Rockies with steep mountains and narrow valleys at elevations ranging approximately 2000–4300 m asl. Steep elevation gradients and high topographic variation across the study area produced a mosaic of conifer and aspen forests extending to alpine tundra, with herbaceous and shrub openings occurring as avalanche paths, meadows, and wetlands. Conifer-dominated forests, which provide most lynx habitat, occur between 2500 m to 3500 m asl in elevation and were composed primarily of Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*). Aspen (*Populus tremuloides*) and willow (*Salix* spp.) were common on disturbed slopes and intermixed with conifers in mid-seral stands, while Douglas fir (*Pseudotsuga menziesii*) occurred at low elevations. Lodgepole pine (*Pinus contorta*) dominated relatively drier forests on the WRNF but was largely absent from the SJNF. Winters were relatively long and cold; summers were drier but included monsoonal rain patterns that resulted in regular but brief afternoon precipitation. Maximum snow depth averaged 138 cm (range = 97–201 cm; Natural Resources Conservation Service, 2015), and snow generally persisted from November through May (low elevations) or June (high elevations and northerly aspects).

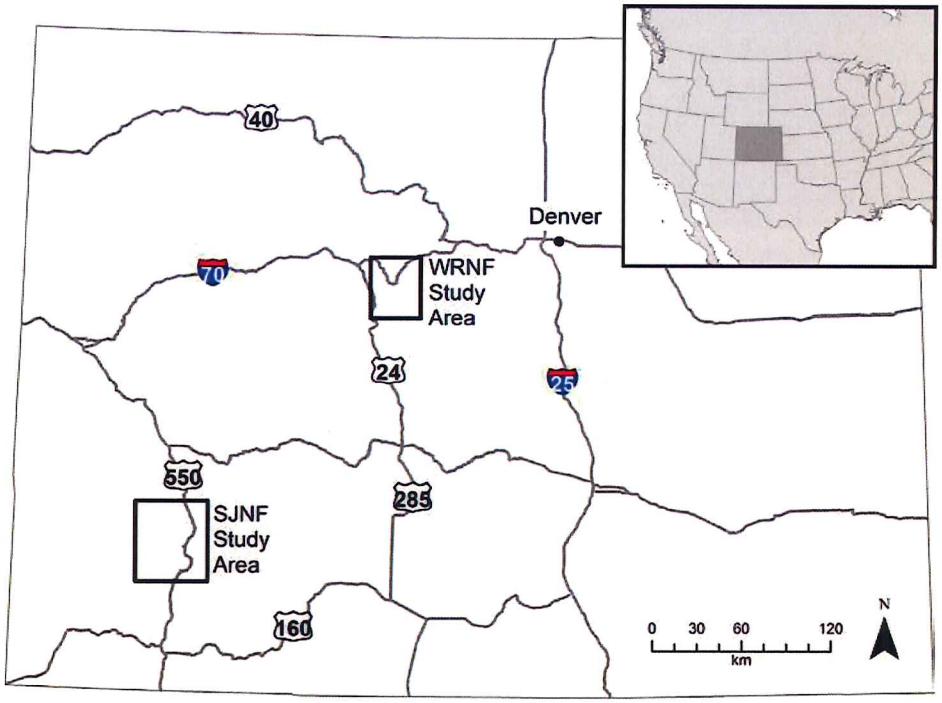

Fig. 1. Canada lynx study areas in western Colorado, USA including the White River National Forest (WRNF) and the San Juan National Forest (SJNF). Major highways in the area are indicated by gray lines; inset shows the location of Colorado in the United States.

2.2. Lynx capture and highway-crossing behavior

During winters 2010–2012, we captured lynx in box traps according to Kolbe, Squires, and Parker (2003). Lynx were captured and handled under the guidelines in Animal Care and Use Permit CDOW-ACUC File#13-2009. We fitted captured lynx with global positioning system (GPS) collars (Sirtrack Ltd., Havelock North, New Zealand) programmed to collect locations every 20 or 30 min, from January to April. We programmed collars to automatically drop off between April and May. Using GPS-collar data, we defined lynx movement segments as straight-line vectors between consecutive GPS locations. We identified lynx crossing segments as movement segments intersecting highway centerlines (Laurian et al., 2008; Schwab & Zandbergen, 2011). We limited analyses to crossing segments with at least one lynx location within 200 m of a highway to ensure accuracy.

We investigated lynx avoidance of highways by quantifying movements within home ranges relative to simulated movements. We created home ranges using package 'adehabitatHR' (Calenge, 2006) in R (R Development Core Team, 2014) and calculated a utilization distribution for each lynx with a 90% kernel density estimate and reference bandwidth as the smoothing parameter (Worton, 1989). In each 90% home range, we compared the number of times that lynx actually crossed a highway to the number of random highway crossings simulated by correlated random walks (CRW; Kareiva & Shigesada, 1983). We used the Geospatial Modeling Environment (GME; Beyer, 2012) to generate 500 CRW simulations per lynx. Each CRW simulation started at the lynx capture location and drew from the observed distribution of movement segment lengths and turning angles to create an equal number of random movement segments within the home range. At each CRW iteration, we tallied the number of movement segments that crossed highways and had either the start or end point within 200 m of a highway, to be consistent with how lynx crossings were counted. We then compared the empirical frequency distribution of random crossing segments generated for each lynx to the observed number of highway crossing segments per lynx as a non-parametric bootstrap test of highway avoidance. We defined significant avoidance of highways to have occurred when the observed number of highway crossings was equal to or less than the bottom 5% of the simulated crossing segment distribution (Shepard, Kuhns, Dreslik, & Phillips, 2008).

Although lynx are active throughout diel periods (Kolbe & Squires, 2007; Olson, Squires, DeCesare, & Kolbe, 2011), we expected most highway crossings would occur at night or during twilight periods when traffic volumes were low (Colorado Department of Transportation, 2014). We defined the time of highway crossing as the midpoint between the start and end times of lynx crossing movements. We categorized crossing times into four time periods: (1) dawn (2 h; sunrise ± 1 h), (2) day (10 h; sunrise + 1 h to sunset − 1 h), (3) dusk (2 h; sunset ± 1 h), and (4) night (10 h; sunset + 1 h to sunrise − 1 h); daily sunrise and sunset times were obtained from the National Oceanic and Atmospheric Earth Systems Research Laboratory (Cornwall, Horiuchi, & Lehman, 2015). We tallied the number of crossing segments within each time period for each lynx and then used a Poisson generalized linear mixed model to fit the number of crossings as a function of time period. We included time period as a fixed effect, individual lynx as a random intercept, and an offset term of log(time period hours) to account for differences in the length of each time period. We further qualitatively examined whether lynx crossed highways during times when they were most active by plotting the temporal pattern of lynx highway crossings relative to the temporal pattern of active lynx movement segments. Active movement segments were defined as those longer than the spatial error of stationary collars (92.5 m; Squires et al., 2013); segments shorter than this distance were considered to be resting or stationary.

2.3. Modeling resource selection

We developed resource selection functions (RSFs) at a fine (field-collected variables) and a landscape (remotely-sensed vari-

ables) scale to predict highway crossing probability by lynx (Manly, McDonald, Thomas, McDonald, & Erickson, 2002). We restricted our model-fitting to data from two-lane paved highways because of their prevalence in lynx home ranges; however, we did apply the model predictions (see *Model Validation* section) to I-70, the only four-lane highway in lynx habitat in western Colorado. We also provide anecdotal observations of lynx crossing I-70 due to the central role that this high-volume, four-lane highway could have on lynx population connectivity. At fine and landscape scales, we used the glmer function in package 'lme4' (Bates, Maechler, Bolker, & Walker, 2014) in R to build RSF models using mixed-effects logistic regression, and accounted for differences in crossing behavior of individual lynx with a random intercept for individual. Predictor covariates were standardized by subtracting the mean and dividing by the standard deviation to facilitate comparison between variables measured at different scales. We developed plausible *a priori* multivariate candidate models (Appendix A) with covariates that were more informative than the null model in a univariate sense based on Akaike's Information Criterion (AIC; Burnham & Anderson, 2002). We excluded covariates with high collinearity ($|r| > 0.6$); if correlated, we retained the variable that was most biologically meaningful and available to managers. We estimated logistic regression models describing the probability of lynx highway crossing as:

$$\hat{w} = \exp\left(\beta_0 + \beta_1 x_1 + \ldots + \beta_n x_n\right) / \left(1 + \exp\left(\beta_0 + \beta_1 x_1 + \ldots + \beta_n x_n\right)\right) \quad (1)$$

where $\hat{w}$ is the probability of selection as a function of x_n covariates, β_n are the parameter coefficients, and β_0 is the intercept (Manly et al., 2002). We evaluated candidate models using AIC and identified top models as those within 4 ΔAIC of the best performing model that did not contain uninformative parameters (Arnold, 2010; Burnham & Anderson, 2002).

For fine-scale resource-use modeling, we quantified predictor covariates in the field at lynx highway crossings. We buffered used points by 100 m then selected available points from outside the buffers. This ensured that used and available points were non-overlapping to reduce the potential of used crossings being also considered as available (sample contamination; Johnson, Nielsen, Merrill, McDonald, & Boyce, 2006; Keating & Cherry, 2004). We randomly selected 15 actual crossing locations per lynx and 15 "crossings" randomly available in each lynx home range. For three lynx with <15 total highway crossings, we sampled all used crossing points regardless of overlap. We fit 13 multivariate candidate models (see Appendix A).

At the landscape scale, we evaluated lynx highway crossing behavior by comparing used lynx crossings ($n = 593$) to available crossing locations ($n = 4331$) distributed across highways in western Colorado. Since a large available sample is required to minimize bias in RSF models (Hooten, Hanks, Johnson, & Alldredge, 2013; Northrup, Hooten, Anderson, & Wittemyer, 2013), and to allow prediction across all highways in western Colorado within the elevation zone of lynx, we sampled available crossing points systematically spaced 1 km apart along all highways within the elevation zone used by lynx in our sample (2000–4183 m asl). We considered 29 multivariate candidate models (see Appendix A). Our mixed model framework required an available sample specific to each individual lynx; however, since our available landscape was common to all lynx, we used a bootstrap procedure to refit the model with a different random sample of all systematic points to verify model performance. We performed 1000 bootstrap iterations that randomly sampled each lynx's used and all available crossing points with replacement and fitted all 28 candidate models at each iteration. We used AIC values for model selection, and verified this using the number of times each model was ranked best across bootstrap iterations. We then spatially extrapolated our best-performing model to predict probability of crossing along major highways in western Colorado above 2000 m asl elevation.

2.4. Predictor covariates

We quantified fine-scale vegetation covariates at crossing points with eight plots aligned in an "X" configuration (Appendix B1; Fig. 2). At each vegetation plot, we quantified tree basal area with a 10-factor prism and recorded diameter at breast height (DBH) by species. We also measured vegetative horizontal cover in each cardinal direction using a cover-board viewed at 10 m away, consistent with Squires et al. (2010). We measured distance to vegetative cover as the shortest distance to continuous vegetation greater than 2 m tall and in patches >25 m^2. We measured roadside covariates at three points to account for the spatial uncertainty of crossing locations (Appendix B1; Fig. 2). We quantified the slope of approaches to highways at 10 m perpendicular to the road with a clinometer. We used a rangefinder to measure the length of highway visible to a crossing animal, defined as the line-of-sight distance of continuous pavement in both directions. Given that highway structures can have physical or visual impact on wildlife crossings (Gunson, Mountrakis, & Quackenbush, 2011), we mapped the locations of physical barriers (e.g., guard rails, jersey barriers, vertical cliffs). We calculated the mean and standard deviation for all variables across all eight vegetation or three roadside plots at each crossing point.

At the landscape scale, we used remotely-sensed topographic and vegetation data (Appendix B2) at two spatial scales (200 m and 500 m radii circular moving windows) that we selected arbitrarily to capture the environment associated with highways. We selected landscape-scale covariates that best represented important variables associated with crossings identified during fine scale sampling and those that we thought were most biologically meaningful for landscape-level modeling. Topographic variables including slope, aspect, and terrain roughness were obtained from a 10 m digital elevation model (DEM; Gesch, 2007). Terrain roughness was calculated from the standard deviation of elevation values (Wilson & Gallant 2000). We calculated an index of "northness" using the percentage of cells in a 200 m or 500 m neighborhood with slope >10% and northerly aspects (>270° and <90°). Topographic position index (TPI), a measure of terrain concavity or convexity (Jenness, 2006), was calculated at a 1000 m scale, in addition to 200 and 500 m; the 1000 m radii plot was added to better characterize drainages in mountainous topography. Euclidian distance to hydrologic features was determined using the National Hydrography Dataset (NHD; United States Geological Survey, 2013). We obtained six 30 m resolution Landsat 5 Thematic Mapper (http://earthexplorer.usgs.gov/) scenes dated 8 June to 24 June 2011, each with less than 1% cloud cover. From these images, we derived the Normalized Difference Vegetation Index (NDVI; Jensen, 2005), an index of vegetation biomass, and performed tasseled cap transformations (Crist & Cicone, 1984), which created variables that index soil reflectivity (brightness), vegetation presence (greenness), and soil or surface moisture (wetness). We calculated the mean and standard deviation of NDVI, Brightness, Greenness, and Wetness. Finally, we evaluated forest structure based on a 30 m LANDFIRE v. 1.2.0 (Rollins, 2009) layer of canopy cover.

2.5. Model validation

We evaluated our best fine-scale model using four-fold cross validation (Boyce, Vernier, Nielsen, & Schmiegelow, 2002). We randomly divided all used locations into four groups, sequentially withheld each group, fit the model on the remaining three groups, and used the model to predict the outcome of the withheld group according to Boyce et al. (2002). This method

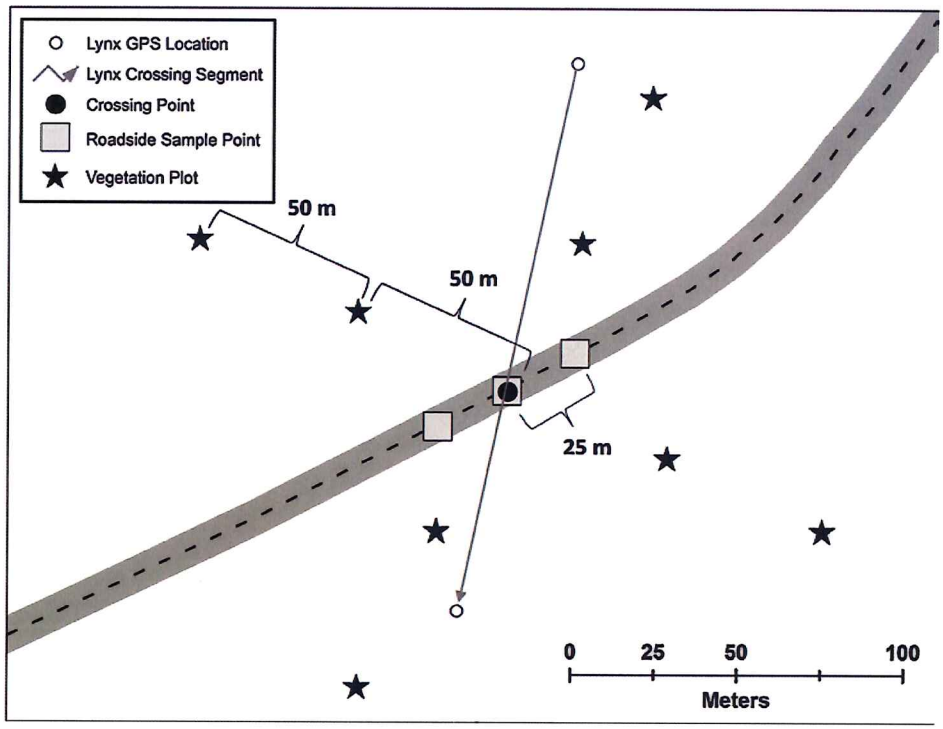

Fig. 2. Configuration of fine-scale vegetation plots at lynx highway crossings in western Colorado; eight plots in an "X" configuration were sampled. Three roadside sample points were spaced across putative crossing zones to quantify roadside characteristics.

should generate a high Spearman's rank correlation coefficient (r_s) between predictions from the withheld sample and the bin numbers generated from the entire dataset if the model is predicting the relative probability of road crossings given the range of probabilities over the entire area sampled (Boyce et al., 2002).

We evaluated the landscape-scale RSF model using two methods. First, we conducted a 10-fold cross validation according to Boyce et al. (2002), similar to the fine scale. Second, we used an independent dataset of lynx highway crossings in Colorado that consisted of winter lynx back-tracks from 2000 to 2009 ($n = 117$; Colorado Parks and Wildlife, unpublished data) and lynx highway mortalities from collisions with vehicles 1999–2015 ($n = 11$; Colorado Parks and Wildlife, unpublished data). We believed these independent data provided our best evaluation of model performance that mimicked actual field application. We extracted the RSF predicted probability value at each independent crossing location using our landscape-scale model; higher crossing probabilities indicated better predictive performance.

3. Results

We collected an average of 4810 GPS locations (SD = 2415, range: 752–8300) on each of 14 lynx (7 M, 7 F). Data collection ranged between 27 Jan and 17 Jun (Appendix C). Home ranges of all but one lynx were bisected by 4.0–52.9 km of two-lane highway ($\bar{x} = 18.7$ km, SD = 14.8). We documented 735 total lynx highway crossings; 88 of these were lower quality crossings (GPS locations >200 m off the highway and/or >40 min between locations) that were eliminated from further analysis. We used 11 of 13 lynx to model resource selection at 593 crossings; data from two lynx were not available for resource-use modeling due to late collar drop-offs. Elevation of lynx crossings averaged 3041 m (SD = 134 m, range: 2778–3451).

3.1. Highway crossing behavior

Lynx crossed highways more frequently during dusk and night than during dawn and day ($\beta_{dawn} = -0.17$, SE = 0.13, $p = 0.18$; $\beta_{dusk} = 0.76$, SE = 0.09, $p < 0.001$, $\beta_{night} = 1.31$, SE = 0.05, $p < 0.001$). Lynx crossed highways at increased frequency after sunset until 0100 h; crossing frequency remained relatively high until sunrise, after which it declined (Fig. 3). Lynx crossed highways during all hours, but crossings were 1.85 times more frequent during night ($n = 393$) than day ($n = 212$). Also, observed diel pattern of lynx highway crossings appeared to deviate from the general pattern of lynx activity (Fig. 3). For example, lynx movement activity generally decreased from sunset (1800 h) to 2400 h, while the frequency at which lynx crossed highways increased during this period.

Lynx crossed two-lane highways an average of 0.6 times per day (SD = 0.4, range: 0.2–1.4; Appendix C). The mean number of highway crossings per lynx was 50 (SD = 45.4; range: 6–148) compared to CRW paths that crossed an average of 90 times (SD = 60.0; range: 20–221; Appendix C). Correlated random walk simulations suggested that 5 (3 F, 2 M) of 13 lynx crossed highways significantly less than expected ($p < 0.05$) whereas 8 lynx exhibited no highway avoidance ($0.07 < p < 0.52$; Appendix C); all lynx with highways in their home ranges crossed more than once (Fig. 4).

Three of 5 lynx with adjacent home ranges crossed the four-lane interstate I-70 on 25 occasions. These crossings provided important anecdotal observations of behavior associated with crossing a high traffic volume highway, but the number of observations was insufficient for statistical evaluation with a resource selection function. These lynx mostly crossed I-70 near first- and second-order stream tributaries where eastbound interstate lanes were elevated by bridges 75–100 m long and 15–25 m in height with continuous tall woody vegetation underneath. The highway median between east and west-bound traffic in these areas was approximately 150–200 m wide and included patches of forest cover. Although traffic averaged approximately 1200 vehicles/hr during

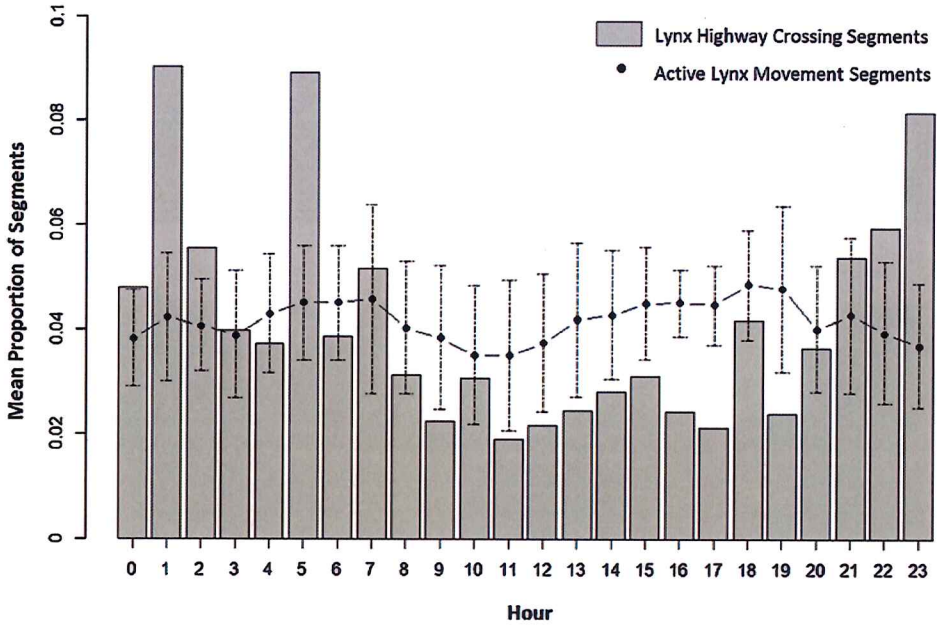

Fig. 3. Proportion of lynx GPS movement segments that cross highways (gray bars) each hour, versus proportion of all active movement segments (black circles +/−standard deviation) per hour for Canada lynx (N = 13) in western Colorado.

the day, volume was reduced to <200 vehicles/hr between 0100 h and 0500 h (Colorado Department of Transportation, 2014). Seven of 25 crossings occurred during this 0100–0500 h period of low traffic, while 9 crossings occurred during other dark hours. Snow tracking data from an independent data set of lynx not included in this study indicated that lynx successfully crossed I-70 on at least three occasions, all about 30 km east of where collared individuals crossed. Large elevated bridges over natural habitat were absent from this stretch of the interstate and these crossings occurred at grade, over the road surface. However, two lynx in the independent data set were killed while attempting to cross at grade in this area and two were killed attempting to cross at grade near the underpasses described above. It is unclear whether those killed while attempting to cross I-70 had crossed successfully in previous attempts.

3.2. RSF models at multiple scales

At the fine scale, lynx were most influenced by vegetation characteristics. No topographic or highway infrastructure covariates performed better than null models in univariate analyses, so they were not considered further. Based on final multivariate models, lynx selected highway crossing zones that were closer to vegetative cover (MaxDistCover) and had greater mean basal area (AvgBasalArea) (Table 1). There were five models within four ΔAIC; following Arnold (2010), we considered models that differed by one extra parameter but were within two AIC of the top-performing model to contain uninformative terms. Thus, only MaxDistCover and AvgBasalArea were meaningful predictors of lynx crossings, although AvgBasalArea was only weakly predictive, as its 95% confidence interval slightly overlapped zero (Table 3). This suggested that lynx were most sensitive to the amount of forest and other vegetative cover along roads when selecting highway crossings. The mean MaxDistCover for used lynx crossings was 17.8 m (SD = 16.3 m), compared to 29.8 m (SD = 34.3 m) for available highway crossings. For every 1 m increase in distance to cover, the odds of highway crossing declined approximately 1.9%. Lynx also tended to select crossing zones with higher tree density compared to random: trees basal area was 78.3 m^2/ha (SD = 31.3 m^2/ha) at crossings compared to 59.5 m^2/ha (SD = 31.3 m^2/ha) at available locations. Mean horizontal cover and the proportion of spruce and fir trees at a crossing appeared among the top models but did not contribute to model performance. Lynx appeared insensitive to roadside slope, the presence of barriers, or line-of-sight distances when selecting highway crossing locations.

At the landscape scale, lynx selected crossings in areas of high forest canopy cover within the surrounding 500 m (LfCanCvr_500), concave topographic positions relative to the surrounding 1000 m (TPI_1000), and predominately northerly aspects within 200 m of the highway (PctNorth_200; Table 2). This top multivariate model ranked best in 57% of bootstrap iterations and was four times more likely than the next candidate model to explain the probability of where lynx crossed highways (Table 2). The second best performing multivariate model ranked best in 42% of bootstrap iterations and included canopy cover within the surrounding 500 m (LfCanCvr_500) and the standard deviation of brightness within the surrounding 500 m (StdBrt_500). All four predictors were strong with 95% confidence intervals that did not overlap zero (Table 3). We averaged predictions from the top 2 multivariate models (<4 ΔAIC) to produce a statewide RSF surface of potential lynx crossing zones along 4359 km of highways (i.e., those above 2000 m elevation) in western Colorado (Fig. 5). Model results suggest that 80% of highways within the elevation zone of lynx habitat in Colorado had less than a 50% chance of being used by lynx for crossings. In contrast, high probability crossing areas were relatively few and were concentrated in areas of high forest cover on north-facing slopes (Fig. 6).

3.3. Model validation

Cross-validation of the fine- and landscape-scale models indicated good model fit. A four-fold cross-validation of the best performing fine-scale RSF model had a Spearman correlation coefficient of $|r_s| = 0.94$. The 10-fold cross-validation for the landscape-scale averaged model yielded a Spearman correlation coefficient of 0.95. The independent data that we used for the landscape model validation consisted of 117 snow tracks of lynx crossing highways and 11 road-killed lynx mortalities. These inde-

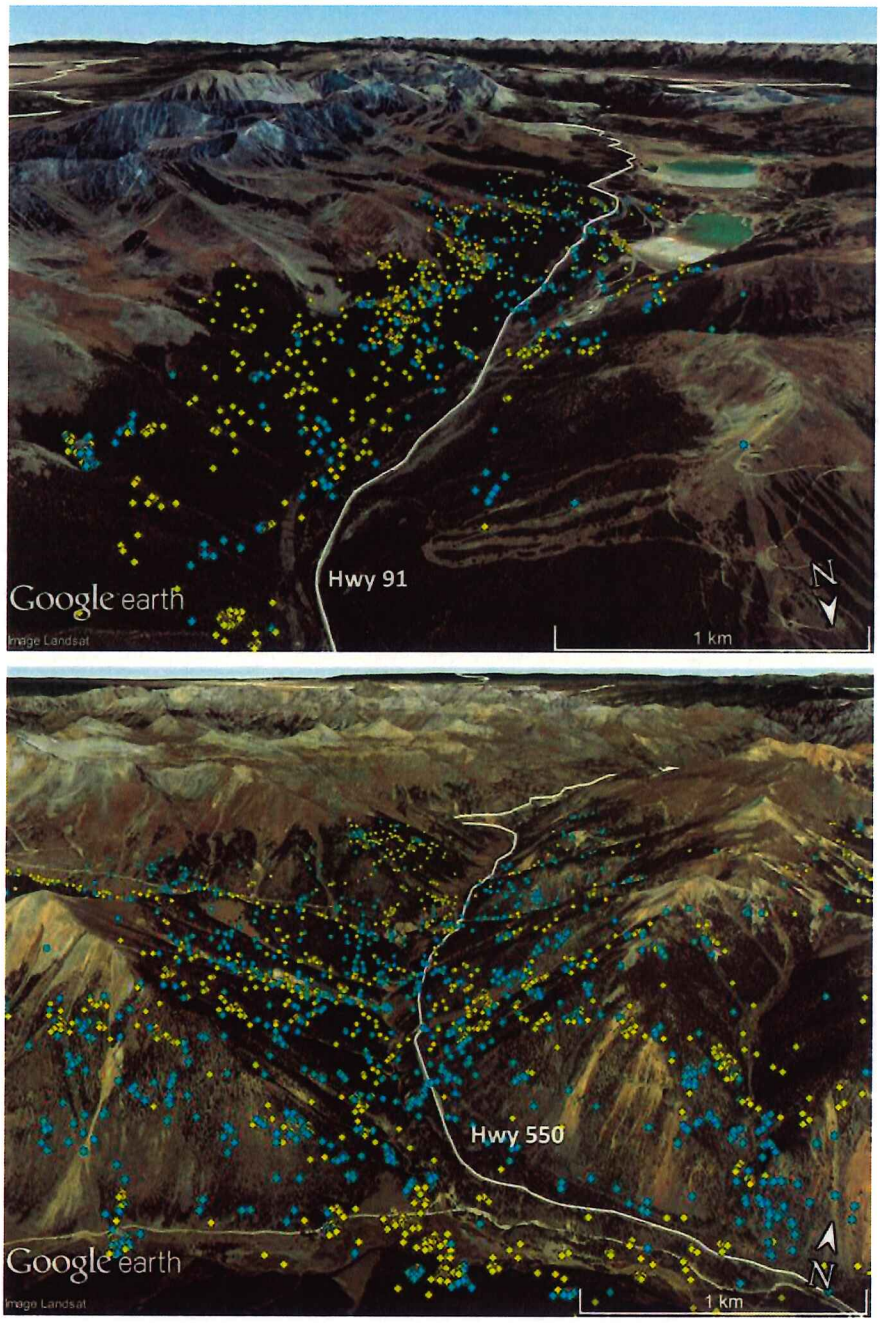

Fig. 4. Examples that illustrate most avoidance (top) and least avoidance (bottom) of 2-lane highways by Canada lynx based on GPS locations, western Colorado. Night locations (20:00 h–06:00 h) are shown in blue, while day locations (07:00 h–19:00 h) are shown in yellow. Even the individual exhibiting most highway avoidance (top) frequently used habitats immediately adjacent to the road. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 1
Model selection results for fine-scale mixed-effects logistic regression models predicting Canada lynx highway crossings in western Colorado. The number of fixed effect parameters (K), AIC score, ΔAIC, AIC weight, and log-likelihood (LL) are given. Model variables include maximum distance to cover (MaxDistCover), mean basal area (AvgBasalArea), mean horizontal cover (AvgHorizCover), and the proportion of spruce and fir trees (PropSF). Only the 5 best performing models plus the null are reported.

	Model	K	AIC	ΔAIC	AICwt	LL
1	MaxDistCover + AvgBasalArea	4	409.79	0.00	0.36	−200.90
2	MaxDistCover	3	411.23	1.43	0.18	−202.62
3	MaxDistCover + AvgBasalArea + AvgHorizCover	5	411.29	1.50	0.17	−200.65
4	MaxDistCover + AvgBasalArea + PropSF	5	411.76	1.97	0.13	−200.88
5	MaxDistCover + AvgBasalArea + AvgHorizCover + PropSF	6	413.23	3.43	0.06	−200.62
6	NULL	2	424.77	14.84	0.00	−210.38

Table 2
Model selection results for landscape-scale mixed-effects resource selection models predicting Canada lynx highway crossings in western Colorado, giving the number of fixed effect parameters (K), AIC score, ΔAIC, AIC weight, log-likelihood (LL), and proportion of bootstrap iterations each model was ranked best (Prop Best). Variables included in the top models were mean percent canopy cover (LfCanCvr_500), topographic position index, percentage of area composed of north-facing aspects, standard deviation of brightness (StdBrt_500), and mean wetness (MeanWet_200). The number after each covariate denotes the size of the radius at which each covariate was calculated. Only the 5 best performing models plus the null are reported.

	Model	K	AIC	ΔAIC	AICwt	LL	Prop Best
1	LfCanCvr_500 + TPI_1000 + PctNorth_200	5	828.03	0.00	0.80	−409.01	0.57
2	LfCanCvr_500 + StdBrt_500	4	830.80	2.78	0.20	−411.40	0.42
3	LfCanCvr_500 + MeanWet_200 + TPI_1000	5	839.22	11.19	0.00	−414.61	0.01
4	LfCanCvr_500 + TPI_1000	4	851.11	23.08	0.00	−421.56	0
5	LfCanCvr_500 + MeanWet_200 + PctNorth_200	5	868.10	40.07	0.00	−429.05	0
6	Null	2	1510.81	682.79	0	−753.41	0

Table 3
Model coefficients, with 95% confidence intervals, of covariates in top performing models within 4 ΔAIC used to predict Canada lynx highway crossings at two spatial scales (fine and landscape) in western Colorado. Model numbers correspond to Tables 1 and 2. Covariates included are maximum distance to cover (MaxDistCover), mean basal area (AvgBasalArea), mean percent canopy cover (LfCanCvr), topographic position index (TPI), percentage of an area composed of north-facing aspects (PctNorth), and the standard deviation of brightness (StdBrt). Numbers after the landscape scale model covariates indicate the size of the radius at which each covariate was calculated.

Scale	Model	Variable	Coefficient	Lower 95% CI	Upper 95% CI
Fine Scale Models	Model 1	MaxDistCover	−0.44	−0.80	−0.12
		AvgBasalArea	0.24	−0.01	0.51
	Model 2	MaxDistCover	−0.57	−0.91	−0.27
Landscape Scale Models	Model 1	LfCanCvr_500	1.82	1.66	2.01
		TPI_1000	−0.56	−0.68	−0.45
		PctNorth_200	0.38	0.28	0.48
	Model 2	LfCanCvr_500	2.38	0.86	1.05
		StdBrt_500	0.86	0.67	1.05

pendent lynx crossings had a predicted average RSF value of 0.75 (range 0.15–0.98; SD = 0.18) from the landscape-scale RSF model (Fig. 6). Additionally, the predicted RSF values associated with all independent lynx crossings were largely between 0.6 and 0.8, with only 7% of independent data associated with modeled values less than 0.5 (Fig. 6). In contrast, the distribution of RSF values at all available locations across Colorado was largely between 0 and 0.1, with 78.82% of predicted probabilities less than 0.5. This suggested the landscape model was effective at predicting the actual areas that lynx would use when crossing highways.

4. Discussion

Canada lynx in the Southern Rocky Mountains of western Colorado crossed 2-lane highways (traffic volumes of 2000–4000 vehicles/day) approximately every other day. We found that most lynx (8 of 13) did not appear to avoid crossing roads, likely due to the habitat configuration of lynx home ranges in our study area. Lynx whose home ranges included extensive sections of highways lived in close proximity to them and crossed frequently. Lynx mitigated the risk of increased highway exposure by crossing roads at greater frequency during dusk and night, when traffic volume was lower. Our resource selection models were successful at predicting the probability of lynx crossing given fine- and landscape-scale environmental characteristics. At both spatial scales, lynx were more likely to cross highways in areas with greater vegetative cover, while at the landscape scale, lynx also preferred north-facing slopes and areas of topographical concavity, such as river drainages.

Despite the fact that all lynx crossed highways, we found that 5 of 13 individuals (39%) exhibited some degree of road avoidance behavior as defined by crossing significantly less than CRW simulations. Other studies have documented highway-avoidance behavior by lynx (Apps, 2000; Squires et al., 2013), although the lynx in our study that exhibited road avoidance behavior still frequently crossed roads in some regions of their home range, depending on forest vegetation near crossing zones (Fig. 4). Lynx reintroduced to the Southern Rocky Mountains occupied habitat in high-elevation mountain valleys that were bounded at upper elevations by open rock and tundra. Given the mountainous topography, two-lane highways in western Colorado were present in valley bottoms with vegetation too sparse for lynx, while other sections were high on mountain passes in good lynx habitat. We acknowledge that reintroduced lynx may exhibit different crossing behavior than native populations. However, of the 13 individuals in our study, five were born in the Southern Rockies, and the remaining eight were resident in the Southern Rocky Mountains for more than 5 years and had established home ranges. Thus, we believe our results reflected behaviors of established individuals and were not uninformed movements of naïve individuals in a new environment.

One way that lynx accommodated vehicle-related disturbance was to cross highways more frequently at night when traffic volumes were relatively low. The proclivity for lynx to cross highways at night was similar to other wide-ranging felids such as bobcat (*Lynx rufus*; Cain et al., 2003) and European wildcat (*Felis silvestris*; Klar, Herrmann, & Kramer-Schadt., 2009), as well as other taxa such as grizzly bears (*Ursus arctos*; Waller & Servheen, 2005) and elk (*Cervus elaphus*; Gagnon, Theimer, Dodd, Boe, & Schweinsburg, 2007). Tigas et al. (2002) reported that bobcats and coyote (*Canis latrans*) tended to utilize areas with high human activity more often at night. Nighttime traffic volumes on highways in western Colorado were generally <5% of peak early-afternoon volumes of 200–400 vehicles per hour (Colorado Department of Transportation, 2014). We assumed that increased crossings at night were an avoidance behavior to vehicle-related disturbance because lynx were generally active across all diel periods (Fig. 3). The tendency of lynx to preferentially traverse highways during periods of low traffic volume may also reduce the risk of vehicle-related mortality (Neumann et al., 2012). For example, Waller and Servheen (2005) demonstrated that grizzly bears experience lower risk in crossing highways at night compared to peak traffic volumes.

At a fine scale, lynx crossed highways in close proximity to vegetative cover, similar to several other large mammal species (Clevenger & Waltho, 2005). Vegetative cover was primarily provided by conifers in stands with higher basal area compared to randomly available along highways. We assume that road-side vegetation provided security cover and that higher horizontal

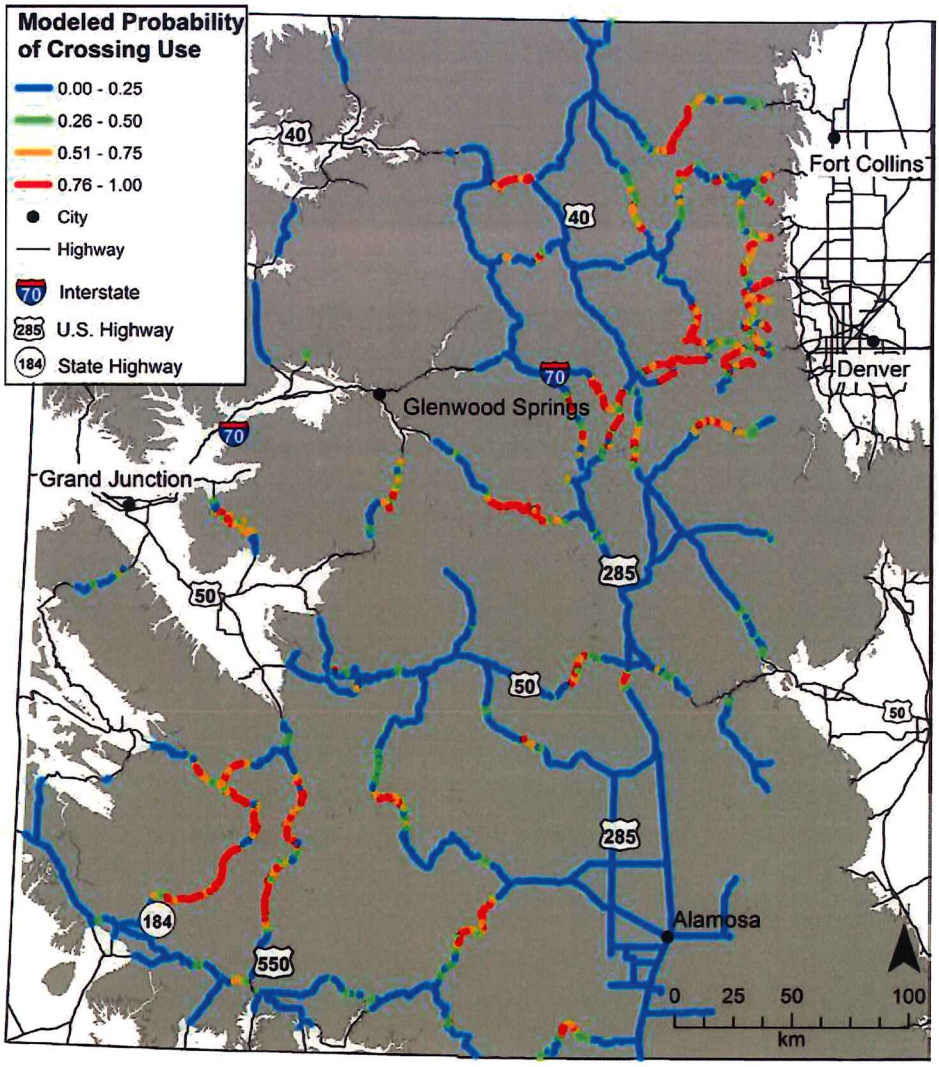

Fig. 5. Resource selection probability surface predicting Canada lynx crossings of highways (gray area indicates >2000 m elevation) at a landscape scale across western Colorado.

cover could support greater snowshoe hare densities (Fuller & Harrison, 2010; Hodges, 2000; Squires et al., 2010). Consistent with fine-scale results, lynx at the landscape scale selected north-facing crossings in areas of high forest canopy cover primarily in drainage bottoms. The landscape-scale model we developed generally agreed with other studies of wildlife highway crossings that identified important crossing areas near drainages with forest cover (Clevenger et al., 2003; Grilo et al., 2009). Our landscape model based on remotely-sensed environmental covariates provides a useful management tool to predict areas of high permeability to lynx movement, as evidenced by performance with independent crossing data. The fact that independent lynx crossing locations were generally associated with high-probability crossing zones supports the use of model outputs by highway planners to evaluate potential crossing zones in western Colorado.

Species with high adjacency to transportation corridors have a heightened vulnerability to vehicle-related mortality compared to those with considerable spatial separation. The high frequency at which lynx crossed highways suggests that risk of vehicle-related mortality was high, which in turn justifies appropriate highway mitigation. Model results at the landscape scale indicate that mitigation actions that promote forest cover immediately adjacent to highways may increase permeability by lynx, especially on north-facing slopes and in drainage bottoms. In addition, the diel crossing pattern of lynx suggests that lower nighttime speed limits on highways in lynx habitat may decrease collision mortality. These suggested mitigation measures are based on resident lynx in winter-spring home ranges that contain highways; we did not directly investigate movements of dispersers or individuals making long distance movements from established territories. Thus, we acknowledge that transient or dispersing felids, or those engaging in exploratory movements, may cross highways where few predictive factors occur (Tewes & Hughes, 2001); these lynx may be more susceptible to vehicle collision than resident animals due to unfamiliar terrain (Beier, 1995; Ferreras et al., 1992).

Physical crossing structures, such as over/under passes and fencing, effectively facilitate safe wildlife crossings of major highways (Foster & Humphrey, 1995; Ng, Dole, Sauvajot, Riley, & Valone, 2004; Yanes, Velasco, & Suárez, 1995). However, the extent to which these improvements benefit lynx may depend on size of the highway and related traffic volume, as well as the landscape structures around the passes. Our GPS locations at 20 min intervals were inadequate to provide detailed depictions of how lynx responded to physical highway structures, like guard rails and cul-

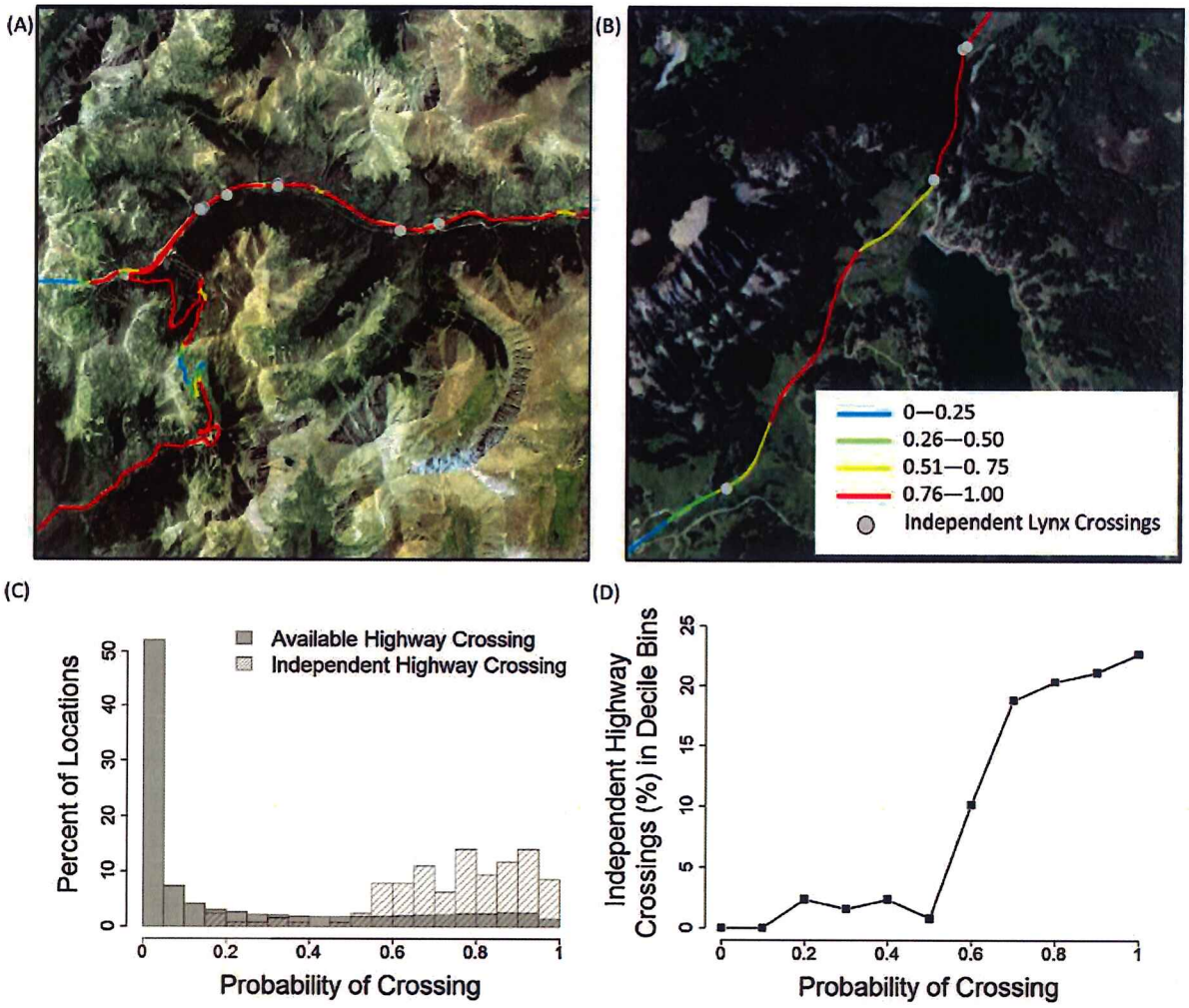

Fig. 6. Examples of the predicted resource selection function surface showing the probability of Canada lynx crossing a highway compared to independent known crossing locations (snowtracking and vehicle-related mortalities; indicated by gray dot) in western Colorado (panels A, B). Panel C shows distribution of predicted probabilities of crossing at all available locations in the landscape-scale RSF versus actual probabilities at independent crossing locations; independent crossings occurred with increasing frequency within the top deciles of binned crossing probabilities (panel D).

verts. In future studies, collars with greater temporal resolution, such as 10 or even 5 min intervals, might be more successful in documenting animal movement relative to highway structures at a fine spatial and temporal scale. However, the broad spatial distribution and sheer number of highway crossings that we documented indicate that lynx mostly crossed two-lane highways at road grade, and they did not depend on physical highway improvements to traverse two-lane highways. Similarly, Tigas et al. (2002) reported a preference by bobcats to cross highways at the surface and Crooks et al. (2008) failed to detect lynx using any of seven underpasses that were constructed specifically to reduce lynx highway mortalities in Colorado.

Our anecdotal observations of lynx crossing I-70, a high traffic four-lane divided highway, suggested that resident lynx did locate safe, below-grade crossings at large underpasses and used them repeatedly. They were also capable of crossing I-70 at road-grade during periods of low traffic volume. The use of underpasses for crossing high volume roads was consistent with other studies. For example, Beier (1995) observed numerous cougars crossing underneath major highway bridges over watercourses and Henke, Cawood-Hellmund, and Sprunk (2001) showed that several mammalian species in Colorado, including bobcats, used below grade highway crossings on major interstate highways. We assume lynx cross high-volume, four-lane highways similar to other wildlife in their proclivity to use larger underpasses with dense native vegetation close to passage entrances (Cain et al., 2003) in favorable habitat with low human disturbance (Beier, 1995; Ng et al., 2004).

5. Conclusions

We demonstrated that, at a fine scale, lynx crossed two-lane highways in forests with higher tree basal area and lower distance to cover. At the landscape scale, lynx selected highway crossings in areas of high forest canopy cover, especially in drainages and on north-facing slopes. The presence of highway infrastructure (guard rails and barriers) was not predictive of crossing two-lane highways. Model results indicated considerable individual variation in crossing behavior and the presence of multiple crossing zones within home ranges when bisected by extensive highway sections. Thus, appropriate mitigation to enhance connectivity for Canada lynx across 2-lane highways may include reduced speed limits at night and vegetation management rather than intensive investments for physical overpasses in few putative crossing zones. However, our anecdotal observations ($n = 25$ crossings) of lynx crossing a high-volume four-lane highway (I-70) suggest that investment in large elevated underpasses across drainages,

especially in highway sections with forested medians, may be warranted.

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Appendix A. Candidate RSF models

Candidate fine- and landscape-scale resource selection function models considered to predict Canada lynx highway crossing locations in western Colorado.

Scale	Model #	Model Structure
Fine Scale Models	1	AvgDistCover
	2	MaxDistCover
	3	AvgBasalArea
	4	AvgHorizCover
	5	MinHorizCover
	6	MaxDistCover + AvgBasalArea
	7	MaxDistCover + AvgBasalArea + AvgHorizCover
	8	MaxDistCover + AvgBasalArea + AvgHorizCover + PropSF
	9	MaxDistCover + AvgBasalArea + PropSF
	10	AvgDistCover + AvgHorizCover
	11	AvgBasalArea + AvgHorizCover
	12	AvgBasalArea + AvgHorizCover + PropSF
	13	Null
Broad Scale Models	1	MEANBRT500
	2	MEANWET200 + MEANBRT500
	3	MEANWET200 + MEANBRT500 + STDBRT500
	4	MEANBRT500 + STDBRT500
	5	LFCNCVR500
	6	MEANWET200 + LFCNCVR500
	7	MEANWET200 + NDVI200 + LFCNCVR500
	8	NDVI200 + STDBRT500 + LFCNCVR500
	9	MEANBRT500 + PCTNRTH200
	10	MEANBRT500 + TPI1000
	11	MEANBRT500 + TPI1000 + PCTNRTH200
	12	MEANBRT500 + ROUGH500
	13	MEANBRT500 + MEANSLP500
	14	MEANWET200 + MEANBRT500 + PCTNRTH200
	15	MEANWET200 + MEANBRT500 + TPI1000
	16	MEANWET200 + MEANBRT500 + TPI1000 + PCTNRTH200
	17	MEANWET200 + MEANBRT500 + ROUGH500
	18	MEANWET200 + MEANSLP500
	19	MEANBRT500 + STDBRT500 + PCTNRTH200
	20	MEANBRT500 + STDBRT500 + TPI1000
	21	MEANBRT500 + STDBRT500 + TPI1000 + PCTNRTH200
	22	MEANBRT500 + STDBRT500 + ROUGH500
	23	MEANBRT500 + STDBRT500 + MEANSLP500
	24	LFCNCVR500 + PCTNRTH200
	25	LFCNCVR500 + TPI1000
	26	LFCNCVR500 + TPI1000 + PCTNRTH200
	27	MEANWET200 + LFCNCVR500 + PCTNRTH200
	28	MEANWET200 + LFCNCVR500 + TPI000
	29	NDVI200 + STDBRT500 + LFCNCVR500 + TPI1000

Appendix B. Predictor variables

Table B1

Variables aggregated from eight vegetation plots and three roadside sample points at used and available lynx highway crossing points, used to evaluate fine scale resource selection functions predicting Canada lynx highway crossing locations in western Colorado.

Type	Variable Name	Description
Vegetation Plots	PropSpruceFir	Percentage of "In" trees on plots that were Engelmann spruce or Subalpine fir.
	AvgBasalArea	Average basal area (sq. meters/ha) of plots, measured with a 10-BAF prism.
	MaxBasalArea	Maximum basal area among plots, measured with a 10-BAF prism.
	AvgHorizCover	Mean horizontal cover of plots.
	MinHorizCover	Minimum horizontal cover among plots.
	AvgPlotSlope	Average slope (%) of plots.
	MaxPlotSlope	Maximum slope (%) among plots.
	PctTreesLess	Percentage of "In" trees on plots with diameter <5".
	PctTreesGE5Less9	Percentage of "In" trees on plots with diameter ≥5 and <9".
	PctTreesGE9Less20	Percentage of "In" trees on plots with diameter ≥9 and <20".
	PctTreesGE20	Percentage of "In" trees on plots with diameter ≥20".
Roadside Sample Plots	AvgRoadSlope	Average roadside slope (%) at sample points.
	MaxRoadSlope	Maximum roadside slope (%) among sample points.
	AvgRoadVisibility	Average distance of continuous pavement visible from sample points.
	AvgDistCover	Average distance from sample points to the nearest stand of continuous trees or shrubs >2 m tall and ≥25 m^2.
	MaxDistCover	Maximum distance among sample points to the nearest stand of vegetation >2 m tall and ≥25 m^2.
	MinDistCover	Minimum distance among sample points to the nearest stand of vegetation >2 m tall and ≥25 m^2.
	RoadCliff	Tally of vertical roadside cliffs >5 m high within 25 m of sample points
	RoadManBarrier	Tally of man-made structures, including guard rails and jersey barriers, within 25 m of sample points.

Table B2

Variables extracted from GIS at used and available lynx highway crossings and used to evaluate landscape scale resource selection functions to predict Canada lynx highway crossing locations in western Colorado. Variables were calculated at two spatial scales: within a 200 or 500 m buffer around each crossing point.

Type	Variable Name	Description
Topography	MEANSLOPE	Average slope (%) from a 10 m digital elevation model.
	ROUGH	An index of terrain roughness, calculated as the standard deviation (SD) of elevations.
	PCTNORTH	Percentage of area composed of north-facing aspects (>270° and <90°) for slopes >10%.
	TPI	Relative topographic position index, where negative values represent topographic concavities and positive values represent ridges.
	DISTHYDRO	Average distance to the nearest 14th-level (HUC) national hydrography dataset stream or waterbody.
Vegetation	LFCANCVR	Average of LANDFIRE canopy cover values, expressed as a percentage.
	NDVI	Average Normalized Difference Vegetation Index values derived from Landsat 5 TM images.
	MEANBRT	Average spectral variations in soil background reflectance (Brightness) derived from a Tasseled Cap transformation of Landsat 5 TM images.
	STDBRT	Standard deviation of spectral variations in soil background reflectance (Brightness) derived from a Tasseled Cap transformation of Landsat 5 TM images.
	MEANGRN	Average spectral variations in the vigor of green vegetation (Greenness) derived from a Tasseled Cap transformation of Landsat 5 TM images.
	STDGRN	Standard deviation of spectral variations in the vigor of green vegetation (Greenness) derived from a Tasseled Cap transformation of Landsat 5 TM images.
	MEANWET	Average spectral variations related to canopy and soil moisture (Wetness) derived from a Tasseled Cap transformation of Landsat 5 TM images.
	STDWET	Standard deviation of spectral variations related to canopy and soil moisture (Wetness) derived from a Tasseled Cap transformation of Landsat 5 TM images.
	MEANPCA1	Average of values from the first Principal Component transformation of Landsat 5 TM image band ratios, which generally correspond to image brightness.
	MEANPCA2	Average of values from the second Principal Component transformation of Landsat 5 TM image band ratios, which generally describes variations in vegetation cover.

Appendix C. Lynx Highway Crossing Summary

Table C1

Summary information for each Canada lynx used to assess highway crossing avoidance within a home range in western Colorado, 2010–2012. Columns show the lynx ID, sex, start and end date of collaring, number of days the animal was collared, number of GPS points collected during this time, percent of GPS fix attempts that were successful, number of road crossings exhibited during this time, number of crossings per day, mean number of crossings as simulated by correlated random walk (Avg Sim Cross), and the non-parametric p-value from the comparison of actual crossings against the simulated distribution. Bold values indicate significantly fewer crossings than expected by chance at $\alpha = 0.05$.

Lynx	Sex	Start Date	End Date	# Days	# Points	% Success	# Cross	Cross/Day	Avg Sim Cross	p-value
F02	F	16-Mar-10	16-Apr-10	31	1925	86	24	0.77	64	0.01
F03	F	28-Feb-12	31-May-12	92	5602	85	62	0.67	61	0.52
M01	M	19-Feb-12	31-May-12	101	6730	93	68	0.67	88	0.35
F04	F	22-Mar-10	10-Apr-10	19	1096	80	6	0.32	19	0.13
M02	M	11-Mar-11	14-Apr-11	34	752	92	9	0.26	79	**0.01**
F06	F	22-Feb-12	31-May-12	98	5693	81	33	0.34	114	**0.04**
M04	M	25-Feb-12	31-May-12	95	6510	95	105	1.11	142	0.17
F07	F	27-Jan-12	17-Jun-12	141	8300	82	106	0.75	221	**0.02**
M05	M	12-Feb-12	31-May-12	108	7399	95	148	1.37	184	0.21
M06	M	18-Feb-12	31-May-12	102	6658	91	27	0.26	53	0.29
M07	M	28-Feb-12	31-May-12	92	5883	89	19	0.21	41	0.24
M08	M	17-Feb-11	14-Jun-11	117	2611	93	29	0.25	71	**0.01**
F08	F	5-Feb-11	15-Jun-11	130	2890	93	11	0.0	32	0.07

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California Unions for Reliable Energy v. Mojave Desert Air Quality Management Dist.

E046687

COURT OF APPEAL OF CALIFORNIA, FOURTH APPELLATE DISTRICT, DIVISION TWO

178 Cal. App. 4th 1225; 101 Cal. Rptr. 3d 81; 2009 Cal. App. LEXIS 1746

October 30, 2009, Filed

NOTICE:

As modified Nov. 16, 2009. CERTIFIED FOR PARTIAL PUBLICATION*

* Pursuant to California Rules of Court, rules 8.1105(b) and 8.1110, this opinion is certified for publication with the exception of footnote 3.

SUBSEQUENT HISTORY: Modified by Cal. Unions v. Mojave Desert Air Quality Mgmt. Dist., 2009 Cal. App. LEXIS 1831 (Cal. App. 4th Dist., Nov. 16, 2009)

COUNSEL: Adams Broadwell Joseph & Cardozo, Marc D. Joseph and Gloria D. Smith for Plaintiffs and Appellants.

Edmund G. Brown, Jr., Attorney General, J. Matthew Rodriguez, Chief Assistant Attorney General, Ken Alex, Assistant Attorney General, Sally Magnani and Susan L. Durbin, Deputy Attorneys General, for the State of California as Amicus Curiae on behalf of Plaintiffs and Appellants.

Best Best & Krieger, Michelle Ouellette, Brian D. Mabee; and Karen K. Nowak, District Counsel, for Defendants and Respondents.

JUDGES: Opinion by Richli, Acting P. J., with Gaut and Miller, JJ., concurring.

OPINION BY: Richli

OPINION

RICHLI, Acting P. J.--In 2007, the Mojave Desert Air Quality Management District (the District) adopted "Rule 1406." [1] Rule 1406 concerns the use of road paving--which reduces airborne dust--to offset increases in airborne dust as well as other forms of particulate air pollution.

1 Rule 1406 was amended in October 2008, after this appeal was already pending. The amendments do not appear to have any relevant substantive effect. Nevertheless, our opinion deals exclusively with rule 1406 as it stood before the amendments.

The parties offer strikingly different characterizations of Rule 1406.

According to the District, Rule 1406 merely provides a "protocol" to be used in applying for, calculating, and issuing paving offsets. It does not authorize any actual road paving; hence, it cannot possibly have any environmental effects. Any future paving offsets will be subject to environmental review if and when applicants seek them, but at this point, their environmental effects are speculative.

Based on this characterization, the District found that its adoption of Rule 1406 was exempt from environmental review under the California Environmental Quality Act (CEQA) (Pub. Resources Code, § 21000 et seq.) under the "Class 8" categorical exemption, which applies to "actions taken by regulatory agencies ... to assure the maintenance, restoration, enhancement, or protection of the environment where the regulatory process involves procedures for protection of the environment." (Cal. Code Regs., tit. 14, § 15308.)

By contrast, according to plaintiffs, [2] Rule 1406 "would allow the paving of up to 5,000 miles of dirt roads," and thus it would have adverse environmental effects. Moreover, the fine particulate matter produced by combustion is a worse pollutant than the coarse particulate matter produced by unpaved roads, so that using the latter to offset the former would, in itself, have adverse environmental effects. Plaintiffs conclude that Rule 1406 does not qualify for the claimed exemption.

2 The plaintiffs are (1) California Unions for Reliable Energy, "a coalition of unions whose members construct and maintain industrial projects throughout California"; (2) the Center for Biological Diversity, "a non-profit environmental organization dedicated to the protection of native species and their habitats through science, policy, and law"; and (3) Frank Leivas, a concerned resident of the District.

CEQA does not demand the impossible; it simply requires public agencies to consider the reasonably foreseeable environmental effects of their actions. Plaintiffs may have overstated their case a bit by harping on the unlikely possibility that Rule 1406 may result in the paving of all 5,000 miles of unpaved road within the District's jurisdiction. Still, it is reasonably foreseeable--indeed, it is almost undeniable--that the adoption of Rule 1406 will result in *some* road paving. Plaintiffs showed that road paving would tend to have adverse environmental effects; the District, for its part, failed to show that these effects would be either de minimis or too speculative to analyze. Accordingly, there was insufficient evidence to support the District's finding that the adoption of Rule 1406 would "*assure* the maintenance, restoration, enhancement, or protection of the environment ... ." (Cal. Code Regs., tit. 14, § 15308, italics added.)

I

FACTUAL BACKGROUND

A. *General Legal Background.*

Particulate matter (PM) refers to very small solid or liquid particles that can be suspended in the atmosphere. Particulate matter consisting of particles that are 10 micrometers or less in diameter (PM10) is considered an air pollutant. (40 C.F.R. § 50.6(c) (2009).) PM10 can be further subclassified into fine particles, which are 2.5 micrometers or less in diameter (PM2.5) (40 C.F.R. § 50, appen. L (2009)) and coarse particles, which are between 10 and 2.5 micrometers in diameter (PM10-2.5) (40 C.F.R. § 50, appen. O (2009)).

The federal Clean Air Act (42 U.S.C. § 7401 et seq.) requires the Environmental Protection Agency (EPA) to prescribe national ambient air quality standards (Standards). (42 U.S.C. § 7409(a), (b).) These include separate Standards for PM10 (40 C.F.R. § 50.6(a) (2009)) and PM2.5 (40 C.F.R. § 50.7 (2009)). Areas that fail to meet the Standards are designated as "nonattainment" areas. (42 U.S.C. § 7407(d).)

Each state is required to adopt a state implementation plan (Plan) that "provides for implementation, maintenance, and enforcement" of the Standards. (42 U.S.C. § 7410(a); see also *id.*, § 7407(a).) A Plan must include a permit program for major new or modified stationary sources of air pollution in nonattainment areas (new source review). (42 U.S.C. §§ 7410(a)(2)(C), 7502(c)(5), 7503.) A permit for a new source may be granted only if it obtains emission reduction credits to offset the increased emissions that it will produce. (42 U.S.C. § 7503(a)(1)(A), (c).)

The District "is the local agency with the primary responsibility for the development, implementation, monitoring, and enforcement of air pollution control strategies" for most of the Mojave Desert Air Basin. (Health & Saf. Code, § 41211; see also Health & Saf. Code, §§ 41200-41267; Cal. Code Regs., tit. 17, § 60109 [defining the Mojave Desert Air Basin].) The Legislature intended the District "[t]o successfully develop and implement a comprehensive program for the attainment and maintenance of state and federal ambient air quality standards ... ." (Health & Saf. Code, § 41200, subd. (d).) To that end, the District has the power to make rules that become part of the state Plan. (Health & Saf. Code, § 41230; see generally *id.*, § 41200 et seq.)

Parts of the District have been designated as nonattainment areas for PM10. (40 C.F.R. § 81.305 (2009); 67 Fed. Reg. 50805, 59005 (Aug. 6, 2002); Cal. Code Regs., tit. 17, § 60205.) However, the District does not include any nonattainment areas for PM2.5. (40 C.F.R. § 81.305 (2009); Cal. Code Regs., tit. 17, § 60210.)

The following additional facts are taken from the administrative record. [3]

3 *

*See footnote, *ante*, page 1225.

B. *Rule 1406.*

"Traditional" offset methods include shutting down an existing facility or controlling the emissions from it. The District has identified road paving as an acceptable--albeit "'non-traditional'"--method of offsetting PM10 emissions. The District's jurisdiction includes approximately 5,000 miles of unpaved roads.

Rule 1406 was derived from a similar rule adopted in Maricopa County, Arizona. Its purpose is to ensure that PM10 offsets for road paving meet federal requirements that all offsets must be "[r]eal," "[q]uantifiable," "[p]ermanent," "[e]nforceable" and "[s]urplus." (See 42 U.S.C. § 7503(a); 40 C.F.R. § 51, appen. S, § IV.C.3.(i)(1) (2009).) [4]

4 In connection with a previous project within the District (Blythe Energy Project II), the EPA had taken the position that a Plan that provides for "non-traditional [offsets], such as road paving, ... must contain an approved protocol for quantifying and guaranteeing the permanence, surplus nature and enforceability of such credits."

Rule 1406 is too long to quote here in its entirety. Accordingly, we summarize its principal provisions.

It states that paving offsets "may be used as offsets in accordance with" other District rules governing new source review. It provides two mathematical formulas for determining the PM10 emissions from paved and unpaved roads, respectively, in units of pounds per vehicle mile traveled. It then provides that "[t]he [PM10] emission reductions associated with paving an unpaved [road] shall be calculated as the difference ... between the emissions from the road in the unpaved condition and the emissions from the road in the paved condition." The resulting reduction in PM10 emissions can be used to offset an increase in PM10 emissions on a one-to-one basis. (See also Mojave Desert Air Quality Management District Rule 1305(C), available at <http://www.mdaqmd.ca.gov/Modules/ShowDocument.aspx?documentid=218> [as of Oct. 30, 2009].)

Former Rule 1406 also prescribed procedures for approving or denying an application for paving offsets. It stated, "The [District] shall determine whether to issue or deny [paving offsets] in compliance with the standards set forth in subsection (C)(5) ... ." Subsection (C)(5) then states:

"(a) The [District] shall only issue [paving offsets] pursuant to this Rule, if the emission reductions will be Real, Quantifiable, Permanent, Enforceable and Surplus.

"(b) The [District] shall only issue [paving offsets] pursuant to this rule ... in the amount determined necessary for construction of the new or modified facility or emissions unit ... ."

Finally, former Rule 1406 provided: "After the [District] has determined to issue the [paving offsets] the [District] shall submit the proposed [paving offsets] for public notice and comment ... ." "Upon the expiration of the public comment period; after review of comments accepted, if any; and upon payment of the appropriate analysis fee, if any; the [District] shall issue the [paving offsets] ... ."

C. *The Proposed Class 8 Categorical Exemption Finding.*

A staff report acknowledged that the adoption of Rule 1406 was a "'project'" within the meaning of CEQA. It stated, however: "The potential environmental impacts of compliance with the adoption of proposed Rule 1406 are positive to the environment, as proposed Rule 1406 will encourage additional road paving with commensurate reduction in particulate emissions from unpaved road dust entrainment." [5] It also stated: ?The adoption of proposed Rule 1406 is exempt from CEQA review because it will not create any adverse impacts on the environment. Because there is no[] potential that the adoption might cause the release of additional air contaminants or create any adverse environmental impacts, a Class 8 categorical exemption (14 Cal. Code Reg[s]. § 15308) applies.?

5 "Entrainment" is used here in its technical engineering sense, meaning the suspension of small particles in a flowing liquid or gas. (See <http://dictionary.oed.com/cgi/entry/50076303>, definition 2 [as of Oct. 30, 2009].)

D. *Plaintiffs' Comments.*

In response to the staff report, plaintiffs submitted 86 pages of comments. Their comments were supported by the in-depth analyses of Dr. Petra Pless and David P. Howekamp, who were duly qualified expert environmental consultants.

Plaintiffs objected that the adoption of Rule 1406 could have a number of potentially significant environmental impacts. In this appeal, they focus on the following three.

1. *The differences between combustion-related PM10 and road dust PM10.*

New stationary sources of PM10, such as power plants, tend to generate PM10 through combustion. [6] Plaintiffs commented that "[c]ombustion-related PM10 is qualitatively different from entrained road dust PM10." PM10 from road dust is mostly coarse, with only about 5 to 10 percent PM2.5. By contrast, PM10 from combustion is mostly fine; it can be 98 to 100 percent PM2.5. "Thus," according to plaintiffs, "the District is effectively trading one air pollution problem for another."

6 The District claims that unpaved roads are "a primary component" of PM10 emissions within its jurisdiction. (Underscoring omitted.) In support of this statement, however, it cites a document that was not included in the administrative record. In any event, even assuming this is true, it is significant that any *new* sources requiring offsets are likely to be combustion related.

PM2.5 differs from PM10-2.5 in its tendency to spread through the atmosphere. Larger particles fall out of the air faster than smaller particles. Also, PM10-2.5 particles from road dust are kicked up by vehicles at ground level, whereas PM2.5 particles from combustion "typically exit through tall stacks with high exit velocities ... ." Thus, PM10 from road dust travels only a short distance and settles not far from the road, whereas PM2.5 from combustion is "regionally distributed."

PM2.5 also differs from PM10-2.5 in its tendency to cause disease. "Fine particle pollution" is "link[ed] ... with serious morbidity and mortality." Exposure to fine PM has been shown to be associated with both lung cancer and heart disease.

In addition, plaintiffs noted that the very activity of paving roads would in itself cause PM2.5 emissions, including diesel exhaust, a "[p]articularly damaging" source of fine PM, "contain[ing] nearly 40 toxic substances."

Plaintiffs quoted a letter from the State Air Resources Board (the Board) stating: "'Fine particulate matter emissions are a serious human health concern.'" The Board explained: "'[F]ine particulates ... (PM2.5) have unique pulmonary dynamics. They selectively penetrate into lung alveoli. Whatever chemicals the particulates have absorbed ... are also transported into the body.'" The Board concluded: "'We believe there is no technical justification for allowing PM emission reductions from road paving to offset PM10 increases from natural gas combustion. ... If [offsets] have

been granted for paving roads, those [offsets] should not be allowed to be used to mitigate the impacts of combustion particulate ... .'" (Boldface omitted.)

2. *The effects on animals and plants.*

Plaintiffs also commented that: "Paving ... roads may result in a number of adverse direct and indirect impacts on biological resources. Direct impacts include mortality during road construction and increased frequency of roadkill from vehicle travel on paved roads. ... [I]ndirect impacts include spread of invasive plant species; air, water, soil, and noise pollution; soil disturbance and erosion; and increase of roadway pollutants and associated habitat loss, degradation and fragmentation; alteration of wildlife movement; and changes in wildlife populations."

Paved roads increase roadkill because they attract more vehicles, and they allow vehicles to travel at higher speeds. In addition, they absorb heat during the day and release it at night, thus attracting animals in search of warmth.

The act of road paving would kill "[a]ny vegetation along the unimproved road, ... any species living in that vegetation or on the unimproved road shoulders," and "any sessile or slow-moving organisms in the path of the road."

Animal species that live along unpaved roads in the District, and that therefore could be directly adversely affected by road paving, include the desert tortoise, a state and federal threatened species; the Mojave ground squirrel, a state threatened species; and the Western burrowing owl, a state and federal species of concern.

3. *Growth-inducing effects.*

Finally, plaintiffs commented that road paving could induce growth: "Paving roads may ... encourage land development by improving access to properties that are at present only accessible via unpaved roads. Consequently, newly paved roads would facilitate the already rampant urban sprawl ... ."

E. *The District's Response.*

The District provided responses to plaintiffs' comments. In these, it stated: "There will be no increase in any particulate emissions due to the proposed rule." It also stated, "It is the District's reasonable judgment that detailed environmental review of potential, speculative impacts from paving of particular roads which might occur at some point in the future is unable to be performed due to the highly speculative and unknown nature of any potential paving projects which could be used to generate [offsets] pursuant to this Rule. ... When and if any application for [offsets] is submitted the environmental impacts of such should be assessed by the agency accepting the paving of the road."

The District then adopted Rule 1406 and found that the Class 8 categorical exemption applied.

II

PROCEDURAL BACKGROUND

Plaintiffs filed a timely petition for a writ of administrative mandate pursuant to CEQA. [7]

7 Plaintiffs named as defendants not only the District, but also Eldon Heaston, in his capacity as the District's air pollution control officer. (See Health & Saf. Code, § 40750.) Inasmuch as his interests are wholly aligned with the District's, we will disregard the distinction between them.

After hearing argument, the trial court denied the petition. It ruled: "[S]ubstantial evidence ... supports the [D]istrict's determination that the Class 8 categorical exemption applies. Rule 1406 is [a] component of new source review of any new or modified stationary sources of air pollutants and is intended to assist the [D]istrict in bringing the non-attainment area into attainment with national air pollution standards. As such, it will enhance or protect the environment. It does not relax standards or allow environmental degradation. Indeed, it does not permit any activity that would harm or degrade the environment. Contrary to petitioners' argument, the rule does not permit the paving of any road or the using of any offset ... : the rule simply sets forth a protocol for calculating such an offset if one is sought. Whether the use of such offsets in connection with a particular project is appropriate will be part of the environmental analysis of that project. Nothing in the rule entitles a future applicant to use such offsets." Accordingly, it entered judgment against plaintiffs and in favor of the District.

III

DISCUSSION

A. *General CEQA Principles.*

1. *Overview of the CEQA process.*

"CEQA and its implementing administrative regulations (CEQA Guidelines) establish a three-tier process to ensure that public agencies inform their decisions with environmental considerations. [Citation.] The first tier is jurisdictional, requiring that an agency conduct a preliminary review to determine whether an activity is subject to CEQA. [Citations.] An activity that is not a 'project' ... is not subject to CEQA. [Citation.]

"The second tier concerns exemptions from CEQA review. The Legislature has provided that certain projects, such as ministerial projects and repairs to public service facilities of an emergency nature, are exempt. [Citations.] In addition, ... the CEQA Guidelines list categorical exemptions or 'classes of projects' that the resources agency has determined to be exempt per se because they do not have a significant effect on the environment. [Citations.] [¶] ... [¶]

?If a public agency properly finds that a project is exempt from CEQA, no further environmental review is necessary. [Citation.] The agency need only prepare and file a notice of exemption [citations], citing the relevant statute or section of the CEQA Guidelines and including a brief statement of reasons to support the finding of exemption [citation]. If a project does not fall within an exemption, the agency must 'conduct an initial study to determine if the project may have a significant effect on the environment.' [Citation.] ...

"CEQA's third tier applies if the agency determines substantial evidence exists that an aspect of the project may cause a significant effect on the environment. In that event, the agency must ensure that a full environmental impact report is prepared on the proposed project. [Citations.]" (*Muzzy*

Ranch Co. v. Solano County Airport Land Use Com. (2007) 41 Cal.4th 372, 379-381 [60 Cal. Rptr. 3d 247, 160 P.3d 116], fn. omitted.)

2. *First tier: The existence of a "project."*

"Project" is defined as an "activity which may cause either a direct physical change in the environment, or a reasonably foreseeable indirect physical change in the environment ... ." (Pub. Resources Code, § 21065; see also Cal. Code Regs., tit. 14, § 15378.) "Activity," for this purpose, includes "[a]n activity directly undertaken by any public agency" (Pub. Resources Code, § 21065, subd. (a)), as well as "[a]n activity that involves the issuance to a person of a lease, permit, license, certificate, or other entitlement for use by one or more public agencies" (Pub. Resources Code, § 21065, subd. (c)).

"Under CEQA, 'project' 'refers to the *underlying activity* which may be subject to approval by one or more governmental agencies; it does not refer to each of the several approvals sequentially issued by different agencies.' [Citations.] 'This definition ensures that the action reviewed under CEQA is not the approval itself but the development or other activities that will result from the approval.' [Citation.]" (*Citizens for a Megaplex-Free Alameda v. City of Alameda* (2007) 149 Cal.App.4th 91, 106 [56 Cal. Rptr. 3d 728].)

"'Whether a particular activity constitutes a project in the first instance is a question of law.' [Citation.]" (*RiverWatch v. Olivenhain Municipal Water Dist.* (2009) 170 Cal.App.4th 1186, 1203 [88 Cal. Rptr. 3d 625].)

3. *Second tier: The existence of an exemption.*

"The CEQA Guidelines provide for 33 classes of projects that generally do not have a significant effect on the environment and therefore may be exempted from CEQA review. [Citations.]" (*Committee to Save the Hollywoodland Specific Plan v. City of Los Angeles* (2008) 161 Cal.App.4th 1168, 1186 [74 Cal. Rptr. 3d 665], fn. omitted.)

In this case, the District relies on the so-called "Class 8" categorical exemption, which applies to "actions taken by regulatory agencies, as authorized by state or local ordinance, to assure the maintenance, restoration, enhancement, or protection of the environment where the regulatory process involves procedures for protection of the environment. Construction activities and relaxation of standards allowing environmental degradation are not included in this exemption." (Cal. Code Regs., tit. 14, § 15308.)

"The scope of an exemption may be analyzed as a question of statutory interpretation and thus subject to independent review. [Citations.] But 'the substantial evidence test governs our review of the [agency's] factual determination that a project falls within a categorical exemption.' [Citation.]" (*San Lorenzo Valley Community Advocates for Responsible Education v. San Lorenzo Valley Unified School Dist.* (2006) 139 Cal.App.4th 1356, 1382 [44 Cal. Rptr. 3d 128].)

"Applying the substantial evidence test in the context of a court reviewing an agency's []exemption decision ... means determining whether the record contains relevant information that a reasonable mind might accept as sufficient to support the conclusion reached. Although the agency bears the burden to demonstrate with substantial evidence that its action fell within the exemption, all conflicts in the evidence are resolved in its favor and all legitimate and reasonable inferences are

indulged in to uphold findings, if possible. [Citations.]" (*Great Oaks Water Co. v. Santa Clara Valley Water Dist.* (2009) 170 Cal.App.4th 956, 968 [88 Cal. Rptr. 3d 506], fn. omitted.)

"In determining ... whether the agency's findings are supported by substantial evidence, the trial court and the appellate courts essentially perform identical roles. We review the record de novo and are not bound by the trial court's conclusions. [Citations.]" (*Environmental Protection Information Center v. California Dept. of Forestry & Fire Protection* (2008) 44 Cal.4th 459, 479 [80 Cal. Rptr. 3d 28, 187 P.3d 888].)

B. *CEQA Principles As Applied to This Case.*

The adoption of a rule or regulation can be a project subject to CEQA. (*Wildlife Alive v. Chickering* (1976) 18 Cal.3d 190, 206 [132 Cal. Rptr. 377, 553 P.2d 537]; *Plastic Pipe & Fittings Assn. v. California Building Standards Com.* (2004) 124 Cal.App.4th 1390, 1412 [22 Cal. Rptr. 3d 393].)

"Many agencies take the position that rulemaking actions are [exempt under] CEQA, relying either on the exemption from CEQA that applies when it is certain an activity will not have a significant environmental impact [citation], or the categorical exemptions for actions taken to protect natural resources [citation] or to protect the environment [citation]." (2 Kostka & Zischke, Practice Under the Cal. Environmental Quality Act (Cont.Ed.Bar 2d ed. 2009) § 20.43, p. 981.)

"Rulemaking proceedings cannot be found exempt, however, when the rule has the effect of weakening environmental standards. [Citations.] [¶] [Even a] new regulation that strengthens some environmental requirements may not be entitled to an exemption if the new requirements could result in other potentially significant effects. [Citations.]" (2 Kostka & Zischke, Practice Under the Cal. Environmental Quality Act, *supra*, § 20.43, p. 981.)

For example, in *Dunn-Edwards Corp. v. Bay Area Air Quality Management Dist.* (1992) 9 Cal.App.4th 644 [11 Cal. Rptr. 2d 850], disapproved on other grounds in *Western States Petroleum Assn. v. Superior Court* (1995) 9 Cal.4th 559, 576, footnote 6 [38 Cal.Rptr.2d 139, 888 P.2d 1268], an air quality management district adopted regulations that required new control measures for the emission of volatile organic compounds (VOC) from paint and other "architectural coatings." (*Dunn-Edwards*, at pp. 649-650.) The plaintiffs presented "evidence that the new regulations require[d] lower quality products. As a result, more product w[ould] be used, which w[ould] lead to a net increase in VOC emissions." (*Id.* at p. 658.) The district took the position that its adoption of the regulations was categorically exempt, citing, among other things, the Class 8 exemption. (*Id.* at p. 653.) It argued that the regulations "constitute[d] more stringent standards for VOC and [thus] cannot be said to have created an adverse change." (*Id.* at p. 657.)

The appellate court rejected the district's exemption claim: "The only evidence in rebuttal to that presented by plaintiffs is a[] ... staff response ... [t]hat ... concludes: '[T]he staff disagrees with the assertion that implementation of the [suggested control measures] will result in an emissions increase due to increased thinning, more frequent recoating and increased incidence of job failures. Thus, the staff disagrees with the contention ... that implementation will have adverse environmental impacts.' This conclusion is based on the fact there was no supporting data for plaintiffs' claims. Thus, rejection of plaintiffs' claims is predicated on lack of the very information which would be provided by an EIR. Since the staff likewise was unable to produce evidence of no adverse impact, the District cannot say with certainty 'there is no possibility that the activity in question may have a

significant effect on the environment.' [Citation.]" (*Dunn-Edwards Corp. v. Bay Area Air Quality Management Dist., supra*, 9 Cal.App.4th at p. 658.)

Ordinarily, as noted earlier, we review a categorical exemption finding under the substantial evidence standard. (*Great Oaks Water Co. v. Santa Clara Valley Water Dist., supra*, 170 Cal.App.4th at p. 968.) The District's exemption claim, however, was based not so much on evidence as on logic. If that logic is flawed, or if it is contrary to the evidence, the claim must fail.

The District reasoned, in part, that "Rule 1406 [is] positive to the environment, as [it] will encourage additional road paving with commensurate reduction in particulate emissions from unpaved road dust entrainment." This overlooks the fact that Rule 1406 merely provides for road paving as an *offset* for *new, increased* PM10 emissions. Moreover, it does so in a one-to-one ratio. Thus, even assuming that (1) road dust is environmentally indistinguishable from other PM10 and (2) road paving itself has no deleterious environmental effects, the net effect is, at best, a push. And if either of these assumptions is false, the net effect would be negative.

The District also reasoned that Rule 1406 permits applicants to seek offsets for road paving, but does not require them to do so; if and when an applicant seeks such offsets, the application will be subject to further environmental review. In response to plaintiffs' comments, it added that environmental review at this point would be unduly "speculative."

This argument flows from the District's narrow view of the relevant project as strictly limited to the adoption of Rule 1406. As already noted, however, "'[t]he term "project," ... means the *whole of an action* which has a potential for physical impact on the environment, and ... "[t]he term *'project' refers to the underlying activity and not the governmental approval process*." [Citation.]' [Citation.]" (*Orinda Assn. v. Board of Supervisors* (1986) 182 Cal.App.3d 1145, 1171-1172 [227 Cal. Rptr. 688].) Here, the underlying activity was road paving (when performed by applicants for the purpose of obtaining the District's approval of PM10 offsets in the process of new source review). The approval of Rule 1406 was the first step in a process of obtaining governmental approval for such road paving.

"Under CEQA's definition of a project, although a project may go through several approval stages, the environmental review accompanying the first discretionary approval must evaluate the impacts of the ultimate development authorized by that approval. This prevents agencies from chopping a large project into little ones, each with a minimal impact on the environment, to avoid full environmental disclosure. [Citations.] ... It is irrelevant that the development may not receive all necessary entitlements or may not be built. Piecemeal environmental review that ignores the environmental impacts of the end result is not permitted. [Citations.]" (1 Kostka & Zischke, Practice Under the Cal. Environmental Quality Act, *supra*, § 6.31, pp. 329-330.)

"The scope of review under CEQA is not confined to immediate effects but extends to reasonably foreseeable indirect physical changes to the environment. [Citations.] An agency action is not exempt from CEQA simply because it will not have an immediate or direct effect on the environment. CEQA applies if it is reasonably foreseeable that environmental impacts will ultimately result. [Citations.]" (1 Kostka & Zischke, Practice Under the Cal. Environmental Quality Act, *supra*, § 4.20, p. 170.)

In the classic case of *Bozung v. Local Agency Formation Com.* (1975) 13 Cal.3d 263 [118 Cal. Rptr. 249, 529 P.2d 1017], the Supreme Court defined the issue before it as "whether [CEQA] applies to the approval of annexation proposals by a Local Agency Formation Commission (LAFCO),

where property development is intended to follow the annexation approval and annexation." (*Id.* at p. 268.)

The City of Camarillo and a private landowner had petitioned LAFCO (Local Agency Formation Commission) to allow Camarillo to annex 677 acres of the landowner's land. (*Bozung v. Local Agency Formation Com., supra*, 13 Cal.3d at p. 269.) The Supreme Court observed, "Vital to our disposition of this case is that [the landowner's] application stated that the land was presently used for agriculture and would be used 'for residential, commercial and recreational uses,' and that such development was 'anticipated ... in the near future.'" (*Id.* at pp. 269-270, fn. omitted.)

First, the court held that approval of the annexation was a "project" for purposes of CEQA. (*Bozung v. Local Agency Formation Com., supra*, 13 Cal.3d at pp. 277-278.) It disagreed with the argument "that such an approval is merely permissive and does not compel the city to annex." (*Id.* at p. 278.) "[I]t ... is an activity directly undertaken by a public agency. [Also,] ... it involves the issuance ... of an entitlement for use. That, in theory, the city eventually may not use the entitlement by not annexing, does not retroactively turn a project into a nonproject." (*Id.* at pp. 278-279, fn. omitted.)

The court also held that an EIR (environmental impact report) was required because the "'project' was one 'which may have a significant effect on the environment.' [Citation.]" (*Bozung v. Local Agency Formation Com., supra*, 13 Cal.3d at p. 279.) It rejected "[t]he notion that the project itself must directly have such an effect." (*Ibid.*) "[T]he impetus for the ... annexation is [the landowner]'s desire to subdivide 677 acres of agricultural land, a project apparently destined to go nowhere in the near future as long as the ranch remains under county jurisdiction. The ... application to LAFCO shows that this agricultural land is proposed to be used for 'residential, commercial and recreational' purposes. Planning was completed, preliminary conferences with city agencies had progressed 'sufficiently' and development in the near future was anticipated. In answer to the question whether the proposed annexation would result in urban growth, the city answered: 'Urban growth will take place in designated areas and only within the annexation.' [¶] It therefore seems idle to argue that the particular project here involved may not culminate in physical change to the environment." (*Id.* at p. 281, fns. omitted.) [8]

8 When *Bozung* was decided, "project" was defined solely in terms of whether the activity at issue was being undertaken, supported, or permitted by a public agency. (*Bozung v. Local Agency Formation Com., supra*, 13 Cal.3d at p. 277, quoting Pub. Resources Code, former § 21065; Stats. 1972, ch. 1154, § 1, p. 2271.) In 1994, this definition was amended so that it now also requires that the activity "may cause either a direct physical change in the environment, or a reasonably foreseeable indirect physical change in the environment ... ." (Pub. Resources Code, § 21065; Stats. 1994, ch. 1230, § 4, p. 7682.)

Nevertheless, *Bozung* held that the annexation, although permissive, was a "project" under the then applicable definition, which is now just the first prong of the definition. It also held that the annexation could have a significant effect on the environment, which means that it would meet what is now the second prong of the definition. Accordingly, *Bozung* remains good law, even under the current definition of a "project."

More recently, in *Plastic Pipe & Fittings Assn. v. California Building Standards Com., supra*, 124 Cal.App.4th 1390, the California Building Standards Commission (the Commission) determined that the adoption of regulations allowing the use of cross-linked polyethylene (PEX) pipes

required environmental review under CEQA. (124 Cal.App.4th at p. 1401.) The Plastic Pipe and Fittings Association (PPFA) challenged this position, but the appellate court agreed with the Commission. (*Id.* at pp. 1412-1414.) It stated: "PPFA contends the enactment of regulations allowing the use of PEX is not a project because the causal link between the enactment of regulations and a physical change in the environment is too remote. PPFA argues that PEX is only one of several materials available for plumbing uses and that at this time there is no certainty that PEX will be used in any particular work of construction. A project, however, includes an activity that 'may cause ... a reasonably foreseeable indirect physical change in the environment.' [Citation.] Thus, an activity need not cause an immediate environmental impact to be considered a project." (*Id.* at p. 1413.)

The District notes that, in *Plastic Pipe*, the Commission had already concluded that the regulations could have a significant environmental impact; thus, it argues, that case merely stands for the proposition that a court must defer to an agency's findings if they are supported by substantial evidence. We disagree. The court held that the adoption of the regulations constituted a project as a matter of law. As it stated in its discussion of this issue, "[w]hether an activity constitutes a project under CEQA is a question of law that can be decided de novo based on the undisputed evidence in the record. [Citation.]" (*Plastic Pipe & Fittings Assn. v. California Building Standards Com., supra*, 124 Cal.App.4th at pp. 1412-1413.) Moreover, in this case, as we mentioned earlier, the District determined that Rule 1406 could not have any adverse environmental impacts as a matter of logic, not evidence. *Plastic Pipe* refutes the District's reasoning.

Of course, the District did acknowledge that its adoption of Rule 1406 was a project. Nevertheless, it then cut short its consideration of the project's environmental effects by concluding that the causal link between the adoption of the rule and a physical change in the environment was too remote. This was inconsistent with the holding in *Plastic Pipe*.

Bozung requires us to reject the District's argument that Rule 1406 is merely permissive. Under *Bozung*, the focus must be not on the project alone, but rather on the project's reasonably foreseeable direct and indirect physical effects. While the adoption of Rule 1406 did not cause any road paving *by itself*, certainly it *encouraged* third parties to pave roads. It is reasonably foreseeable that, if the District allows applicants to obtain PM10 offsets by paving roads, at least some applicants will do so. Otherwise, why adopt the rule?

The District argues that *Bozung* is not controlling because there the annexation was "driven by a developer's *specific project* and therefore *sufficiently definite* to require an EIR," whereas here, any future road paving is "speculative." (Underscoring omitted, italics added.) As the Supreme Court itself defined the issue, however, what was crucial was merely that further property development was "intended." (*Bozung v. Local Agency Formation Com., supra*, 13 Cal.3d at p. 268.) The fact that, in *Bozung*, the evidence of that intent was strong does not mean that lesser evidence will not suffice.

Here, the District intended at least some actual road paving to occur. Indeed, as the administrative record shows, at the same time as the District was considering Rule 1406, the City of Victorville was proposing to build a power plant called the Victorville 2 Hybrid Power Project. Victorville proposed to offset the resulting increased PM10 by paving specified roads, totaling 1.37 miles. Indeed, Victorville had been "working closely" with the District in the development of Rule 1406. The District had even drawn up a list of roads within its jurisdiction that were suitable for paving. [9]

9 The District demurred to the complaint--albeit unsuccessfully--on the ground that Victorville had "relied upon the provisions of then unadopted Rule 1406" and was therefore an indispensable party.

The administrative record contains no *evidence* (as opposed to the District's bare assertion) that the environmental effects of the adoption of Rule 1406 are speculative. Plaintiffs' comments were at least some evidence that the *quality* of those effects would in fact be adverse. Basically, plaintiffs showed that trading a pound of PM10 from road dust [10] for a pound of PM10 from combustion would mean that the resulting PM10 would stay in the air longer, spread more widely, and be more likely to cause disease. Also, the very act of road paving would produce still more PM10--mostly made up of PM2.5--while also having adverse biological and growth-inducing effects.

10 One problem we have with Rule 1406--although plaintiffs did not raise this issue in their comments--is that it calculates the offset by taking the emissions from the (actual present) unpaved road and subtracting the emissions from the (hypothetical future) paved road; all emissions are expressed in pounds per vehicle mile traveled. But this assumes that vehicle miles traveled on a road will remain the same after the road is paved. Surely this is an unrealistic assumption?

The only thing that was even arguably speculative about these effects was their *quantity*. Plaintiffs' evidence did not necessarily require a finding that these adverse environmental effects would be *significant*. For example, there was no evidence of how many third parties were likely to apply to pave how many miles of roads. Likewise, it was unclear how many miles of road paving were likely to kill how many burrowing owls.

Nevertheless, the District purported to find that a Class 8 exemption applied. This necessarily meant that the adoption of Rule 1406 would "*assure* the maintenance, restoration, enhancement, or protection of the environment ... ." (Cal. Code Regs., tit. 14, § 15308, italics added.) The District has the burden of proof--there must be substantial evidence to support this categorical exemption finding. In the *absence* of evidence that the negative environmental effects of Rule 1406 would *not* be significant, the exemption finding cannot be sustained.

Here, much as in *Dunn-Edwards*, "rejection of plaintiffs' claims is predicated on lack of the very information which would be provided by an EIR. Since the staff likewise was unable to produce evidence of no adverse impact, the District cannot say with certainty 'there is no possibility that the activity in question may have a significant effect on the environment.' [Citation.]" (*Dunn-Edwards Corp. v. Bay Area Air Quality Management Dist., supra*, 9 Cal.App.4th at p. 658.)

The District argues that *Dunn-Edwards* is distinguishable because here, if and when individual applicants seek paving offsets, there will be further environmental review. Nothing in *Dunn-Edwards* suggests that the outcome there would have been different if there had been a subsequent opportunity for environmental review. Moreover, nothing in the definition of a Class 8 categorical exemption turns on whether there will be a subsequent opportunity for environmental review.

More broadly, the District argues that environmental review at this point is premature and hence unduly speculative. This argument flies in the face of the District's actual determination that the adoption of Rule 1406 would have beneficial environmental effects, and there was no possibility that it would have adverse environmental effects.

"Choosing the precise time for CEQA compliance involves a balancing of competing factors. EIRs and negative declarations should be prepared as early as feasible in the planning process to enable environmental considerations to influence project program and design and yet late enough to provide meaningful information for environmental assessment." (Cal. Code Regs., tit. 14, § 15004, subd. (b).) "To implement the above principles, public agencies shall not undertake actions concerning the proposed public project that would have a significant adverse effect or limit the choice of alternatives or mitigation measures, before completion of CEQA compliance. For example, agencies shall not: [¶] ... [¶] ... take any action which gives impetus to a planned or foreseeable project in a manner that forecloses alternatives or mitigation measures that would ordinarily be part of CEQA review of that public project." (Cal. Code Regs., tit. 14, § 15004, subd. (b)(2)(B).) "Where an individual project is a necessary precedent for action on a larger project ... with significant environmental effect, an EIR must address itself to the scope of the larger project." (Cal. Code Regs., tit. 14, § 15165.)

At a minimum, the District committed itself to allowing paving offsets pursuant to the procedure and the formulas set forth in Rule 1406. Former Rule 1406 stated that: "The [District] shall determine whether to issue or deny [paving offsets] in compliance with [specified] standards ... ." Admittedly, it makes the issuance of a paving offset subject to a public comment period. Nevertheless, it also provides that "[u]pon the expiration of the public comment period; after review of comments accepted, if any; and upon payment of the appropriate analysis fee, if any; *the* [*District*] *shall issue the* [*paving offsets*] ... ." (Italics added.) It does not appear that the District could refuse to issue a paving offset on the ground that the formulas in Rule 1406 failed to adequately account for the environmental effects of road paving.

Thus, by adopting Rule 1406, the District lost the opportunity to consider possible alternatives and mitigation measures. Suppose an applicant seeks to build a new power plant, using paving offsets. Further suppose that a challenger argues that there must be environmental review of the proposed offsets, because they tend to increase PM2.5, or because the very activity of road paving would have adverse environmental impacts. The District would be able to respond that this is, in effect, a CEQA challenge to Rule 1406, and that the statute of limitations has run on any such challenge. (See *Temecula Band of Luiseño Mission Indians v. Rancho Cal. Water Dist.* (1996) 43 Cal.App.4th 425, 434-439 [50 Cal. Rptr. 2d 769] [where statute of limitations had run on challenge to previous project, review of modified project was limited to its incremental effects] [Fourth Dist., Div. Two].)

We therefore conclude that there was insufficient evidence to support the District's finding that the adoption of Rule 1406 was within the Class 8 categorical exemption.

IV

DISPOSITION

The District asked the trial court to deny the petition for one and only one reason--because its categorical exemption finding was appropriate. As we are holding that the categorical exemption finding was *not* appropriate, it appears that plaintiffs are entitled to the writ sought.

Accordingly, the judgment is reversed with directions to the trial court to grant the petition and to issue a writ of mandate commanding the District to set aside (1) its adoption of Rule 1406 and (2) its finding that the adoption of Rule 1406 was within the Class 8 categorical exemption. (See *Valley*

Advocates v. City of Fresno (2008) 160 Cal.App.4th 1039, 1074 [72 Cal. Rptr. 3d 690].) The trial court shall retain jurisdiction over the District's further proceedings by way of a return to the writ. (*Ibid.*; see also Pub. Resources Code, § 21168.9, subd. (b); *Gentry v. City of Murrieta* (1995) 36 Cal.App.4th 1359, 1423 [43 Cal. Rptr. 2d 170].) We do not mean to preclude the trial court from including additional terms in its judgment or in its writ of mandate, nor from holding such further hearings as it may deem necessary to determine what additional terms should be included. Moreover, we do not mean to preclude the District from finding that the adoption of Rule 1406 is within the Class 8 categorical exemption or otherwise exempt, as long as it does so in compliance with CEQA.

Plaintiffs are awarded costs on appeal against the District.

Gaut, J., and Miller, J., concurred.

Methodology for Estimating Fugitive Windblown and Mechanically Resuspended Road Dust Emissions Applicable for Regional Air Quality Modeling

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ABSTRACT

Several years ago the Western Governors' Association (WGA), in conjunction with federal, state, tribal and local entities, formed the Western Regional Air Partnership (WRAP) whose goal is to develop and plan regional programs that will reduce emissions and improve visibility in the Western US. One of the major conclusions reached by the Grand Canyon Visibility Transport Commission (the predecessor organization to WRAP) was that fugitive windblown dust and mechanically resuspended paved and unpaved road dust accounted for a large fraction of the visibility degradation occurring at Class I sites in the west. Over the past year, members of WRAP have worked with a panel of air quality experts from both the private and public sectors to identify the best methodology for developing an emission inventory for fugitive windblown dust and mechanically resuspended road dust that contribute to regional haze. This paper will present the expert panel's findings and identify recommendations for future research activities for improving fugitive dust emissions estimation techniques applicable for regional scale air quality modeling.

INTRODUCTION

The Grand Canyon Visibility Transport Commission (GCVTC) was created in response to the Clean Air Act of 1990 with the goal of identifying measures that could be implemented to reduce emissions and improve visibility in the Colorado Plateau. The Commission prepared a report for the EPA in 1995 that included an emission inventory for the study region, outlined several potential control measures and identified areas of investigation to pursue in the future[1]. One of the recommendations was to investigate the near-field and far-field effects of mechanically resuspended fugitive dust from paved and unpaved roads on visibility in Class I areas in the intermountain west. In 1997 a successor organization to the GCVTC was formed known as the Western Regional Air Partnership (WRAP). The Research and Development (R&D) Forum of the WRAP identified windblown fugitive dust as an area needing further study in addition to that of mechanically resuspended road dust. In 2000 a panel of air quality experts was convened by the R&D Forum to identify the best methodology for estimating emissions of fugitive windblown and mechanically resuspended road dust applicable for regional scale air quality modeling, and to make recommendations for future research activities to generate improved fugitive dust emissions estimation techniques applicable for regional scale modeling. Members of the panel included Bill Barnard (Harding ESE, Inc.), Candis Claiborn (Washington State University), Richard Countess (Countess Environmental), Dale Gillette (National Oceanographic and Atmospheric Administration), Doug Latimer (USEPA Region VIII), Tom Pace (USEPA, OAQPS) and John Watson

(Desert Research Institute). This panel derived a list of recommendations based on eleven findings regarding fugitive windblown and mechanically resuspended road dust.

EXPERT PANEL FINDINGS

Finding #1: Not All Suspendable Particles are Transported Long Distances

Fugitive dust sources are ground-level sources, usually line or area sources. The fraction of emissions that are transported long distances from the source of their emissions can be determined from a combination of factors that vary over a wide continuum of values. These factors include:

- **Deposition rates.** The rate at which particulate matter is deposited to the surfaces of vegetation, man-made structures, and the earth depends upon the size and density of the particles. Also, the characteristics of the earth's surface play a major role. For example, the rate of deposition in forests is greater than in open fields, deserts, and urban areas.
- **Vertical mixing.** Depending upon atmospheric conditions and transport time, vertical mixing can range from a few meters to thousands of meters. Deposition is more efficient if the particulate matter plume is shallow and at ground level.
- **Transport time.** Transport time acts to both increase and decrease the rate of loss of PM. Vertical mixing increases with time during which the PM concentration at the ground decreases resulting in less deposition. On the other hand, transport time increases the cumulative time allowing for increasing deposition.

Deposition Rates

The fine and coarse modes of PM_{10} are deposited at different rates. The coarse mode, the coarse fraction of PM_{10}, with mass median aerodynamic diameters of about 5 to 6 μm deposits relatively quickly (0.5 - 5 cm/s). The fine mode, $PM_{2.5}$, with mass median diameters of about 0.3 to 0.5 μm, deposits more slowly (0.05 - 0.2 cm/s). The difference is due to the fact that larger particles have a higher gravitational settling velocity than small particles. Similarly, particles are differentially deposited by inertial impaction depending on the inertia of the individual particle; particles having larger inertia are deposited preferentially to particles having smaller inertia. Deposition by other mechanisms like thermophoresis and electrophoresis may also be important in particle removal. The two order of magnitude range in deposition rates (0.05 - 5 cm/s) varies between two extremes: a maximum for dense forests and a minimum for barren desert areas, with a continuum of values between these two extremes for crop land, prairie land and urban (paved) surfaces.

Vertical Mixing

The initial vertical extent of the freshly generated particulate plume is shallow and for a brief time may be below the height of nearby vegetation, buildings or other obstacles. While the plume is low, enhanced deposition can occur onto these surfaces. After a short time (a few minutes at most which corresponds to a few hundred meters downwind of the source) diffusion has likely taken much of the remaining plume above these surfaces and gravity as well as wet deposition become the predominant removal mechanisms.

In general, the fraction of the mechanically generated fugitive dust from roads and bare surfaces that is removed from the atmosphere by gravitational settling and by impaction on nearby obstacles (such as vegetation) is much larger than that associated with fugitive windblown dust. This is due to the fact that the mechanically generated particles tend to remain closer to the ground for longer periods after suspension than windblown dust such that there is a higher probability that these mechanically generated

particles will be removed from the atmosphere close to their source. For mechanically generated road dust, the initial vertical energy associated with the moving vehicles that generated the suspendable particles is short-lived and unsustained. And, in the absence of strong winds with a large vertical component to sustain the vertical motion of these mechanically generated particles, these emissions are dispersed vertically above the ground and any downwind obstacles solely by the daytime turbulent eddies caused by solar heating of the ground. On the other hand, windblown dust emissions may be lofted vertically to great heights above the ground by the sustained energy provided by the vertical component of the wind (especially for strong winds with large vertical components such as those associated with dust devils or thunderstorms) and consequently may be transported much longer distances from the source of emissions than mechanically generated fugitive dust emissions.

The well-mixed wake behind a vehicle often extends 1 to 2 times the vehicle height; thus, initial vertical dispersion can range from 1 to 6 meters (depending on the size of the vehicle). This is consistent with the initial vertical distribution of fugitive dust measured near a road; see Figure 1 that illustrates the PM_{10} flux measured within 2 to 5 meters of the roadway. With further transport time (and distance), atmospheric turbulence further increases the vertical depth of the fugitive dust plume. For a neutral atmospheric stability, the Pasquill-Gifford vertical dispersion coefficient (σ_z) for neutral conditions (D stability class) is 5 m at 100 m downwind, 30 m at 1 km, 120 m at 10 km, and 400 m at 100 km. The extent of vertical mixing is roughly twice the neutral stability numbers. For the stable conditions (categories E and F) characteristic of nighttime dispersion, coefficients are 3 - 5 times lower. For unstable conditions (A, B, and C), characteristic of daytime dispersion with solar heating of the earth's surface, the extent of vertical mixing can be 5 times to orders of magnitude greater than for neutral dispersion. Thus, the range of vertical mixing over a few hours can be three orders of magnitude. This variation combined with different deposition rates, discussed above, adds to the broad range of the continuum of conditions.

Transport Time

Transport time (directly related to transport distance) has a large effect on dry deposition. The amount deposited increases with transport time. Theoretically, for very long transport times, virtually all particulate matter is deposited. Generally, at these long transport times precipitation completes the removal of material. The vertical dispersion of the particulate plume also increases as a function of time. Transport time and distance are related to the wind speed. A typical wind speed of 2.5 m/s (5.6 mph) results in transport to 100 m in 40 seconds, 1000 m in 400 s (6.7 min), 10,000 m in 4000 s (1.1 hr).

Conclusion

The fraction of fugitive dust emissions that is transported beyond the source area can approach one on the high end, and zero on the low end, because of the extremely wide range of deposition rates, vertical mixing heights, and transport times. The rate of particulate matter loss is simply the deposition velocity divided by the mixing height. Thus, the loss rate for particles with a 0.1 cm/s deposition velocity and a mixed layer height of 100 m is 10^{-5} s^{-1} (0.04 h^{-1} or 4%/hr). However, increasing the deposition velocity by a factor of 10 and decreasing the mixing height by a factor of 10 will result in increasing the loss rate to 10^{-3} s^{-1} or 6% per minute. To determine the fraction of fugitive dust transported requires knowledge and integration of the combined effects of the landscape (roughness height), the particle size and density, and the meteorological conditions (stability and wind speed). Because of the wide continuum of each of these parameters, nothing specific and quantitative can be said about the fraction of particulate emissions that remains airborne for transport beyond the initial 100 m or so. In general, PM_{10} is deposited at a rate that is about an order of magnitude greater than $PM_{2.5}$ because of its greater gravitational settling velocity. The rate at which fugitive particulate matter will either be deposited or transported depends on the landscape in which fugitive dust is generated. In forest situations, with large roughness heights and surface areas, deposition will be much faster, greatly

reducing (or eliminating) the fraction of PM that is transported. However, in open fields, prairies, deserts, and urban areas, much of the PM emissions will remain airborne. This conclusion demonstrates the importance of characterizing the landscapes of the fugitive dust source, as well as the magnitude and timing of emissions. The fact that $PM_{2.5}$ deposition is roughly an order of magnitude lower than that for the coarse mode suggests that the fine/coarse ratio measured at downwind receptor sites may be a good indicator of the relative contribution of local versus distant sources of fugitive dust emissions.

Finding #2: Regional Scale Vertical Flux is Smaller than the Local-Scale Fugitive Dust Flux

The regional scale vertical dust flux for a large scale transport model applies only to particles that are not deposited in the same grid cell in which they are emitted. Since a portion of the particles are deposited within the same grid cell from which they were emitted, the effective regional scale vertical flux of fugitive dust particles is smaller than the local scale vertical flux. The ratio of the effective regional scale vertical flux to the local scale vertical flux is a function of the friction velocity of the surface and the deposition velocity of the different size particles.

A "lumped control volume" approach was developed by Gillette as part of the WGA sponsored project[4] to relate regional scale vertical dust flux to field-scale fugitive dust for situations where the vertical fugitive dust flux is not uniform across the entire surface of the grid cell. For the condition of steady state emissions, solving the equation for conservation of mass within the control volume (CV) results in a value Φ, defined as the ratio of vertical flux of fugitive dust into the atmosphere to the horizontal flux of fugitive dust:

Equation (1)
$$\Phi = \frac{\frac{dm_{up}}{dt}}{\frac{dm_{surface}}{dt}} = \frac{0.08u_*}{(V_d + 0.08u_*)}$$

where
- dm_{up}/dt = mass per unit time passing out vertically at the top of the CV
- $dm_{surface}/dt$ = mass per unit time emitted from the surface
- V_d = deposition velocity
- u_* = friction velocity

Values of Φ are presented as a function of friction velocity in Figure 2 for different values of deposition velocity.

Finding #3: Fugitive Dust Emission Factors Need to be Appropriate

Many of the past fugitive dust emission inventories were inaccurate since they used inappropriate emission factors. Emission factors should be based on physical models rather than statistically significant variables and should be consistent for different source types with similar suspension mechanisms (e.g., mechanically reentrained dust from paved and unpaved roads; wind erosion from desert, agricultural, and vacant land as well as unpaved roads and construction sites). There have been recent advancements in characterizing the factors that make up the empirically derived emission factor equations as well as the reformulation of the emission factor equations that need to be taken into account. For example, improved algorithms for fugitive dust emissions from construction operations are currently being implemented. Also, the unpaved road dust algorithm is currently under review by the USEPA.

Windblown dust emissions predicted for fugitive dust emission inventories are inaccurate for several reasons. These include using wind erosion models developed for purposes other than air quality

emission inventories, temporally- and spatially-averaged meteorological data that averages out wind gusts, inadequately characterized soil and topographic characteristics, and models that do not properly characterize the emission processes. For a detailed discussion of the processes involved in wind erosion and the various models developed to address fugitive windblown dust, the reader is directed to the report by Countess et. al. (2001)[4] and the companion paper for this conference by Claiborn (2001)[5].

The assessment that resulted in the current revision to the AP-42 emission factor for unpaved roads involved iterative modifications of the original factor first published in 1974 that stated that emissions were proportional to vehicle speed. Our review of the original data[6,7] indicates that the emissions increased as some power of the vehicle speed rather than linearly with vehicle speed. It should be pointed out that vehicle speed was omitted in the recent revision of the emission factor since it provided no additional improvement in the overall correlation. This is an example of a potential flaw in the use of statistical evaluations to determine real world parameterizations of physical processes. Intuitively, it is apparent that when the speed of a vehicle increases on an unpaved road, the visual plume also increases (and thus emissions must also be increasing). Thus removing vehicle speed from the emission factor equation simply because it provides no additional information in a statistical correlation analysis makes no sense. For paved roads, recent work[8] has shown that the AP-42 emission factor model yields highly uncertain estimates because it lacks a mechanistic basis; its formulation is highly dependent on the data set used to derive it; and the accuracy of the model is completely determined by the methods used to measure emissions.

Finding #4: Extent of Source Activity Levels Need to be Accurate

Many of the past fugitive dust emission inventories are inaccurate since they used inappropriate estimates of the extent of the source activity levels. There is a large uncertainty in the extent of the reservoir of suspendable particles (which is especially true for wind erosion and paved roads), as well as the impact of meteorological variables and human intervention. This finding is particularly valid for unpaved roads, somewhat valid for paved roads, and varies between somewhat valid to extremely valid for wind erosion. It applies not only to the extent of activity levels, which strictly speaking for paved and unpaved roads is vehicle miles of travel (VMT), but also applies to the data used in the "correction" parameters in the emission factor equations (e.g. silt content, silt loading, average fleet vehicle weight, etc.). The validity of this finding is exacerbated by inventory scale. As the emission inventory scale goes from local to regional to national, locating consistent, readily available databases of activity data or information required for the correction parameters becomes increasingly difficult. The possible exception is VMT on paved roads. Since paved road mileage far exceeds unpaved road mileage, State or local transportation departments are more likely to collect and report VMT on paved roads. Information on individual field parameters for wind erosion or silt loading for specific roads or areas are much more difficult to locate. By necessity, large-scale emission inventories must use values interpolated from or equal to adjacent measured values, or default values presented in AP-42 to determine emissions. This leads to a reduction in the overall accuracy in the emissions estimates.

Finding #5: Fugitive Dust Emissions are not Continuous Processes

Emission inventories (and the emission factors used to develop emission inventories) incorrectly treat fugitive dust emissions as continuous processes. Emission factors developed using the upwind/downwind method are by default treating emissions as a continuous process, since a continuous line source dispersion model is back-calculated to derive the emission factor. For paved roads, this assumption, especially for multi-lane, high average daily traffic volume, is probably reasonable for periods other than the late evening/early morning where non-continuous situations exist. On the other hand, there are many unpaved roads with fewer than 3 cars per hour on average which would not qualify as a continuous line source.

Finding #6: Annual Fugitive Dust Emission Inventories are not Sufficient

Annual emission inventories are not sufficient to develop emission control strategies for haze events. Improved seasonal and diurnal profiles are needed for use in emission inventories. Wind erosion is highly variable and poorly characterized. Many of these variations are affected by certain meteorological conditions that are not currently considered in emissions models. Fugitive dust emissions have been observed to vary over annual, seasonal, daily, and even diurnal periods owing to differences in the material available for suspension and the activities that cause that suspension[9-11]. Yearly and seasonal variations can be practically addressed in emissions inventories. Day-to-day and diurnal emissions might be addressed for specific episodes for a few sources, but this requires prior planning to track emissions events that is impractical under most circumstances.

Finding #7: Spatial Allocation of Fugitive Dust Emissions is Important

Better spatial surrogates than are currently in use are available for estimating available fugitive dust reservoirs, locations, dust-generating activities, and temporal changes in surface properties and surroundings. Use of these spatial surrogates would provide better information to support the models used for emissions estimates.

Most inventories use national activity surrogates that are remotely related to dust reservoirs and activities that create dust. Meteorological surrogates that affect emissions (moisture, wind speed) are averaged temporally and spatially. Reservoirs are assumed to be unlimited, rather than depletable. Improvements can be made in all of these areas by using spatial surrogates that are related to the availability of dust for suspension (currently done by estimating the "silt" fraction or loading in surface dust) such as maps of roads, vegetative land cover, land use, soil types, and spatially and temporally resolved meteorological data.

Finding #8: The Fine Fraction of Fugitive Dust Emissions is not Adequately Characterized

Few empirical measurements exist for characterizing the fine aerosol fraction of fugitive dust emissions (i.e., that fraction that has the longest residence time in the atmosphere and that has the largest impact on visibility degradation). The majority of the measurements made as part of emission factor development studies focused on total suspended particulates (TSP) since that was the regulatory standard at the time the measurements were made. These measurements were augmented with a modest amount of PM_{10} data when PM_{10} became the regulatory standard coupled with some measurements of $PM_{2.5}$. Few direct measurements of fine particles exist for wind erosion. When these field studies measured fine particles, many used older particulate measurement devices that did not correctly characterize the particle size cut points and/or did not adequately account for particle bounce (Note: any particle bounce would have caused the $PM_{2.5}/PM_{10}$ ratio to be too high.). EPA has recently reviewed the collected information on $PM_{2.5}/PM_{10}$ ratios developed during these measurement programs to determine the effects particle bounce may have had. That review resulted in modifications to the $PM_{2.5}/PM_{10}$ ratio used to estimate emissions for the National Emissions Trend (NET) inventory. In addition, in most of the exposure profile studies, particle size distribution information was only collected at one height in the profiler array. As a consequence, the change in the vertical distribution of particle sizes (or particle size ratios) cannot be adequately determined. Thus, information on the particle size distribution of the vertical flux of material would be difficult to evaluate with the current data.

Finding #9: Air Quality Models Need to Integrate Meteorology and the Emissions Processes

Regional scale air quality models need to integrate all the appropriate meteorological processes with the fugitive dust emissions generation processes. Meteorological parameters used for estimating transport and dispersion should be combined with the fugitive dust emission estimates for both

mechanically-generated and wind erosion-generated conditions. For example, to model windblown dust, if time-averaged wind speeds are used, it is important to account for smaller time-scale wind gusts. The use of air quality dispersion models that account for injection heights and deposition losses should allow one to distinguish the relative impact from near field (i.e., local) emissions versus far field (i.e., regional) emissions on ambient air quality.

One of the problems with a grid model is that it instantaneously mixes emissions throughout a grid cell. For area sources of fugitive dust, such instantaneous diffusion may completely miss the significance of an air quality effect. For example, for a 36 km by 36 km grid cell, emissions would be mixed uniformly throughout this cell, even though in reality a plume would be limited to a few hundred meters on a side and may not touch the ground. Existing air quality models generally do not simulate violent wind events such as dust devils and thunderstorms which can provide sufficient energy to disturb natural surfaces and to entrain dust from already disturbed surfaces. However, by changing the temporal and spatial scale of such model applications, it may be possible to model such events on a crude basis. A serious limitation of traditional Gaussian models is their assumption of steady state emissions. Since fugitive dust emissions are highly variable in nature, traditional Gaussian models need to be revised to handle intermittent emissions. If all of the relevant inputs to the diffusion equation are quantified within a specified accuracy, the diffusion equation can provide realistic estimates of the aerosol concentrations throughout an area or a region. However, in most cases there are large uncertainties associated with the inputs to the diffusion equation; namely the advection, diffusion, emissions and deposition terms. These include uncertainties associated with wind strengths that are highly variable with height and location in the region, atmospheric turbulence that varies depending on the time of day and the amount of insolation, emissions that are diluted to varying degrees based on the meteorological conditions, and deposition that is highly dependent on particle size and the release height of the emissions.

Finding #10: Disturbed Surfaces Produce Significantly More Fugitive Dust than Undisturbed Surfaces

In general, undisturbed surfaces produce much less dust than disturbed surfaces. This is because the undisturbed surface usually requires considerably higher (threshold) wind speeds to become a significant emission source. A surface having a lower threshold velocity produces much more dust than a surface having a higher threshold velocity. The primary influence of disturbing a surface is to lower the threshold velocity and increase dust emissions. Gillette, et. al. (1980) found that the disturbance of vehicular traffic on natural surfaces decreased the threshold velocity[12]. At the same time, the disturbances usually acted to smooth the surfaces which decreased the drag coefficients. For almost all of these surfaces the large decrease in the threshold velocity was sufficient to greatly increase dust emissions even though the drag coefficient was decreased.

Finding #11: Receptor Models May Be Used to Distinguish Contributions from Different Sources of Fugitive Dust

Uncertainties in fugitive dust emission estimates for crustal materials can be estimated and reduced to acceptable ranges by reconciliation with ambient measurements. Variations in particle size and chemical composition of the fugitive dust at a receptor site as well as the temporal and spatial variations in composition and concentration for multiple receptor sites can be used to indicate the spatial scale of the sources, the portion of the day when fugitive dust contributions are large, and whether or not the fugitive dust is wind generated. Additional chemical and physical measurements of the ambient aerosol at receptor sites may shed some light on specific dust sources. Receptor measurements should be used with model estimates to evaluate modeled source contributions and to focus inventory improvement efforts.

The most commonly used receptor models include the Chemical Mass Balance (CMB) receptor model and the Enrichment Factors (EF) receptor model. The EF model utilizes ratios of atmospheric concentrations of chemical components normalized to a reference component compared to the same ratios in geological material that represent an average crustal composition for a region or sampling site to identify different sources. Heavy metal enrichments are usually attributed to industrial emitters; potassium enrichment is attributed to wood combustion. Soil and road dust compositions may differ from regional crustal compositions, and enrichments or depletions for certain species may indicate the presence or absence of more or less of these regional dust contributions.

EXPERT PANEL RECOMMENDATIONS

The expert panel developed a series of recommendations based on the 11 findings presented above. These recommendations are numbered to coincide with the finding to which they pertain, and are listed below.

1.1) Conduct PM_{10} and $PM_{2..5}$ upwind/downwind experiments at different elevations around roadways and exposed surfaces similar to those used to develop TSP and PM_{10} horizontal flux measurements in order to determine the flux of particles at different heights.

1.2) Determine values for parameters such as barrier height, length, permeability, surface roughness and friction velocity for different ground covers for different seasons. These parameters should then be used in emissions models to estimate how wind speeds are attenuated and to derive accurate estimates of deposition velocities that remove particles from long-range transport.

1.3) Make preliminary estimates of deposition velocity for these parameters and link to a gridded database of land cover across the US.

2.1) Test the validity of Gillette's semiempirical "box" model described in Countess et. al., (2001)[4] in a relatively clean environment where fugitive dust from vehicular traffic is a dominant source of PM_{10}.

2.2) Upgrade this semiempirical model with more sophisticated submodels to account for deposition and diffusion near the surface.

3.1) Field test the performance of the Wind Erosion Prediction System (WEPS) model[13] for predicting PM_{10} emissions during windblown dust episodes.

3.2) Adopt the modeling approach developed by Draxler et al. (2001)[14] for predicting PM_{10} emissions during windblown dust episodes. This method requires a limited amount of *a priori* information on the surface to estimate the threshold friction velocity and calculate the horizontal flux. The proportionality constant for estimating windblown dust emissions from the horizontal flux will be needed for specific soils.

3.3) Evaluate alternative forms for EPA's empirical emission factor equations listed in AP-42 and revise these equations in keeping with a mechanistically based physical model in order to improve the accuracy of emissions predictions. This evaluation should include reviewing recent emission factor development (exposure profiling) studies. In addition, the vertical concentration distribution measured during exposure profiling studies should be evaluated to determine if the data are sufficient to make an assessment of the vertical flux.

3.4) Acquire information on silt loadings, silt content and moisture content (i.e., the "correction" factors utilized by the emission factor equations) at the county or sub-county level for areas upwind of Class I areas for different periods throughout the year. Update this information regularly.

4.1) Acquire information on source activity levels at the county or sub-county level for areas upwind of Class I areas for fugitive dust emissions for both windblown dust and mechanically suspended road dust for different periods throughout the year. Update this information regularly.

4.2) Identify the mechanisms leading to particle reservoir replacement, and quantify the time period required for replenishment, and the effects of this replenishment process on emission estimates.

5.1) Investigate the use of "puff" type dispersion models, which assume that emissions are fairly instantaneous rather than continuous, with upwind/downwind exposure profiling measurements to back-calculate source strengths and develop emission factors.

5.2) Characterize emission rates for short time frames.

6.1) Account for emissions on a seasonal basis, for example following the California methodology[10] that includes identifying and evaluating agricultural, meteorological, and land use data bases for selected Class I areas.

6.2) Adapt nephelometer sampling schedules and wind measurements at selected IMPROVE sites to 5-minute averages to better detect pulses that might arise from fugitive dust and other sources.

6.3) Operate continuous particle monitors at 30-minute or shorter time resolution at selected IMPROVE sites, and examine these data to determine the fraction of a 24-hour sample that is contributed by short duration events, and evaluate the magnitude of these events relative to longer-term emissions estimates.

7.1) Catalog, describe, and evaluate spatial data bases such as soil surveys, digital road maps, satellite and other land use data, meteorological measurements and models to interpolate and extrapolate measurements, and traffic demand estimates; determine the availability and costs of these data; and identify technical and cost impediments for using them to improve fugitive dust inventories.

7.2) Develop and apply a systematic program to sample representative soils; determine their PM_{10} and $PM_{2.5}$ indices based on the methodology of Carvacho et. al (1996)[15], which uses the ASTM wet sieve method rather than the dry sieve method used by EPA in AP-42; relate these to soil texture properties in soil surveys; and use these to estimate suspendable particle reservoirs on open lands.

7.3) Develop and apply a practical method to obtain continuous roadway dust loadings such as that being developed by Kuhns et. al., (2000)[16] that uses a pair of forward-scattering nephelometers; evaluate the potential to apply this method during normal driving cycles of park personnel and others in Class I areas; evaluate these data to determine statistical distributions of surface loadings; and determine how they change with different variables.

7.4) Develop and apply a flexible GIS emissions modeling structure that continuously acquires and updates spatial surrogates from existing and planned data bases and propagates this new information into better estimates of reservoirs, dust-suspending activities, and attenuation from obstacles near the point of emission.

8.1) Conduct field tests to quantify the vertical $PM_{2.5}$ flux for fugitive windblown dust and mechanically suspended road dust.

9.1) Reconcile model predictions with measurements by incorporating an interim method for accounting for near source removal of particles into regional models. This will involve running air quality dispersion models utilizing estimates of the vertical fugitive dust emissions flux rather than the local-scale horizontal flux as inputs for the model for those cases where the model(s) predicted ambient concentrations that were considerably larger than the observed downwind concentrations.

9.2) Incorporate more refined particle removal estimation methods into regional models as they become available.

10.1) Catalog existing studies and conduct studies to determine if different surfaces are supply limited or supply unlimited in terms of their particle reservoir.

10.2) Conduct studies to determine the effect that different kinds of disturbance have on the aerodynamic roughness height of different surfaces.

11.1) Examine the IMPROVE data base for enrichments of geological elements relative to median ratios or to soil compositions typical of the areas in which samplers are located; and determine the extent to which different elemental ratios are observed, outside of natural variability, and the extent to which these are correlated with elevated $PM_{2.5}$ soil or coarse particle mass concentrations.

11.2) Examine the impactor measurements for soil related species from IMPROVE special studies; identify typical size distributions and deviations from those distributions; and relate outliers to $PM_{2.5}$ and coarse mass concentrations.

11.3) Examine nephelometer light scattering data from the IMPROVE network; and determine the extent to which spikes are observed and whether or not these can be related to fugitive dust or other sources.

11.4) Critically review previous studies of microscopic, isotopic, organic, and other measurement methods with respect to their ability to distinguish among different land forms and fugitive dust emitters; and determine which methods can be practically applied to source characterization and ambient sampling.

11.5) Design and implement a systematic source profile measurement program for geological samples obtained from open surfaces upwind of Class I areas in the West; examine existing soil and geological maps to identify areas that have suspension potential; obtain sufficient dust quantities from these areas for a variety of analysis methods; suspend and sample these quantities through PM_{10} and $PM_{2.5}$ size selective inlets; analyze samples using selected chemical and physical methods; and apply appropriate mathematical tests to determine the degree to which profiles are collinear or are dissimilar enough to distinguish between fugitive dust source types and areas.

11.6) Implement high time resolution methods, preferably ones that are specific to coarse particles, at several IMPROVE sites and between these sites and suspected source areas; examine these to determine when dust events occur, their durations, and their contributions to 24-hour averages; and use this information to focus emissions inventory efforts.

11.7) Characterize the chemical composition of the coarse aerosol fraction collected at selected IMPROVE sites and use different receptor models to differentiate between different fugitive dust source categories.

11.8) Identify/develop methodology for resolving local sources of fugitive dust from distant sources.

11.9) Identify/develop methodology for resolving road dust from windblown dust.

TIME FRAME FOR IMPLEMENTING RECOMMENDATIONS

The recently enacted Regional Haze Rule requires that many of states complete their SIPs by December 2003. In order for these states to meet the SIP deadline, they will need to implement many of the expert panel's recommendations over the next two years. These recommendations have been grouped into three categories: (1) short term recommendations that can realistically be implemented in the next six to 12 months, (2) intermediate term recommendations that should be implemented in the next 12 to 18 months, and (3) long-term recommendations that should be implemented in the next 18 to 30 months. Recommendations 4.1, 11.1, and 11.7 fall into the short term category; recommendations 2.2, 4.2, 5.1, 6.3, 7.4, 9.2, and 11.6 fall into the long term category; and the balance of the recommendations fall into the intermediate category.

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Figure 1. Cumulative horizontal PM_{10} flux at different downwind elevations above different unpaved roads (Watson et. al., 2000)[2].

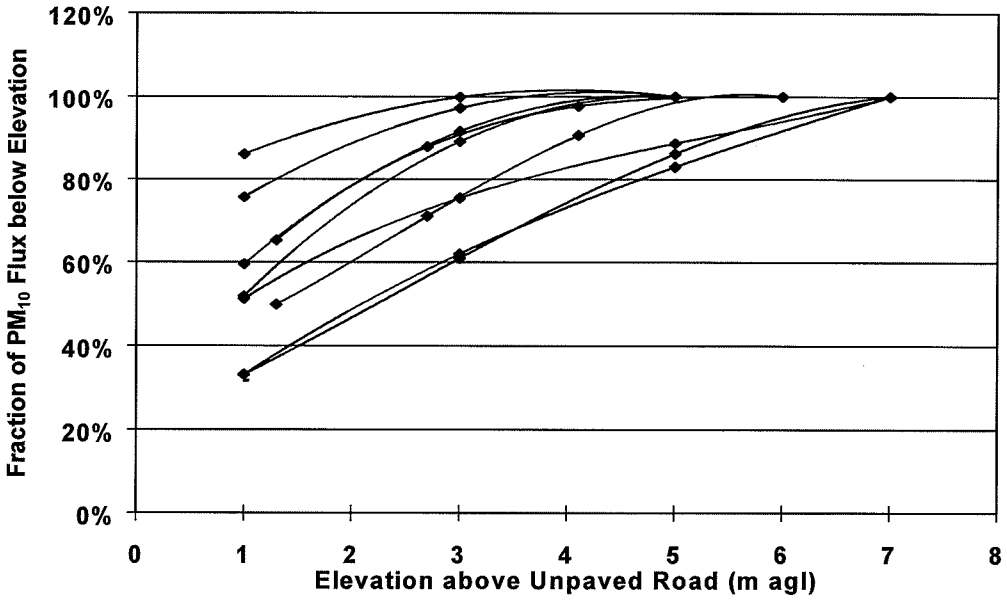
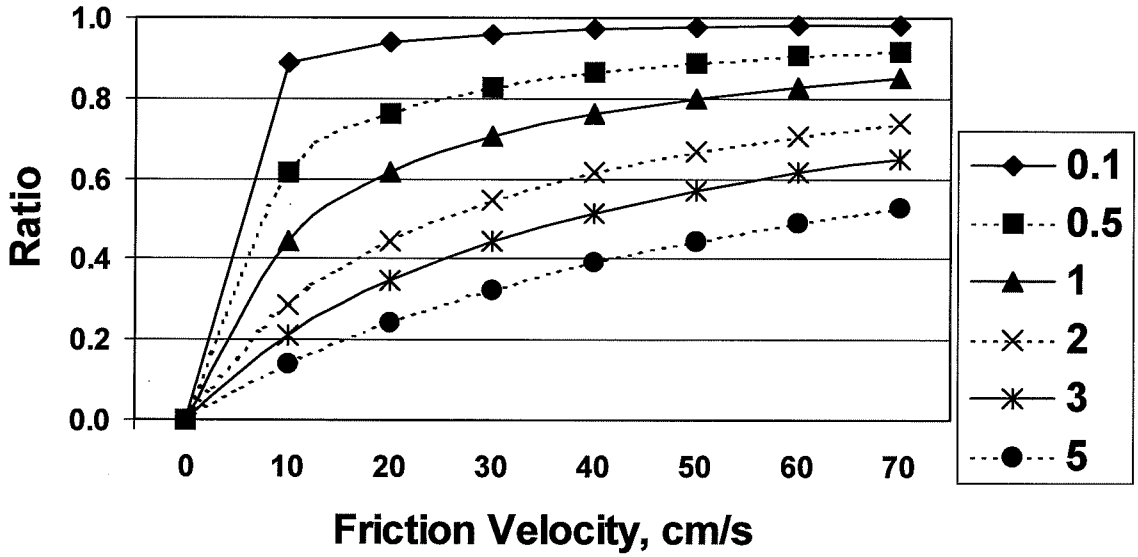


FIGURE 2. Ratio of regional scale vertical fugitive dust flux to local scale horizontal fugitive dust flux as a function of friction velocity for different values of deposition velocity (0.1 to 5 cm/s).



KEYWORDS

Fugitive Dust
Windblown Dust
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Quantification of habitat fragmentation reveals extinction risk in terrestrial mammals

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Although habitat fragmentation is often assumed to be a primary driver of extinction, global patterns of fragmentation and its relationship to extinction risk have not been consistently quantified for any major animal taxon. We developed high-resolution habitat fragmentation models and used phylogenetic comparative methods to quantify the effects of habitat fragmentation on the world's terrestrial mammals, including 4,018 species across 26 taxonomic Orders. Results demonstrate that species with more fragmentation are at greater risk of extinction, even after accounting for the effects of key macroecological predictors, such as body size and geographic range size. Species with higher fragmentation had smaller ranges and a lower proportion of high-suitability habitat within their range, and most high-suitability habitat occurred outside of protected areas, further elevating extinction risk. Our models provide a quantitative evaluation of extinction risk assessments for species, allow for identification of emerging threats in species not classified as threatened, and provide maps of global hotspots of fragmentation for the world's terrestrial mammals. Quantification of habitat fragmentation will help guide threat assessment and strategic priorities for global mammal conservation.

conservation | extinction risk | habitat fragmentation | mammals

The diversity of life on earth is jeopardized by human activities (1) and the world's mammals are at great risk; 27% of mammalian species globally are threatened with extinction and the loss and degradation of habitat has been implicated as a primary threat (2). An important form of habitat degradation is fragmentation, the reduction of continuous habitat into smaller, spatially distinct patches immersed within a dissimilar matrix (3, 4). Fragmented habitat can result from abiotic and biotic factors that generate natural patchiness in landscapes, as well as anthropogenic disturbances that have rapidly accelerated and intensified habitat fragmentation globally (3). Fragmentation can create detrimental edge effects along the boundaries of habitat patches, precipitate population decline, restrict animal movement and gene flow, and sever landscape connectivity (5). Habitat fragmentation also interacts with and intensifies the effects of other agents of global environmental change, including facilitating species invasions and limiting the ability of organisms to shift distributions in response to climate change (6, 7). Despite this potential threat, the effects of habitat fragmentation on global biodiversity and its importance relative to other anthropogenic stressors has been the subject of considerable debate (4, 8). The degree of habitat fragmentation for the world's mammals, however, and its relation to extinction risk, have not been quantified globally. Furthermore, no study has specifically identified the location of global hotspots of fragmentation for terrestrial mammals, or indeed any major animal taxon. Consequently, although fragmentation is commonly assumed to be a driver of global extinction risk, it has not been consistently incorporated into extinction risk assessments (9).

Here, we quantify and map global patterns of habitat fragmentation for the world's terrestrial mammals. We used high-resolution habitat-suitability models developed for mammals (10), including 4,018 species across 26 taxonomic Orders. For each species we quantified the degree of fragmentation of high-suitability habitat (i.e., preferred habitat where the species can persist) by calculating the average Euclidean distance into "core" habitat from the nearest patch edge (11, 12). We then conducted phylogenetic comparative analyses to examine the relationship between habitat fragmentation and various species characteristics, including International Union for Conservation of Nature (IUCN) Red List status, geographic range size (hereafter "range size"), body mass, and the proportion of high-suitability habitat within the range. We then mapped hotspots of fragmentation for terrestrial mammals globally.

Results and Discussion

Our analyses reveal that terrestrial mammal species with higher degrees of habitat fragmentation within their ranges are at greater risk of extinction (Fig. 1). Species classified as threatened in the IUCN Red List had higher levels of fragmentation compared with species classified as Least Concern and Near Threatened (phylogenetic generalized linear model $\beta \pm SE = -0.16 \pm 0.05$, $z = -2.94$, $P = 0.003$) (Table S1, *Upper*, model 1). Importantly, degree of fragmentation improved prediction of extinction risk even after accounting for the effects of key macroecological extinction risk predictors such as body size ($\beta \pm SE = 0.42 \pm 0.03$, $z = 12.22$, $P < 0.001$) and range size ($\beta \pm SE = -0.66 \pm 0.03$, $z = -19.23$, $P < 0.001$) (Table S1, *Upper*, model 1). Mammals with more fragmented

Significance

Despite the critical threat of habitat fragmentation, global patterns of fragmentation and its relationship to extinction risk have not been quantified for any major taxon. We developed high-resolution models that provide a global assessment of the degree of habitat fragmentation impacting the world's terrestrial mammals. Results demonstrate that mammals with more fragmentation are at greater risk of extinction, even after accounting for the effects of key macroecological predictors, such as body size and geographic range size. Species with higher fragmentation had smaller ranges and a lower proportion of high-suitability habitat within their range, and most high-suitability habitat occurred outside of protected areas, further elevating extinction risk. Quantification of habitat fragmentation will help guide strategic priorities for global mammal conservation.

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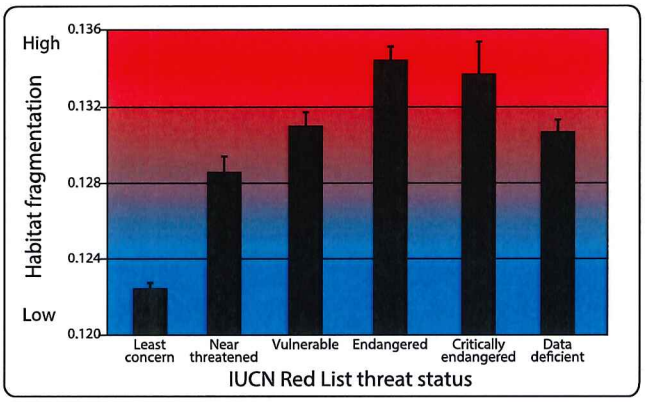

Fig. 1. Degree of habitat fragmentation predicts extinction risk for the world's terrestrial mammals. The fragmentation metric, measuring the amount of core (i.e., interior) habitat distributed within intact high-suitability patches, was ln-transformed and then inverse-coded so high values represent high degrees of fragmentation. Bars represent means and SE (n = 4,018 species). Extinction risk assessed by IUCN Red List threat status. Vulnerable, Endangered, and Critically Endangered species had higher levels of habitat fragmentation compared with Least Concern and Near Threatened species. Similarly, Near Threatened and Data Deficient species had higher levels of fragmentation than Least Concern species (see main text).

habitat, smaller ranges, and larger body sizes face the highest risk of extinction. The model including fragmentation along with body size and range size had the strongest empirical support from the data, with a model probability of 88% (Table S1, *Upper*, model 1). This top model was 7.4 times more likely than the next ranked model (Table S1, *Upper*, model 2), which excluded fragmentation [model probability = 12%; ΔAIC (Akaike's Information Criterion) = 4]. Furthermore, when assuming Near Threatened species face some extinction risk, a conservative and precautionary approach (13), the second-ranked model without fragmentation had very little empirical support (Table S1, *Lower*, model 2) (model probability < 0.001; ΔAIC = 15) and was 1,808 times less likely compared with the top model including fragmentation (Table S1, *Lower*, model 1) (model probability = 1.00).

Range size was the most important predictor of extinction risk, occurring in all top models (Table S1), consistent with prior findings identifying range size as a key extinction risk correlate (12, 14–16). Data from range size alone, however, can provide misleading information on conservation status, potentially misclassifying naturally narrow-ranging species as threatened and wide-ranging species as nonthreatened (17) and incorrectly assuming species to be homogenously distributed throughout their range (10, 18). Our analyses indicated that fragmentation, consistently in the most supported models, had explanatory power beyond that provided by range size alone. Indeed, our models implicate habitat fragmentation as a potential mechanism underlying the well-known relationship between range size and extinction risk, empirically demonstrating that greater fragmentation in small-ranged species (r = 0.43, phylogenetic generalized least-squares $\beta \pm SE = 0.17 \pm 0.01$, $t_{4,018} = 34.44$, $P < 0.001$) (Table S2, model 1) contributes to elevated extinction risk (Fig. 2 and Fig. S1). Large-ranged species tend to be habitat generalists (19), whereas range-restricted species often have more narrow environmental niches and specialized habitat preferences, characteristics that increase extinction risk (20–22). Specifically, range-restricted specialists are particularly vulnerable to habitat fragmentation given discontinuous distributions, reduced local abundance, and sensitivities to anthropogenic disturbances (23, 24). Habitat fragmentation was not associated with body mass (r = –0.02, phylogenetic generalized least-squares $\beta \pm SE = -0.01 \pm 0.03$, $t_{4,018} = -0.40$, $P = 0.687$) (Table S2, model 4).

Predictably, species with more fragmented habitat had a lower proportion of high-suitability habitat within their range (r = 0.77, phylogenetic generalized least-squares $\beta \pm SE = 2.10 \pm 0.03$, $t_{4,018} = 77.07$, $P < 0.001$) and a lower proportion of high-suitability habitat within protected areas (r = 0.16, $\beta \pm SE = 1.46 \pm 0.20$, $t_{4,018} = 7.48$, $P < 0.001$), further elevating extinction risk. As sole predictors of extinction risk, the model with fragmentation ($\beta \pm SE = -0.89 \pm 0.06$, $z = -15.0$, $P < 0.001$; model probability = 1.00) had considerably more explanatory power (ΔAIC = 387) compared with the model with proportion of high-quality habitat ($\beta \pm SE = -0.69 \pm 0.12$, $z = -5.57$, $P < 0.001$; model probability <0.001). These findings emphasize the utility of measuring not only the proportion of suitable habitat remaining within the range (reflecting habitat loss per se), but also evaluating how such remaining habitat is distributed within large, intact patches of core habitat, as assessed by our fragmentation metric.

Notably, the relationship between fragmentation and extinction risk remained evident ($\beta \pm SE = -0.59 \pm 0.08$, $z = -7.04$, $P < 0.001$) even after excluding threatened species that met IUCN Red List criterion B, used to list species that have restricted geographic ranges (13). Species listed under criterion B have severely fragmented ranges or exist in few locations (subcriteria B1a/B2a), or are undergoing continuing decline (B1b/B2b) or extreme fluctuations in population size or distribution (B1c/B2c) (13). Exclusion of criterion B species avoids potential circularity between our extinction risk modeling and the IUCN criteria adopted to classify extinction risk, thus providing stronger inference regarding the relationship between fragmentation and extinction risk (25–27). Even when excluding criterion B species, the most-supported models still included fragmentation and had the greatest weight of evidence from the data (Table S3, *Upper* and *Lower*, model 1), with the remaining models having little to no support.

Our quantitative measures of fragmentation also allowed evaluation of extinction risk assessments by IUCN experts to evaluate if a taxon belongs in a threatened category, in particular those assessed using subcriteria (B1a/B2a) relating to habitat fragmentation. As expected, threatened species classified under subcriteria B1a/B2a had significantly more fragmentation than threatened species that did not meet the B1a/B2a subcriteria (phylogenetic

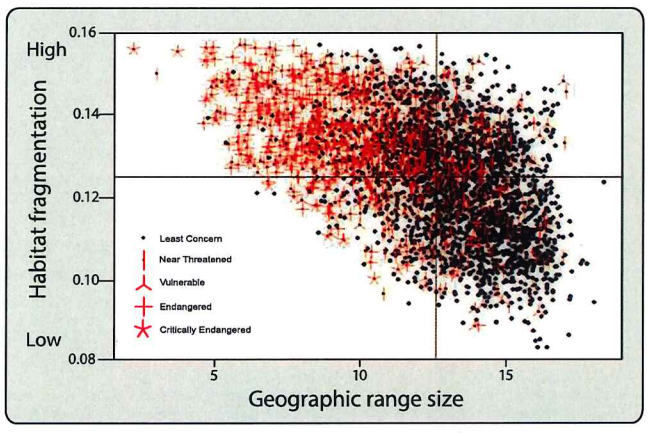

Fig. 2. Terrestrial mammals with higher degrees of habitat fragmentation and smaller geographic range sizes have a greater risk of extinction. Each black point represents an individual species, with the number of red line segments corresponding to extinction risk according to IUCN Red List threat status: Least Concern, Near Threatened, Vulnerable, Endangered, and Critically Endangered (see legend within figure). Visually, across the scatter plot of all points, more red represents higher extinction risk. Fragmentation and geographic range size (km^2) ln-transformed, and the fragmentation metric then inverse-coded so high values represent high degrees of fragmentation. Vertical and horizontal lines represent means (see also Fig. S1).

generalized linear model $\beta \pm SE = -1.00 \pm 0.13$, $z = -7.78$, $P < 0.001$). IUCN Red List assessments are based on expert opinion, which can rely on qualitative knowledge, especially for poorly known species. Consequently, assessments of habitat fragmentation for different species can suffer from limited consistency (9). Furthermore, subcriteria B1a/B2a do not distinguish between the two conditions of fragmentation and restricted number of locations. By quantifying fragmentation specifically, our models thus can improve threat assessment. For example, because of a lack of information regarding fragmentation, a recent attempt to use satellite imagery to consistently assess extinction risk of >11,000 forest-dependent species necessarily assumed that all species with small ranges and declining habitat were also subject to significant levels of fragmentation (9). Our fragmentation models can fill this important methodological gap, allowing more accurate satellite-derived classification of fragmentation and hence extinction risk using Red List criterion B.

Our models also reveal evidence for increased fragmentation in species not classified as threatened by the IUCN (Fig. 1). Specifically, species classified as Near Threatened (phylogenetic generalized linear model $\beta \pm SE = -0.46 \pm 0.08$, $z = -5.86$, $P < 0.001$) and Data Deficient ($\beta \pm SE = -0.76 \pm 0.07$, $z = -10.67$, $P < 0.001$) had more fragmented habitat than Least Concern species (Fig. 1). Although Data Deficient species have inadequate information to formally assess extinction risk (13), they tend to have smaller body and range sizes (17, 28), are nocturnal and thus difficult to study (28), and many are likely to be threatened (17). It is possible that the range size of many of these poorly known species is underestimated, and the degree of ecological specialization overestimated, because of limited available information (17), potentially inflating our measure of habitat fragmentation. More information regarding the distribution, life history, and ecology of Data Deficient species, including their habitat affinities and responses to human disturbances, will help refine our models. Nonetheless, available evidence suggests that both Near Threatened and Data Deficient species have increased fragmentation within their known ranges, indicating that the threat of fragmentation exists at the earliest and least-understood stages of endangerment. Our models quantifying fragmentation allow us to better identify such emerging threats.

Summing the fragmentation metric across all species reveals global patterns of core habitat and fragmentation for the world's terrestrial mammals (Fig. 3*A*). Primary areas of intact high-quality core habitat include northern Africa and much of the Amazon Basin in South America, and portions of western and central North America, sub-Saharan Africa, Australia, and northern, southwestern, and southeastern Asia. Of these areas, the Amazon Basin supports the greatest richness of terrestrial mammals, followed by sub-Saharan Africa and portions of western and central North America and southeastern Asia (Fig. S2*A*). Standardizing the fragmentation models by species richness more strongly highlights species-poor locales (most notably desert regions of northern Africa and southwestern Asia) with extensive core habitat for the relatively few species that occur there (Fig. S2*B*). Terrestrial mammalian diversity, however, is sufficiently low in these regions that they are de-emphasized as core habitat in our global fragmentation models (Fig. 3).

Conversely, fragmentation hotspots are regions with relatively low interior distances within high-suitability habitat, summed across all species present in an area (Fig. 3*A*). Such regions include much of South America outside the Amazon Basin, as well as portions of south-central Asia, eastern North America, and Europe. Interestingly, our models identify notable fragmentation for high-latitude (e.g., arctic) and high-elevation (e.g., Himalayan) species (Fig. 3*A*). For the arctic, the models are primarily identifying natural fragmentation of suitable habitat because of ice, water bodies, coastlines, and islands at the edge of species ranges. Similarly, for high-elevations, the models are identifying patterns of natural fragmentation above the altitudinal limits of species. Weighting the global fragmentation map with a recently developed high-resolution, global human modification layer (29) highlights regions that have been fragmented by human development specifically and de-emphasizes regions with natural fragmentation, such as high-latitude and high-elevation areas (Fig. 3*B* and Fig. S3). We emphasize, however, that arctic and montane species, including high-altitude endemics, are particularly vulnerable to climate change (30, 31) and thus still impacted by natural fragmentation that might prevent distributional shifts in response to altered climate regimes.

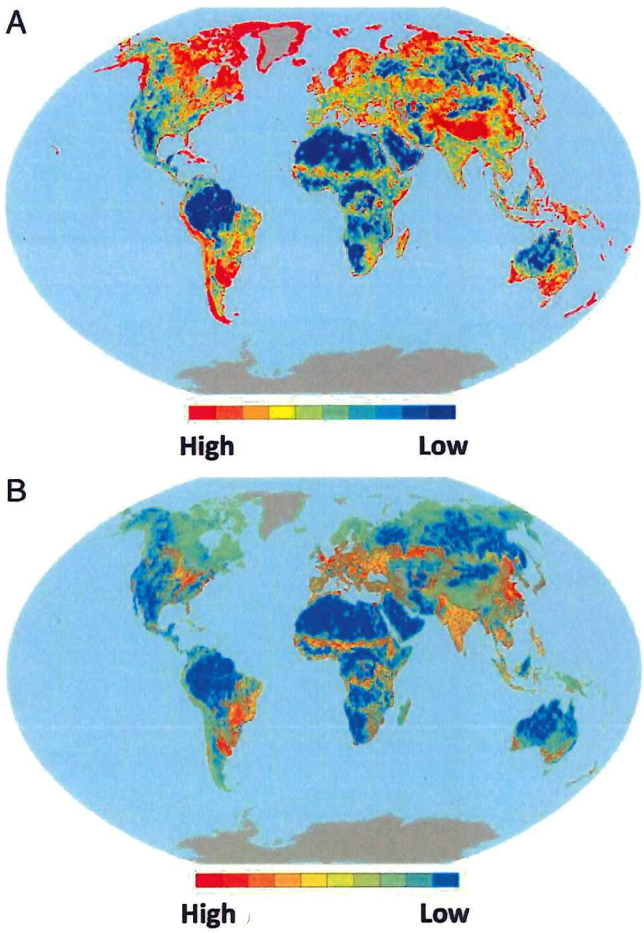

Fig. 3. Degree of habitat fragmentation for the world's terrestrial mammals. (*A*) Degree of habitat fragmentation as indexed by the fragmentation metric, measuring the amount of core (i.e., interior) habitat, and (*B*) degree of anthropogenic habitat fragmentation, calculated by weighting data in *A* by a recently developed global HM model (Fig. S3). The resulting map identifies regions that have been fragmented by human development specifically, and de-emphasizes regions that are naturally fragmented such as high-elevation areas and landscapes with water bodies interspersed. The color gradient in the legends are the original (*A*) and weighted (*B*) fragmentation values binned into deciles. Blue denotes regions with low fragmentation, where mammal species occur in large patches of intact high-suitability core habitat. Red denotes regions with high fragmentation, where mammal species have little core habitat. Fragmentation metrics are spatially quantified by summing the metric at each 300 × 300-m cell for all terrestrial mammal species worldwide.

On average, across the 4,018 species of terrestrial mammals included in our analyses, only 48.6% (range: <0.001–100%; SE = 0.004) of the current geographic range of a species was comprised of high-suitability habitat (10). Moreover, only 3.6% (range: 0–100%; SE = 0.001) of the average range was comprised of high-suitability habitat located within known protected areas, well below the approximately 15% of terrestrial areas that are currently protected globally (32), further emphasizing the inadequacy of the global network of protected areas (33). Of additional concern is that

habitat degradation is especially prevalent in many of the global hotspots of mammal habitat identified in our models, particularly tropical regions in the Americas, Africa, and Asia that experience high deforestation (2). For example, much of the tropical forest in the Amazon Basin, a critical global hotspot of core mammalian habitat, had experienced rapid deforestation from human development (34, 35), although it appears that such habitat destruction has slowed recently as a result of policy-driven government action (36).

Our models can inform the management and conservation of mammals globally. First, unlike most comparative extinction-risk analyses, we focus on an urgent yet manageable anthropogenic threat (i.e., habitat fragmentation) rather than solely on intrinsic biological traits (e.g., body mass), which addresses ongoing concerns about the utility of comparative analyses for applied conservation (15, 37). Second, our habitat models narrow the focus of mammal distribution to include only regions of high-suitability habitat; this is critical, because species are not homogeneously distributed throughout their ranges (18) and less than half of the range of terrestrial mammals is on average comprised of high-suitability habitat (10). Third, our fragmentation models not only evaluate global patterns of species richness based on suitable habitat (10), they also quantify the degree to which suitable habitat exists within core habitat patches. This is essential, given that hotspots of species richness and extinction threat may not overlap (38, 39), and our analyses demonstrate that the degree of fragmentation of patches influences extinction risk. Finally, the 300-m resolution of the global-habitat models facilitates more detailed analyses of fragmentation patterns at the local scale, which approaches the scale of conservation action (40). For example, our models can be used to identify the degree to which reserve networks designed for umbrella species, such as jaguars, maintain high-quality core habitat for sympatric mammals (41). Such real-world application of our fragmentation models demonstrates their utility for conservation practitioners, particularly in comparison with simple boundaries of the geographic range, which provide no information about the expected occurrence of species within their broad distributional extents.

Additional efforts to apply these models to local scales, and validating them with empirical data on fine-scale distribution and habitat use, such as that derived from GPS telemetry or remote camera surveys, will help to more thoroughly assess their utility for real-world conservation application. In addition, exploration of alternative fragmentation and connectivity metrics, including metrics that assess patch isolation and configuration (5, 12), would also yield further insight into how habitat fragmentation and landscape connectivity are related to extinction risk. More complex patch and landscape metrics might be particularly valuable at finer scales or for smaller subsets of species. Development of a comprehensive database estimating dispersal distances for mammal species, and incorporation of such data to assess how variability in species-specific dispersal ability influences scaling of patch sizes and responses to fragmentation effects, would represent another important advancement. Finally, given that anthropogenic fragmentation increases contact and potential conflict between humans and wildlife, human tolerance of and behavior toward wildlife are fundamental determinants of their ability to persist within fragmented landscapes; consequently, social science research will be critical to mitigate fragmentation effects in human-dominated systems (42–44).

Ultimately, habitat fragmentation has severe effects on the composition, structure, and function of ecosystems (3, 5, 8), and our results demonstrate that fragmentation degrades suitable habitat and increases the extinction risk of mammals globally. Such impacts warrant intensified efforts to protect remnant habitat and restore broad-scale landscape connectivity to ameliorate the effects of fragmentation (5, 12). Quantification of fragmentation will help prioritize such global conservation efforts and develop more effective strategies for conserving the world's mammals.

Methods

Habitat-Suitability Models. As the basis of our fragmentation models, we used habitat-suitability models developed by Rondinini et al. (10) for the world's extant terrestrial mammals (n = 5,027 species). The completion of the Global Mammal Assessment by the IUCN Species Survival Commission (IUCN/SSC) (2) provided an unprecedented opportunity to develop global-habitat models for all terrestrial mammals. The Global Mammal Assessment dataset, based on the taxonomy published by Wilson and Reeder (45), received the input of thousands of mammal experts belonging to more than 30 Specialist Groups of the IUCN/SSC. The dataset, which contains the known geographic range (i.e., extent of occurrence as defined by IUCN), species-specific qualitative textual descriptions of habitat preferences, and conservation status of each mammal species, is available through the IUCN Red List of Threatened Species (1).

From this database, the habitat-suitability models were developed at a 300-m resolution and limited to occur within the geographic range of the species (10). Three environmental variables formed the basis of the habitat models: elevation, type of land cover, and hydrological features. Elevational range where a species is found, when known and recorded in the IUCN Red List, was incorporated into the habitat models. Expert information on other habitat affinities, including preferred types of land cover, tolerance to human impact, and relationship to water bodies, were extracted from textual description within the IUCN database and input as quantitative data into the habitat models. Habitat models ranked areas with a three-level gradient of habitat suitability: (*i*) high, corresponding to primary habitat (i.e., preferred habitat where the species can persist); (*ii*) medium, corresponding to habitat where a species can occur, but not persist without nearby primary (i.e., high-suitability) habitat; and (*iii*) unsuitable, where a species is expected to seldom or never be found (10). A subset of models and their associated habitat-suitability ranks were validated against available points of known species occurrences. Habitat was further classified as to if it occurred within protected areas, using IUCN categories I–IV from the World Database of Protected Areas (46, 47). Full details regarding the development of these habitat models are available elsewhere (10), and data are available upon request from the model developers (https://globalmammal.org/activities/research/distribution-modelling/).

Fragmentation Models. We measured fragmentation of high-suitability habitat, because such habitat is defined as essential for species persistence. When delineating high-suitability patches in the geographic range, we eliminated small patches (<four adjacent cells at 300-m resolution) potentially created by artifacts contained in underlying land-use and cover maps. This approach reduced the influence of spurious, isolated patches and improved computational efficiency of our fragmentation analyses. We then defined high-suitability habitat patches to be formed as clusters of suitable cells that were adjacent in any of the eight-neighborhood cells.

For each species we quantified the degree of fragmentation of high-suitability habitat by calculating the average Euclidean distance of all cells within high-suitability habitat from the nearest edge [that is, "GISfrag" (11, 12)]; edges demarcated the boundary between high-suitability and medium-suitability or unsuitable habitat, distributed either in the matrix external to habitat patches or as internal perforations within a patch. Low values of the average Euclidean distance into habitat for each species represent more highly fragmented habitat, whereas high values represent more core habitat and less-fragmented habitat. We considered a variety of other landscape metrics (including FRAGSTATS) and selected the GISfrag metric because it does not require an arbitrary distance threshold of what constitutes an "edge," accounts for different shapes of patches and landscapes patterns and arrangements, is a robust measure that accounts for the distribution of patch area (48), is comparable across landscapes of different extents, and provides stable, readily interpretable information (12). Furthermore, Euclidean distance-to-edge was found to be singularly valuable in quantifying global forest fragmentation (8). We did not calculate distance between patches through the intervening landscape "matrix," so our metric does not report on patch isolation or landscape configuration. For graphical display (Figs. 1 and 2 and Fig. S1), we inverse-coded the GISfrag metric to facilitate a more intuitive interpretation, where high GISfrag values represented high degrees of fragmentation.

Our analysis of fragmented habitat is also robust to any specific scaling assumption. Although information on dispersal ability can help inform the scale of fragmentation effects (49, 50), a comprehensive database of dispersal distance for all mammal species does not exist. Prior studies have attempted to approximate dispersal using allometric relationships based on body mass alone (51, 52). However, dispersal distances are highly heterogeneous even within the same species and are influenced by a variety of life-history traits and ecological factors, such as diet, sociality, and home-range area; thus, body size can be an inaccurate predictor of dispersal (50). Additionally, our inclusion of body mass as a predictor of extinction risk (see next section) further accounts for the

potential latent influence of scale-dependent effects on species-specific responses to fragmentation, and inclusion of dispersal estimates would potentially lead to circularity and redundancy with our body size covariate. Rather than speculate about the effects of spatial scale on dispersal distance or other species-specific responses to fragmentation, our primary assumption is that further distance into the interior of a habitat patch is beneficial, given that it signifies larger patches and fewer edge and fragmentation effects [see also Haddad et al. (8) for a similar assumption to assess global forest fragmentation].

Phylogenetic Comparative Methods. We used phylogenetic comparative methods to examine the relationship between the fragmentation metric and various species characteristics, including IUCN Red List status, range size, body mass, and the proportion of high-suitability habitat within the geographic range. We first used Pagel's λ (53) to determine the strength of the phylogenetic signal in these variables. We found that the phylogenetic signal in the fragmentation metric was moderate ($\lambda = 0.60$) and similar to the values we obtained for range size ($\lambda = 0.56$), the proportion of high-suitability habitat within the range ($\lambda = 0.45$), and IUCN Red List status ($\lambda = 0.67$). Pagel's λ value, however, was much higher for body size ($\lambda = 0.99$), a variable for which a strong phylogenetic signal was expected given that it is an evolved trait intrinsic to organisms. We therefore corrected for phylogenetic signal in our analyses. Because of nonnormal distributions, we ln-transformed the fragmentation metric, range size, and body mass, and arcsine square-root–transformed the proportion of high-suitability habitat in all statistical analyses.

Mammal Phylogeny and Life-History. We used the extant mammalian supertree phylogeny developed by Bininda-Emonds et al. (54, 55) that used the best estimates of divergence times (n = 4,510). To link this phylogeny to the taxonomy used by Rondinini et al. (10), we edited the two datasets to reconcile synonym species using Wilson and Reeder (45), and deleted species that were not common to both datasets. We did not incorporate new species into either dataset, and pruned all nonterrestrial mammals (cetaceans, seals, and sirenians) and *Homo sapiens* from the phylogeny, leaving a total of 4,018 species from 26 taxonomic orders. All phylogenetic analyses were conducted in the R statistical package (v3.1.3, R Development Core Team, 2015) using the ape (56), Geiger (57), and phylolm (58) packages.

Data on body mass were extracted from the PanTHERIA database (59). Where no body mass was listed, we first checked if it was present in the MOM database (60). If it was not, we followed the same methods as in Crooks et al. (12) and used the midpoint of the body mass range presented in Nowak (61) for that species. If not listed in Nowak (61), we used data from the closest member of the same species group, sister species of the same genus, or closest relative as indicated by Wilson and Reeder (45). If no other data were available, an average of all species in the genus was used. In other cases where PanTHERIA data were missing, information was copied and pasted from a synonym or sister species.

Fragmentation as a Predictor of Extinction Risk. We used a phylogenetic generalized linear model (58) to evaluate the relative capacity of our fragmentation metric and two widely used macroecological variables, body mass and range size, to explain extinction risk, as indexed by IUCN status categories (13). Data Deficient species (n = 388) were initially excluded from these analyses given they have inadequate information to assess extinction risk (13), so we evaluated five status categories, including Least Concern (n = 2,633 for phylogenetic analyses), Near Threatened (n = 266), Vulnerable (n = 345), Endangered (n = 315), and Critically Endangered (n = 71). A species is classified by the IUCN as Least Concern when it is widespread and abundant and does not qualify for listing in other categories, and as Near Threatened when it does not qualify for a threatened category now but is close to qualifying for a threatened category in the near future (13). A species is classified as Vulnerable, Endangered, or Critically Endangered when the best available evidence indicates it faces a high, very high, or extremely high risk of extinction in the wild, respectively. Given these criteria, we reclassified the IUCN categories into a binary threat using two classification schemes. In the first analysis, we assumed species classified by the IUCN as Least Concern and Near Threatened faced no immediate extinction risk, whereas species classified as "threatened" (i.e., Vulnerable, Endangered, and Critically Endangered) faced some degree of extinction risk. This is a standard binary classification scheme in prior extinction-risk studies (16). We then conducted a second analysis, again categorizing Least Concern species as having no immediate extinction risk, but assuming Near Threatened species face some extinction risk, given that the IUCN identifies such species as close to being threatened; we thus view this comparison as a conservative and precautionary approach regarding extinction risk of Near Threatened species (13). We used AIC (62, 63) to compare models with all combinations of fragmentation, body mass, and range size as predictors of extinction risk; AIC analyses included calculations of model probabilities (the likelihood of the model given the data and model set) and evidence ratios (the weight of evidence of each model relative to the best model). Finally, to further explore patterns of fragmentation in species classified as nonthreatened by the IUCN, we also used phylogenetic generalized linear models to compare species listed as Least Concern to those listed as Near Threatened or Data Deficient.

The IUCN Red List process is expert-driven, and the IUCN uses five criteria to assign species to categories of extinction risk (13). One of those criteria is criterion B, used to list species that have restricted geographic ranges, with subcriteria for species that are severely fragmented or exist in few locations (subcriteria B1a/B2a), or are undergoing continuing decline (B1b/B2b) or extreme fluctuations in population size or distribution (B1c/B2c). To evaluate the reliability of criteria used by the IUCN to assess if a taxon belongs in the threatened category, in particular those subcriteria (B1a/B2a) relating to habitat fragmentation, we used a phylogenetic generalized linear model to compare fragmentation levels for threatened species classified under subcriteria B1a/B2a to fragmentation levels for threatened species that did not meet the B1a/B2a subcriteria. As expected, threatened species classified under subcriteria B1a/B2a had significantly higher degrees of fragmentation (*Results and Discussion*).

These results, however, might imply that our use of habitat fragmentation as a predictor of extinction risk may lead to potential circularity with the IUCN Red List criteria. To explore this issue, we followed prior approaches (25–27) and conducted additional analyses after first excluding threatened species listed under relevant listing criteria. Red List assessment guidelines stipulate that assessors should evaluate each species against all listing criteria, and all relevant criteria should be applied (13). Furthermore, the Red List guidelines encourage assessors to adopt a precautionary attitude to uncertainty when applying the criteria, so if range restriction or fragmentation was deemed a plausible threat by assessors, criterion B should be applied, even in the presence of uncertainty. Because of the relationship between range size and fragmentation (*Results and Discussion*, Fig. 2, and Fig. S1), we decided to adopt a conservative approach to account for potential circularity and exclude all species categorized because of range restriction (i.e., under any combination of subcriteria of criterion B, representing 46.8% of threatened species). We then used phylogenetic generalized linear models and AIC to compare models with all combinations of fragmentation, body mass, and range size as predictors of binary extinction risk. As above, we used two classification schemes to model extinction risk, assuming Near Threatened species (*i*) face no immediate extinction risk or (*ii*) face some extinction risk. For each model, we compared Least Concern/Near Threatened species to those threatened species not listed under criterion B.

We also evaluated how our fragmentation metric related to body mass and range size. We first conducted simple correlation analyses, corrected for phylogeny, relating fragmentation to body mass and also to range size. We then evaluated these relationships further with a phylogenetic generalized least-squares regression (64) that assessed the relative influence of body mass and range size on the fragmentation metric; we used AIC to compare models with all combinations of body mass, range size, and their interaction as predictors of habitat fragmentation. For our generalized least-squares regressions, we assumed that the continuous covariates evolved randomly after a speciation event (65), so we used a Brownian-motion model to define the structure of the correlation among species.

In addition to the macroecological variables, we also conducted two additional phylogenetic generalized least-squares regressions relating fragmentation to proportion of high-suitability habitat within the range and to proportion of protected high-suitability habitat within the range. Prior work has demonstrated that prevalence of remaining suitable habitat within the geographic range, or conversely the proportion of unsuitable human-affected land cover, is predictive of threat status in mammals (10, 14, 16) and other taxa (66, 67). We also conducted separate phylogenetic generalized linear models to evaluate the relative importance of fragmentation versus proportion of suitable habitat as sole predictors of extinction risk. These tests thus helped distinguish between the effects of habitat loss per se (as assessed by proportion of suitable habitat remaining in the range) from how remaining suitable habitat was distributed into intact, core habitat patches (as assessed by our fragmentation metric).

Mapping Fragmentation Hotspots. We generated global maps of fragmentation by summing the fragmentation metric at each 300 × 300-m cell for all terrestrial mammal species worldwide. Because we summed metrics for all species within a given area (Fig. 3), degree of fragmentation in part reflects global patterns of species distribution and richness. Thus, we also generated global maps displaying an average fragmentation index that was corrected for species richness (for details, see *Supporting Information*).

Our fragmentation analyses are based on the extent and geometry of high-suitability habitat and do not distinguish as to whether fragmentation is caused by natural factors (e.g., elevational or hydrological barriers) or anthropogenic disturbances (e.g., human development). To further identify the sources of fragmentation, we generated another map that highlighted anthropogenic

fragmentation specifically by weighting the global fragmentation map with a recently constructed human modification (HM) model, which combines the effects of multiple stressors (e.g., urban and agricultural land cover, energy production, nighttime lights, and roads) into an overall score of HM globally [approach and technical details in Theobald (29) and *Supporting Information*]. When weighting our original fragmentation map with the HM model, the resulting map identifies regions that have been fragmented by human development specifically, and de-emphasizes regions that are naturally fragmented such as high-elevation areas and landscapes with water bodies interspersed (e.g., relictual glaciated areas).

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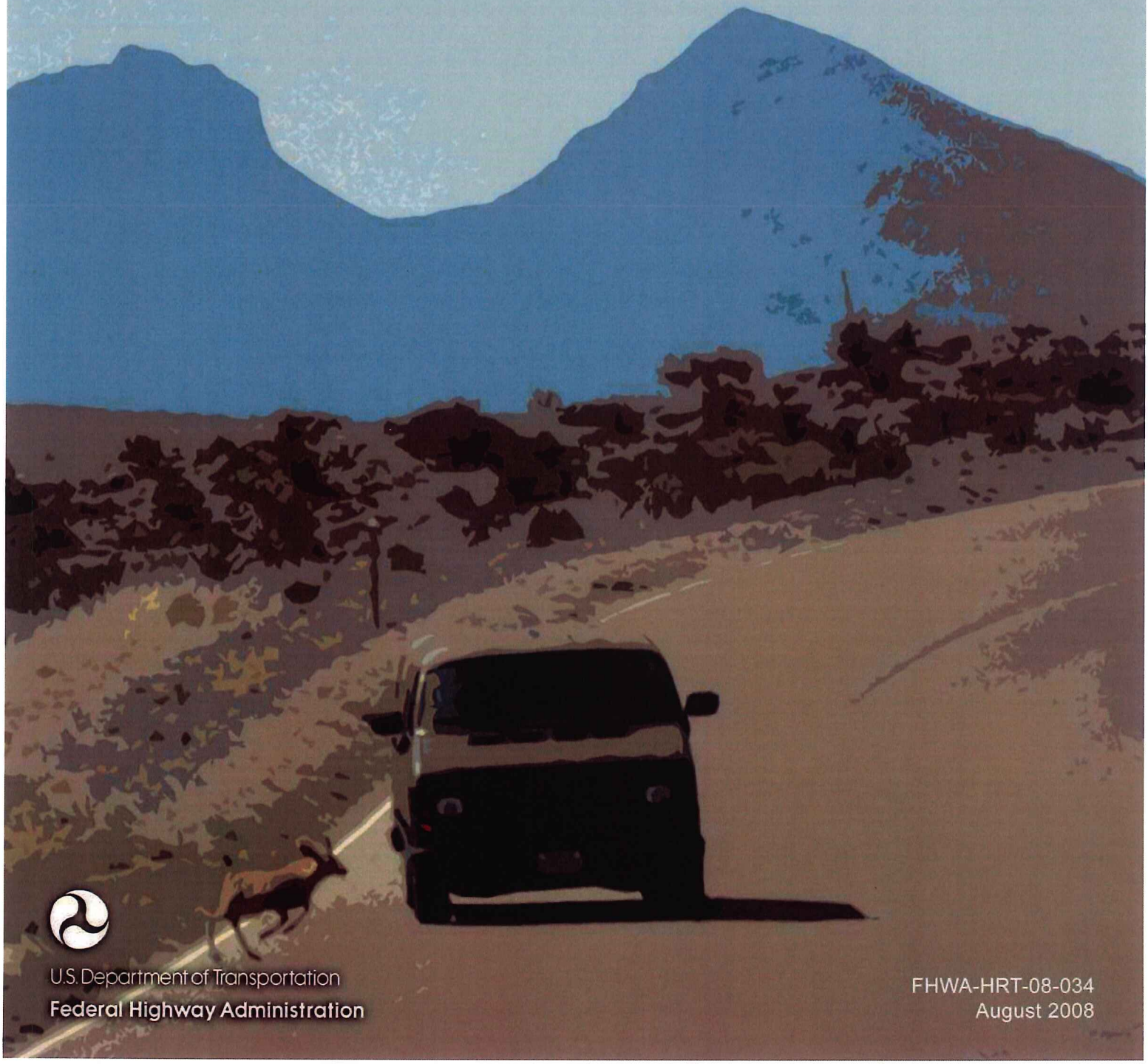
Making America's Highways Safer for Drivers and Wildlife

Wildlife-Vehicle Collision Reduction Study

REPORT TO CONGRESS



U.S. Department of Transportation
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FHWA-HRT-08-034
August 2008

FOREWORD

America's highways allow people and products to travel to every corner of our nation. Along the way, these roads cut across the habitat of many native wildlife species. When these paths cross, collisions occur, and in greater numbers than most people realize. This presents a real danger to human safety as well as wildlife survival. State and local transportation agencies are looking for ways to find a balance among travel needs, human safety, and conserving wildlife.

This national study details the causes and impacts of wildlife-vehicle collisions and identifies potential solutions to this growing safety problem. This Report to Congress focuses on tools, methods, and other measures that reduce the number of collisions between vehicles and large wildlife, such as deer, because these accidents present the greatest safety danger to travelers and cause the most damage.

Michael F. Trentacoste
Director, Office of Safety
Research and Development

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16. Abstract
Under the SAFETEA-LU Congressional Bill, the Secretary of Transportation was directed to conduct a national wildlife-vehicle collision (WVC) reduction study. The study was to advance the understanding of the causes and impacts of WVCs and identify solutions to this growing safety problem.

This report contains the findings of this study, beginning with estimates on the current magnitude and trend for WVCs in the United States. Based on several national datasets, the study found that there are between one and two million WVCs annually in the United States and that the number is increasing. Estimates are provided for the costs associated with WVCs, and the impact of direct road mortality is described for 21 federally listed threatened and endangered species. The core of the report is an in-depth review of over 34 WVC mitigation methods assembled from information obtained from hundreds of literature sources (both published and "gray" literature). Each mitigation measure is described in detail, and information including case studies, benefits, costs, undesirable effects, and design guidelines is provided. The report also covers planning and design considerations and provides cost-benefit analyses for the mitigation methods that had sufficient data available to support these analyses. A working group of seven national experts provided input and evaluated the effectiveness of the mitigation methods, categorizing them as either recommended for implementation, recommended for future research, or not recommended for future research or implementation. A summary of their evaluation is included in this report. Recommendations for implementation of effective measures and for further investigation of promising mitigation measures are provided.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	$candela/m^2$	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS FOR COLLISIONS WITH ANIMALS

AVC	Animal-vehicle collisions. Collisions with wild and domestic animals in cases where domestic animals could not be separated from the dataset.
WVC	Wildlife-vehicle collisions. Collisions with all species of wild animals.
DVC	Deer-vehicle collisions. WVCs that involve only deer. A separate term is used for deer and no other specific type of animal because deer account for a majority of WVCs when data are available. When information is specific to one type of animal other than deer, no abbreviation is used (e.g., moose-vehicle collision).

ABBREVIATIONS

ADT	Average daily traffic, is defined as the total volume during a given time period (in days), greater than 1 day and less than 1 year, divided by the number of days in that time period.[1] In this report the time period is always 1 year.
AASHTO	American Association of State Highway and Transportation Officials
ADOT	Arizona Department of Transportation
BTS	Bureau of Transportation Statistics of the U.S. Department of Transportation
CaMg	Chemical formula for calcium magnesium acetate, a common alternative to road salt for deicing.
CSD/CSS	Context-sensitive design/context-sensitive solutions, is a planning and/or design strategy that attempts to consider scenic, aesthetic, historic, environmental, and community values.
DOT	see State DOT
DMS	Dynamic message signs, also referred to as variable message signs
FARS	Fatal Accident Reporting System, is a national dataset that includes all crashes with a human fatality.
FHWA	Federal Highway Administration
GES	General Estimates System, is a dataset that enables estimates of national crash numbers based on a national sample.
GIS	Geographic Information Systems, which relates to spatial data standards and in some cases, sets of spatial data.
GPS	Global Positioning System

HSIS	Highway Safety Information System, is a dataset that includes all reported crashes from Washington, California, Illinois, Maine, Michigan, Minnesota, North Carolina, Ohio, and Utah.
IUCN	International Union for Conservation of Nature and Natural Resources
km/h	Kilometers per hour
LED	Light-emitting diode, a technology used for, among other things, lighted signs and flashers.
MNDOT	Minnesota Department of Transportation
mi/h	Miles per hour
MUTCD	*Manual on Uniform Traffic Control Devices,* which provides national guidance and standards for, among other things, warning signs and signals.
NaCl	Chemical formula for sodium chloride (salt), a common deicing chemical
NCHRP	National Cooperative Highway Research Program
NPS	National Park Service
NYSDOT	New York State Department of Transportation
ROW	Right of way, refers to the area owned by the transportation agency, including the roadside.
SAFETEA-LU	Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users, which is the primary congressional bill for surface transportation programs, signed by President George W. Bush in August 2005.
State DOT	State department of transportation in general (i.e., not a specific state)
USDOT	U.S. Department of Transportation
USFWS	U.S. Fish and Wildlife Service
VMT	Vehicle miles traveled

SYMBOLS

$	Followed by a numerical value refers to dollar value. Unless otherwise specified, reported values are in U.S. dollars.
Can$	Followed by a numerical value refer to Canadian dollars.
€	Followed by a numerical value refers to Euros.

EXECUTIVE SUMMARY

America's highways allow people and products to travel to every corner of our nation. Along the way, these roads cross through the habitat of many native wildlife species. When these paths intersect, collisions can occur, and in greater numbers than most people realize. Based on the results of this study, there are an estimated one to two million collisions between cars and large animals every year in the United States. This presents a real danger to human safety as well as wildlife survival. State and local transportation agencies are looking for ways to meet the needs of the traveling public, maintain human safety, and conserve wildlife.

Under Section 1119 (n) of the Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), the U.S. Congress directed the Secretary of Transportation to conduct a national wildlife-vehicle collision (WVC) study. This study details the causes and impacts of WVCs and identifies potential solutions to this growing safety problem. The report focuses on mitigation methods that reduce the number of collisions between vehicles and large wildlife, such as deer, because these accidents present the greatest safety danger to travelers and cause the most damage (figure ES1).

This summary of the full report highlights the major findings and serves as an introduction to the issue of WVCs. Major findings include:

- WVCs are a growing problem and represent an increasing percentage of the accidents on our roads.

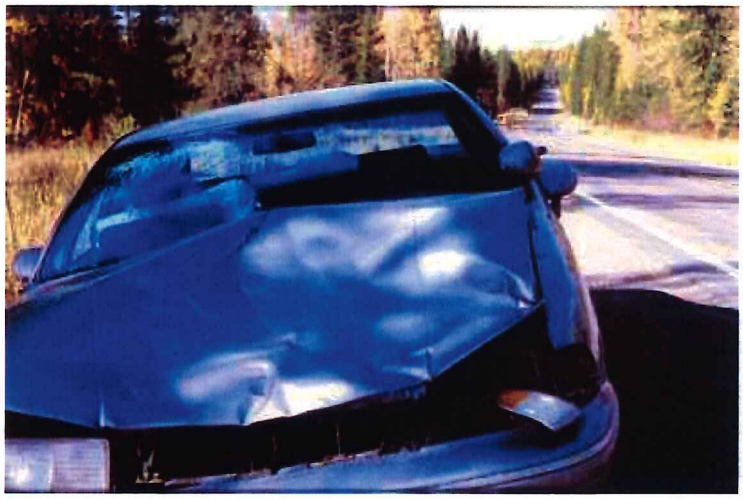


Figure ES1. Photo. A collision with a white-tailed deer can result in extensive property damage (copyright: Marcel Huijser).

- WVCs have significant impacts on drivers and wildlife. For motorists, WVCs present a safety danger and can result in significant costs from vehicle damage. For animals, WVCs often kill the individual animals and can even pose a threat to the very survival of

certain species. This study identified 21 federally listed threatened or endangered animal species in the United States for which road mortality is documented as one of the major threats to their survival.

- There are no simple solutions to reducing WVCs. In this study, the research team reviewed 34 mitigation techniques, a number of which are effective in reducing WVCs, show promise, or are considered good practice, including integrated planning efforts, wildlife fencing and wildlife crossing structures, animal detection systems and public information and education (figure ES2 through figure ES4).



Figure ES2. Photo. Standard deer warning sign along Montana Highway 83 (copyright: Marcel Huijser).



Figure ES3. Photo. Seasonal deer migration sign in Utah (copyright: Marcel Huijser).



Figure ES4. Photo. Wildlife warning and advisory speed limit reduction signs triggered by an animal detection system in 't Harde, The Netherlands (copyright: Marcel Huijser).

- A major challenge that must be addressed before WVCs can be systematically reduced is improving the consistency and precision of data collection on WVCs. Inconsistent and imprecise data make it difficult to identify and prioritize road sections that require mitigation.

This document concludes with recommendations for further action. Policymakers who are interested in reducing WVCs can begin by considering the following actions:

- Incorporate WVC reduction into the early stages of planning and design for transportation projects.
- Develop and implement guidelines and standards for collecting data on and reporting WVCs.
- Develop and implement guidelines for evaluating mitigation methods.
- Evaluate the effectiveness of mitigation methods that have been recommended for further research.
- Implement (or install) proven mitigation measures where appropriate.
- Develop and apply wildlife population models to assist with locating and designing mitigation methods.

- Conduct technology transfer to State departments of transportation, resource agencies, and other transportation professionals regarding the findings of this study. A handbook and training course on WVC reduction techniques will be developed by August 2008, which will help in making this information available to practitioners.

WILDLIFE-VEHICLE COLLISIONS: A GROWING PROBLEM ON U.S. ROADS

Isn't This Just a Rural Problem?

According to data from national crash databases, 89 percent of all WVCs (2001–2005) were on two-lane roads. This might lead some people to conclude that WVCs are only a problem in remote, rural locations, but two-lane roads and WVCs are also prevalent in areas where many people live and commute to work in nearby cities. Such two-lane highways are critical travel corridors, and, in the United States, drivers use two-lane roadways for the majority of the total highway miles they travel. Therefore, WVCs are a challenge in every state and for almost all drivers across the country.

How Many Accidents Are There?

Estimates of the total number of WVCs are based on several sources, including crash statistics (from police and highway patrol report information), roadside carcass counts, insurance industry claims information, and interviews with the public.

National crash databases estimate the total number of reported collisions at 300,000 per year. However, most researchers believe that WVCs are substantially under-reported for a number of reasons. Crash databases typically exclude accidents that have less than $1,000 in property damage, not all drivers report collisions with animals, and not all law enforcement, natural resource, or transportation agencies have the resources to collect detailed information on WVCs. Furthermore, many animals that are injured wander away from the road before they die and are never found.

Using a combination of carcass count data, insurance industry information, police-reported crashes, and interviews with the public, this study estimates that there are between one and two million collisions between vehicles and large animals in the United States every year. Almost all animal-vehicle collisions (AVCs) resulted in no human injury (95.4 percent). Collisions with moose and other large animals can have a higher likelihood of resulting in harm to the vehicle occupant (figure ES5 and figure ES6).

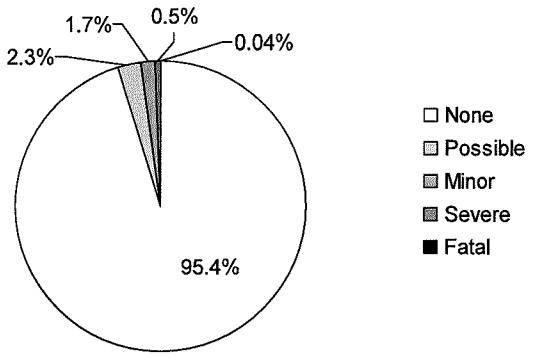


Figure ES5. Graph. Human injury from AVCs (primarily deer).

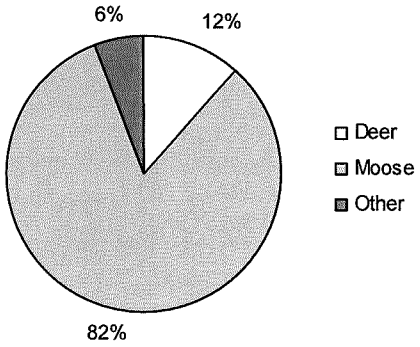


Figure ES6. Graph. Animal species involved in fatal (to human) collisions, Maine.

Is the Number of Accidents Increasing?

National trends were studied in a review of several sources of crash data. Figure ES7 and figure ES8 illustrate that from 1990 to 2004, the number of all reported motor vehicle crashes has been holding relatively steady at slightly above six million per year. By comparison, the number of reported AVCs (includes wildlife and domestic animals) has increased by approximately 50 percent over the same period, from less than 200,000 per year in 1990 to a high of approximately 300,000 per year in 2004. Looking at the data another way, AVCs now represent approximately 5 percent (or 1 in 20) of all reported motor vehicle collisions.

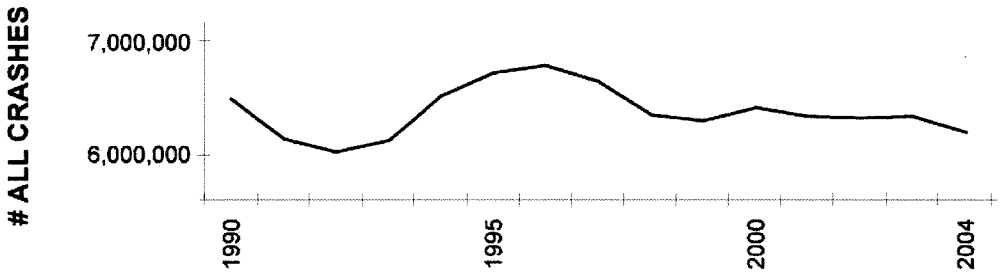


Figure ES7. Graph. Total vehicle crashes.

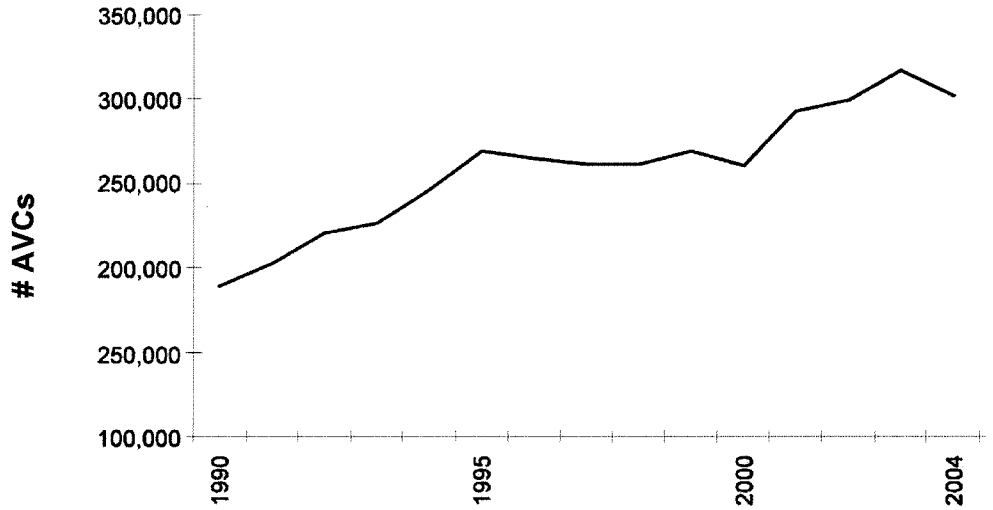


Figure ES8. Graph. Total AVCs (including wildlife and domestic animals).

The increase in WVCs appears to be associated with an increase in vehicle miles traveled (VMT) and an increase in deer population sizes in most regions in the United States. The occurrence of WVCs, however, is associated with many more factors, as reflected by their characteristics, which include:

- More than 98 percent of WVCs are single-vehicle crashes.
- 89 percent of WVCs occur on two-lane roads.
- WVCs occur more frequently on low-volume roads.
- Compared to all motor vehicle collisions, WVCs occur more frequently on straight roads with dry road surfaces.

- WVCs occur more frequently in the early morning (5–9 a.m.) and evening (4 p.m.–12 a.m.), when deer are more active and traffic volume is relatively high.

- WVCs occur more frequently in spring and especially in fall, when animals move around more due to migration, mating, or hunting seasons.

- The vast majority (as high as 90 percent in some states) of reported WVCs involve deer.

- White-tailed deer-vehicle collisions are associated with diverse landscapes with abundant edge habitat (transitions from cover to more open habitat) and riparian habitat.

WHAT ARE THE CONSEQUENCES? THE COSTS AND IMPACTS TO DRIVERS AND ANIMALS

WVCs can have a broad range of consequences for both motorists and animals. Though human injuries and fatalities resulting from WVCs are relatively rare, they do occur and are a serious consequence. More common results are vehicle damage, secondary motor vehicle crashes, emotional trauma, and less direct impacts such as travel delays. WVCs can also require the assistance of law enforcement personnel, emergency services, and road maintenance crews for potential repairs and carcass removal. For animals, WVCs present an immediate danger to their individual survival, and certain threatened and endangered species are faced with a further reduction in their population survival probability.

Impacts on Travelers

Safety Risk

Collisions with large animals pose a safety risk to humans as well as wildlife (figure ES9). Based on research from various states, roughly 4–10 percent of reported WVCs involving large animals result in injuries to drivers and their passengers. While this may not appear to be a large percentage, this translates into approximately 26,000 injuries per year that are attributable to these accidents.



Figure ES9. Photo. A mule deer is hit by a vehicle in Big Bend National Park, TX (copyright: Marcel Huijser).

Similarly, only a very small proportion of crashes with large animals result in human fatalities. Nonetheless, an estimated 200 people die from WVCs in the United States every year. From 2001 to 2005, an average of 38,493 fatal crashes occurred.[2] Hence WVCs represent roughly 0.5 percent of fatal crashes.

Direct Monetary Impacts

For vehicle owners, the most common direct cost incurred from a WVC is damage to their vehicle. Most research indicates that more than 90 percent of collisions with deer result in damage to the driver's car or truck. Nearly 100 percent of collisions with larger animals—such as elk or moose—end with substantial vehicle damage.

Due to the size and weight of the animals, damage to the vehicle can be costly. Based on numerous studies, the average cost of repairing a vehicle after colliding with a deer was estimated at $1,840. For collisions with elk and moose, the averages increase to $3,000 and $4,000, respectively.

Drivers may incur other direct costs if they must have their vehicle towed after the accident. If an injury occurs, drivers and passengers may face expenses from medical care and possibly lost wages from missed work.

WVCs have financial implications for public agencies as well. Law enforcement agencies face direct costs of investigation and traffic control following a collision. Transportation agencies typically are responsible for carcass removal and disposal costs and infrastructure repair costs, if necessary. Public agencies may incur some financial losses based on the monetary value of the animal itself, value associated with its hunting or license fees or recreational attraction for wildlife viewing.

The best estimate of the total annual cost associated with WVCs, based on available data, is calculated to be $8,388,000,000. Collisions with deer constitute the single largest collision category involving human and vehicle costs. The average costs from a collision with a deer include the following:

- $1,840 in vehicle repair costs.
- $2,702 in medical costs.
- $125 in towing and law enforcement services.
- $2,000 for the monetary value of the animal.
- $50 for carcass removal and disposal.
- Costs can increase substantially if a car collides with a larger animal (such as an elk or moose).

Indirect Impacts on Travelers

WVCs can have other impacts on travelers that are more difficult to quantify in fiscal terms. Accidents involving large animals can lead to travel delays or secondary accidents for subsequent motorists if the vehicle or animal lies in the right of way. Some drivers also experience emotional trauma as a result of the danger they experienced and the killing of a large animal.

Impacts on Wildlife

WVCs are a serious safety risk for animals. In most cases, an animal that has been hit by a vehicle dies immediately or shortly after a collision. Clearly, these deaths affect the immediate survival of many individual animals. However, they also represent a serious conservation issue. For some species, the long-term survival of a local or regional population may be threatened, especially in combination with other factors such as habitat loss due to agriculture and urbanization.

This study identified 21 federally listed threatened or endangered animal species in the United States for which road mortality is among the major threats to the survival of the species. These species include birds such as the Hawaiian goose (figure ES10), reptiles such as the desert tortoise (figure ES11), mammals such as the San Joaquin kit fox (figure ES12), and amphibians such as the California tiger salamander.



Figure ES10. Photo. Hawaiian goose warning sign (copyright: Haleakala National Park, National Park Service).



Figure ES11. Photo. Desert tortoise (copyright: Marcel Huijser).



Figure ES12. Photo. San Joaquin kit fox (copyright: Brian L. Cypher, California State University, Stanislaus, Endangered Species Recovery Program).

THREATENED AND ENDANGERED SPECIES

This study identified 21 federally listed threatened or endangered species in the United States for which road mortality is among the major threats to the survival of the species:

Mammals

Lower Keys marsh rabbit, Key deer, bighorn sheep (peninsular California), San Joaquin kit fox, Canada lynx, ocelot, Florida panther, red wolf

Reptiles

American crocodile, desert tortoise, gopher tortoise, Alabama red-bellied turtle, bog turtle, copperbelly water snake, eastern indigo snake

Amphibians

California tiger salamander, flatwoods salamander, Houston toad

Birds

Audubon's crested caracara, Hawaiian goose, Florida scrub jay

Note that other factors such as habitat loss due to agriculture and urbanization also impact these species and that a substantial reduction in WVCs may not automatically result in viable populations.

CAN THE NUMBER OF COLLISIONS BE REDUCED? METHODS FOR PREVENTING COLLISIONS

For this study, 34 different techniques aimed at reducing the number of WVCs were identified and reviewed. This section presents only some examples of the mitigation measures aimed at reducing WVCs; other measures are described and evaluated in the main text of the report. The measures are grouped into four major categories: efforts to change or influence the behavior of wildlife, efforts to reduce wildlife population size, efforts to change or influence a driver's behavior, and planning and design approaches. It should be noted that the Federal Highway Administration (FHWA) is not recommending these measures by including them in this report.

Influencing Wildlife Behavior

WVCs can be reduced by influencing the behavior of animals. These efforts either attempt to deter animals from approaching the roadway or direct the animals toward a safer location to cross the road.

Wildlife fences that separate animals from the roadway have a successful record of reducing WVCs and are now used extensively. Wildlife fences typically consist of wire mesh fence material that is 2 to 2.5 m (6.5 to 8 ft) tall, running parallel to the roadway (figure ES13). Numerous studies in the last 20 years have demonstrated that wildlife fencing, with or without wildlife crossing structures, can reduce collisions with deer and other large animals by 87 percent on average (80–99 percent).

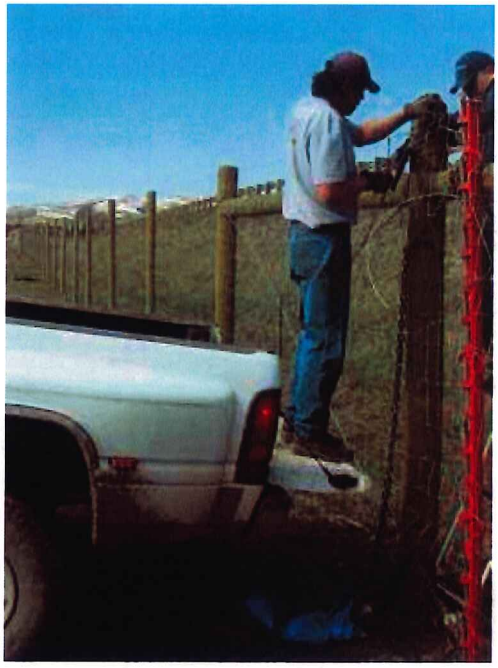


Figure ES13. Photo. Wildlife fencing along Interstate 90 near Bozeman, MT (copyright: Marcel Huijser).

While correctly installed wildlife fencing is highly effective in reducing collisions, it must be carefully applied to avoid unintentional effects such as creating an absolute barrier that keeps animals from accessing habitat on the other side of the road. In addition, animals are more likely to break through the wildlife fencing if safe crossing opportunities are not provided or if these opportunities are too few, too small, or too far apart. Therefore wildlife fencing is usually combined with safe crossing opportunities, such as wildlife underpasses (figure ES14 and figure ES15) and overpasses. In addition, wildlife jump-outs are usually integrated with wildlife fencing. These features allow animals that do manage to cross the fence to escape from the fenced road and right of way.

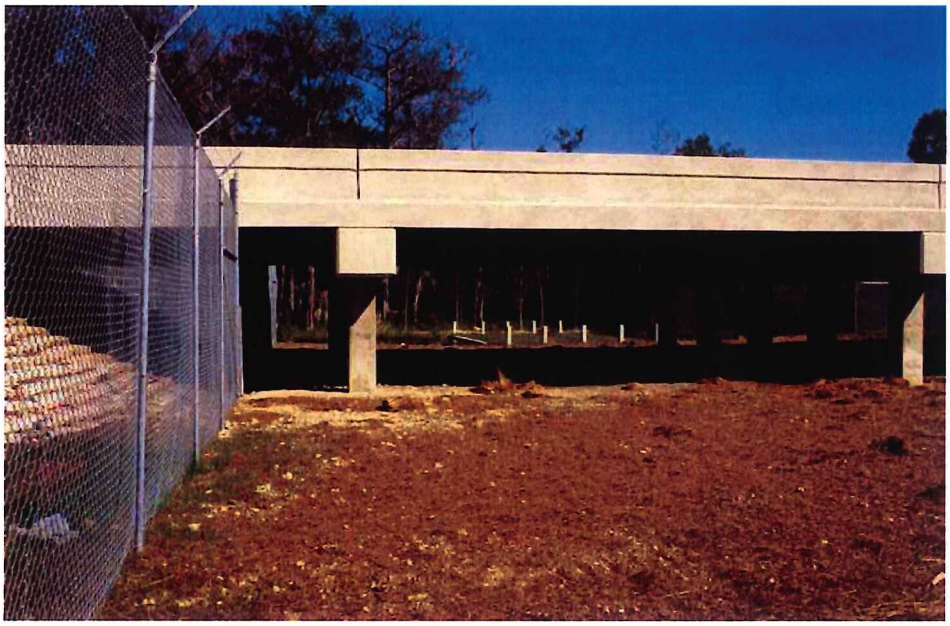


Figure ES14. Photo. Wildlife underpass in southern Florida that allows for ecosystem process (hydrology) as well as wildlife use, including the Florida panther (copyright: Marcel Huijser).

Wildlife underpasses and overpasses provide safe road crossing opportunities for a wide array of species, allowing them to continue to move across the landscape. These structures are typically used in combination with wildlife fences that keep the animals from entering the roadway and that funnel the animals toward the overpasses and underpasses. In some cases wildlife underpasses and overpasses have no or very limited wildlife fencing, making them the primary measure to reduce WVCs on short road sections. The location, type, and dimensions of wildlife crossing structures must be carefully planned with regard to the species and surrounding landscape. For example, grizzly bears, deer, and elk tend to use wildlife overpasses to a greater extent than wildlife underpasses, while black bears and mountain lions use underpasses more frequently than overpasses. In addition, different species use different habitats, influencing their movements and where they want to cross the road. Other factors that should be considered are the vegetation in the direct vicinity of the crossing structure, co-use by humans, and the time it

takes for animals to learn the location of the structures and to learn that they are safe to use. Although wildlife overpasses are more common in Europe than North America, some of the best studied examples are located in Banff National Park in Canada, and multiple large overpasses are planned in the United States.



Figure ES15. Photo. Large culvert with vegetative cover and fencing on Highway 1 in Canada (copyright: Tony Clevenger).

Large boulders parallel to the road can be an alternative to wildlife fencing, especially if landscape aesthetics are a concern. Preliminary data suggest that hoofed animals are reluctant to walk across large boulders. Smaller rocks have also been used at fence ends to discourage hoofed animals from wandering in between the fences.

Long tunnels (or landscape bridges) are tunnels that are at least several hundreds or thousands of yards long (figure ES16). Long bridges (or elevated road sections) are bridges that span a similar distance. Long tunnels and bridges are primarily constructed because of the nature of the terrain (e.g., through a mountain, across a floodplain), but in some cases they are constructed to avoid areas that are ecologically very sensitive and where no alternatives are available. If the nature of the terrain permits, animals can move freely over long tunnels or under long bridges, and because the animals are physically separated from traffic, WVCs are eliminated. However, long tunnels or bridges are rarely specifically designed to reduce WVCs.



Figure ES16. Photo. Long bridge on Arizona Highway 260 constructed in such a way as to minimize the impact to soil and vegetation (copyright: Marcel Huijser).

Reducing Wildlife Population Size

Wildlife culling involves a substantial reduction in the population size of a particular species in a certain area. When used, this measure is typically applied to deer. Culling is sometimes done by recreational hunters through increased deer quotas and sometimes it is accomplished by hiring professionals. The elimination of does (females) is more effective than the killing of bucks (males) because there is a greater impact on the reproductive potential of a population. Culling efforts are more likely to result in a substantial reduction in deer population size if the herd size is relatively small to begin with and if it is a closed population that does not allow influx of animals from nearby places. Data on the effect of culling on deer-vehicle collisions (DVCs) are scarce. One field test in Minnesota showed that a deer population reduction program reduced winter deer densities by 46 percent and DVCs by 30 percent. Sharpshooting by professionals using bait was deemed to be the most effective and adaptable culling method in an urban setting, as opposed to controlled hunts in large parks and refuges or opportunistic sharpshooting by professionals. The effort will have to be repeated periodically, as the deer population will return to the same levels if the habitat conditions remain similar; culling is not a one-time-only measure. In addition, the effort involved for population size reduction programs increases disproportionately with higher population size reduction goals, and substantial reductions (for example $\geq$ 50 percent) may be hard to obtain, perhaps capping the potential reduction in DVCs at 50 percent. Finally, wildlife culling can meet with strong public opposition.

Modifying Driver Behavior

Efforts aimed at helping motorists avoid collisions depend on providing the driver with information. The driver may then take action, for example, by choosing when or where to drive, remaining alert, or lowering vehicle speed (figure ES17).



Figure ES17. Photo. Permanently flashing Florida black bear warning signs in the Ocala National Forest, FL (copyright: Marcel Huijser).

Animal detection systems use sensors to detect large animals that approach the road. Once a large animal is detected, warning signals are activated to inform drivers that a large animal may be on or near the road at that time. Such systems have been installed at over 30 locations in North America and Europe. Limited data exist on the effectiveness of animal detection systems, but a Swiss study showed that collisions with large hoofed animals were reduced by 82 percent on average for seven different locations. While these data are encouraging, animal detection systems should still be regarded as experimental, as more data on their effectiveness is needed. Animal detection systems applied over long road sections do not restrict animal movements. Animal detection systems may also be applied at gaps in a wildlife fence or at fence ends. This mitigation measure still allows large animals to be on the roadway, and the posts, sensors, and other equipment associated with the system may pose a safety hazard of their own.

Public information and education programs aim to increase motorists' awareness of the impacts, causes, and high risk locations of WVCs. These campaigns may also offer advice on how to avoid crashes with animals or how to reduce their severity. Dissemination of this information is often targeted to drivers at specific high risk locations or during seasons of high wildlife movement. Little research has been conducted to conclude whether these efforts are effective on their own; therefore, they are generally integrated with other mitigation measures.

Planning and Design Methods

Integration of transportation planning and wildlife management on a regional or statewide level can help to reduce WVCs. These efforts do not generally reduce WVCs in a direct or easily quantifiable manner. However, by working together, planners from transportation, resource, park, and other agencies find opportunities to share information and make planning decisions that help prevent or reduce WVCs. Examples include:

- Avoidance of key habitat. Some states have chosen to avoid impacts in the most sensitive areas, for example by choosing an alternative route for a new road. This may avoid increased WVCs.

- Identification and prioritization of WVC problem areas. Some transportation agencies use roadkill data, animal movement data, aerial photos, and mapping tools to identify habitat linkage zones (areas of high animal movement) and WVC locations. With this information, transportation agencies can focus limited resources on mitigating high priority locations. Having such information available also allows for the early integration of these WVC reduction measures with road building or road upgrading plans. This increases the probability that mitigation measures will be implemented and that WVCs will be reduced.

- Data collection. Planners need good data regarding the magnitude and trends of WVCs so that they can identify and prioritize areas that may require mitigation. In addition, these data help in evaluating the effectiveness of potential mitigation measures. Some states have established data standards; others are developing methods to make it easier to collect detailed and accurate information (figure ES18). Having good data increases the probability that mitigation measures will be implemented and that WVCs will be reduced.

- Consideration of geometric and roadside design features can reduce WVCs:

- Steeper fill slopes may not allow drivers to see deer approaching the roadway until the animals leap over the guardrail. If a steeper side slope is unavoidable, a landing area may allow drivers to see animals before they jump over the guardrail.

    - At locations where the roadway crosses drainages, known migration corridors, or known animal habitat, avoid curves, steep side slopes, and narrow clear zones, which may make animals visible to drivers.

    - At locations where culverts or bridges are installed, culverts and bridges can possibly be widened to include opportunities for animals to cross under the road.

    - Drainage features can be designed to minimize wildlife attraction and influence wildlife movement. Avoid creating pooled water in the right of way which increases vegetation and attracts wildlife. Some wildlife will avoid crossing rip-rap (large boulders). If rip-rap funnels animals to an undesirable crossing location, consider filling gaps in the rip-rap with sand and gravel (which may make it more

conducive to animals crossing) or extend the rip-rap to a more suitable crossing location.

- When considering seeding mixes for the roadside, consider unpalatable species. Also consider plants that do not grow so tall as to visually obscure animals approaching the roadway.

- Concrete median barriers may cause wildlife to pause at the barrier or turn around, increasing their time in the roadway.

Which Methods Are Most Effective?

There is no single, low-cost solution for WVCs that can or should be applied everywhere. A successful mitigation strategy requires a detailed, location-specific analysis of the problem and often involves a combination of different types of mitigation measures. Nonetheless, wildlife fences, with or without wildlife crossing structures, animal detection systems, and long tunnels or bridges, reduce or may reduce WVCs substantially ($\geq$ 80 percent). Of these mitigation measures, wildlife fences, with or without wildlife crossing structures and animal detection systems, are among the most cost-effective measures.

ARE WE MAKING PROGRESS? CHALLENGES FACED BY TRANSPORTATION AGENCIES

With several successful WVC mitigation methods available, why hasn't more progress been made toward reducing the number of WVCs? This study identified several challenges that currently prevent a systematic, nationwide approach to WVC reduction.

Gaps in Knowledge, Insufficient Information, and Lack of Data

There are no standards or guidelines for the collection of data on WVCs. Data are collected inconsistently and often haphazardly, and methods vary between states and agencies. Some transportation agencies do not collect this type of data at all. Without reliable, consistent data, it is difficult to identify road sections where mitigation methods may be required, to select an appropriate mitigation measure, or to evaluate whether that effort is making a difference. Future analyses should also include additional statistical methods to analyze the data.

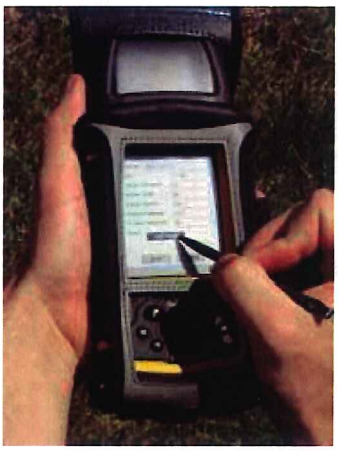


Figure ES18. Photo. Roadkill observation collection system (ROCS), a GPS-enabled PDA for animal carcass data collection (copyright: Amanda Hardy, WTI).

Research and Evaluation of Mitigation Measures

While several mitigation methods show promise, transportation agencies need data that show the effectiveness of different types of mitigation measures to justify their deployment. Additional research and field demonstration of WVC reduction techniques (figure ES19) help advance the state of the practice as results depend on the type of problem, the species involved, and local circumstances. Long-term monitoring of the effectiveness of the mitigation measures is needed, as WVC numbers are highly variable in nature. In addition, wildlife use of crossing structures tends to increase over time, as animals need time to learn their locations and learn that they are safe to use.

Training

While many transportation agencies are interested in reducing WVCs, their staff may not have the knowledge or experience to select effective methods. DOT planners and design engineers need training and guidance materials before they can begin to implement WVC reduction plans.



Figure ES19. Photo. Animal detection system along U.S. Highway 191 in Yellowstone National Park, MT (copyright: Marcel Huijser).

WHERE DO WE GO FROM HERE? OPPORTUNITIES AND NEXT STEPS

This study has provided an opportunity to document the central issues related to WVCs on America's highways: the magnitude and trend of the problem, the dangers posed to both drivers and animals, successful and promising methods for reducing the number of collisions, and challenges that lie ahead.

More importantly, the findings of this study can help policymakers make informed choices regarding future efforts to reduce WVCs. Policymakers who wish to take the lead in advancing effective WVC safety measures can begin by considering the following recommendations:

- Incorporate WVC reduction into the early stages of planning and design for transportation projects.
- Develop and implement standards and guidelines for the collection of data on and reporting of WVCs.
- Develop and implement guidelines for the evaluation of mitigation measures.
- Evaluate the effectiveness of mitigation measures that have been recommended for further research.
- Conduct additional analysis of the data and conduct research to further develop and improve existing mitigation measures (figure ES20).

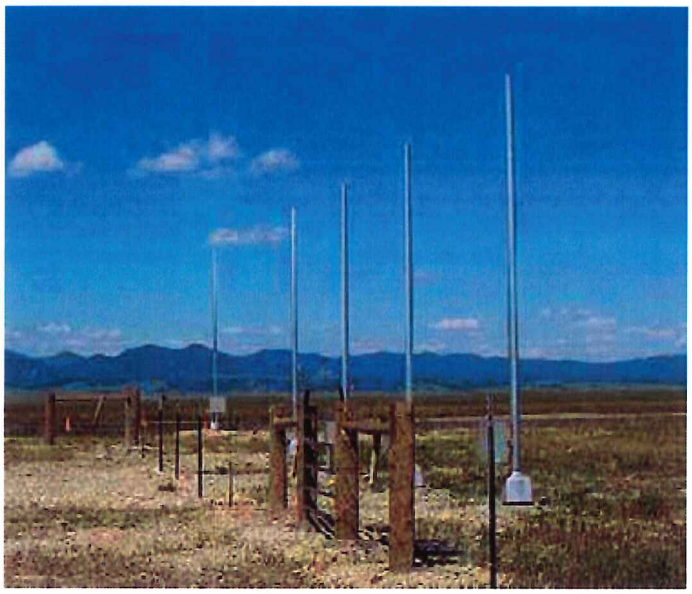


Figure ES20. Photo. Animal detection test-bed used to test the reliability of multiple animal detection systems, Lewistown, MT (copyright: Marcel Huijser, WTI).

- Implement (or install) proven mitigation measures where appropriate.
- Develop and apply wildlife population viability models to assist with locating and designing mitigation measures.
- Conduct technology transfer to state DOTs, resource agencies, and other transportation professionals regarding the findings of this study. A handbook and training course on WVC reduction techniques will be developed by 2008, which will help in making the information available to practitioners.

CHAPTER 1. INTRODUCTION

In the recently enacted transportation bill, the Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU Public Law 109-59), the U.S. Congress directed the Secretary of Transportation to conduct a national WVC study. In response, FHWA sponsored a WVC study aimed at reviewing methods to reduce collisions between motor vehicles and wildlife. The Study will advance the understanding of the causes and impacts of WVCs and identify solutions to this growing safety problem. This Study is a unique opportunity to synthesize current knowledge from the United States, Canada, Europe, and elsewhere to promote the expertise, coordination, and effectiveness of transportation agencies in addressing WVCs and, ultimately, reduce WVCs on U.S. roadways.

Approximately 300,000 reported collisions between cars and large animals (i.e., animals capable of causing substantial property damage upon impact) occur every year in the United States, and the number is steadily increasing. Including unreported collisions, the total number is more likely between one and two million WVCs annually. The increasing trend is expected to continue as both traffic volumes and deer populations continue to increase nationwide. Of the reported crashes, approximately 26,000 resulted in human injuries and 200 resulted in human fatalities per year. This study identified 21 federally listed threatened or endangered animal species in the United States for which road mortality was documented as a major threat to their survival.

The remainder of this report provides information relating to WVCs and associated mitigation measures based on the literature review. The primary sections are listed below:

- **Causes and Characteristics** of WVCs provides an overview of what is known about WVCs. It includes those issues documented in the literature and provides an analysis of national crash datasets. This section is primarily focused on large animals.

- **Economic Impacts of Wildlife-Vehicle Collisions** summarizes the known costs of WVCs nationally. This section is also primarily focused on large animals.

- **Impacts to Wildlife** provides a list and discussion of endangered species that are known to be impacted by WVCs directly. This report does not include issues relating to habitat loss, habitat fragmentation, or other impacts of roadways on wildlife.

- A broad range of **Mitigation Methods** are discussed in several sections (organized into major categories). For each mitigation method, the report provides, if available, (1) a general description, (2) case studies (with contacts), (3) benefits and drawbacks, (4) costs, and (5) design guidelines. The major mitigation categories considered are as follows:

    - Methods that aim to influence driver behavior.

    - Methods that aim to influence animal behavior with no or minimal structures on/over the road or in the right of way.

    - Methods that seek to reduce the wildlife population size.

    - Methods that aim to physically separate animals from the roadway.
    - Planning considerations.

- Results are summarized for an **Evaluation of Mitigation Methods by a Technical Working Group** of national experts.
- **Gaps in Current Knowledge** provides a summary of topics related to WVCs that require further research and investigation.
- **Cost-Benefit Analyses** provides an overview of the costs and benefits of the different mitigations.
- A brief **Conclusion** ends the report.

This document reports on Tasks 1–3 of the study, which include a literature review and technical working group meeting. Other elements of this project, which will be covered in later separate deliverables, include the following:

- Best Management Practices Manual.
- Training Course.

In this document three terms are used to describe collisions with animals. Animal-vehicle collisions (AVCs) refer to collisions with wild and domestic animals in cases where domestic animals could not be separated from the dataset. WVCs include all species of wild animals. Deer-vehicle collisions (DVCs) include WVCs that involve only deer (*Odocoileus* sp.). The reason a separate term is used for deer and no other specific type of animal is that deer account for a majority of WVCs when data are available. When information is specific to one type of animal other than deer, no abbreviation is used (e.g., moose-vehicle collision).

CHAPTER 2. CAUSES AND CHARACTERISTICS OF WILDLIFE-VEHICLE COLLISIONS

The primary method of investigating the causes and characteristics associated with WVCs is to analyze data on previous collisions. This chapter provides a summary of current knowledge about WVCs, based on information from the literature and an update from national crash databases. After discussing data sources and evaluation methods, this chapter investigates the following characteristics of WVCs:

- Total magnitude.
- Growth rate.
- Temporal distribution by:
    - Time of day.
    - Time of year.
- Severity of human injuries and fatalities.
- Roadway facility type.
- Traffic density and speed.
- Weather conditions.
- Animal species.
- Landscape adjacent to roads.
- Number of vehicles involved.
- Deer population density.
- Driver characteristics.

DATA SOURCES

Numbers and factors related to WVCs have been reported extensively in the literature. Possibly the most commonly quoted statistic is that there are over one million WVCs with large animals annually in the United States. This number originally comes from a survey of states completed by Romin and Bissonette.[3] States responded to this survey with a mix of crash record numbers, carcass counts, and estimates. Approximately 500,000 DVCs were reported by 35 states. Conover and others estimated that DVCs are underestimated by at least 50 percent, so most researchers increase this number to one million or more to include the missing states and unreported crashes.[4]

There are three common sources of data for WVCs: carcass counts, the insurance industry, and police-reported crashes. The first source, carcass counts, includes counts of dead animals on the side of the roadway that likely died from collisions with a vehicle. Sometimes these data include more detail than just the species (e.g., sex, age, size, etc.). Unlike the two other sources discussed

below, carcass counts are not always focused on safety and can include smaller animals since conservation concerns are also a reason to collect carcass data. This source of data may be sufficient for corridor or regional studies, but the lack of consistency in reporting methods limits evaluation on a statewide or national level. However, it is often thought that carcass counts are the most comprehensive data available since the following two sources tend to underreport the total number of WVCs.

Another source of information on WVCs is data from the insurance industry, which is based on reported claims. Claims typically relate to major damage, and major damage is typically associated with relatively large animals (e.g., deer size and up). State Farm Insurance estimated the number of claims for collisions with deer, elk, and moose and then estimated the total number nationally based on the company's proportion of market share of insurance policies.[5] This estimate is questionable. The number may underreport total collisions, since it only includes vehicles with comprehensive insurance; accidents with uninsured vehicles are not reported to the insurance industry. On the other hand, it could be overestimating crashes, since people may be likely to say they hit a deer when they actually hit something else in an attempt to keep their insurance rates low. As shown in figure 1, there are approximately one million WVC insurance claims annually (years are shown as fiscal years, July 1–June 30). This source of data typically does not contain detailed information about each crash.

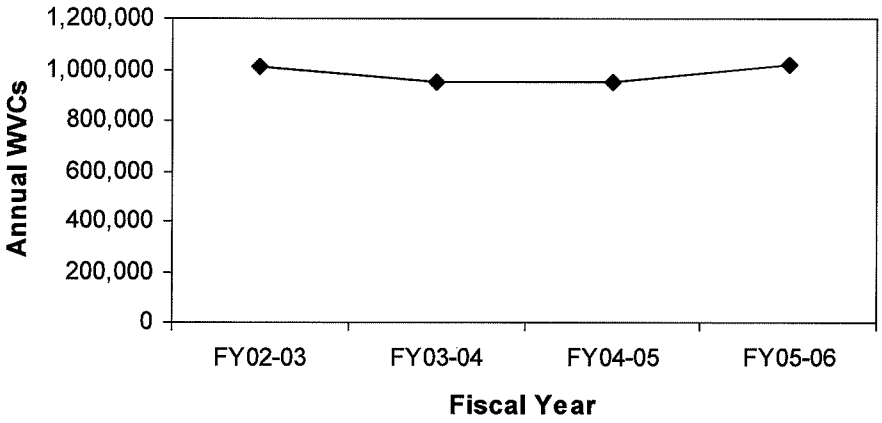


Figure 1. Graph. Annual WVCs estimated by insurance industry.[5]

The third source of WVC information is police reports of total crashes of all types (including WVCs). These reports are more effective for analyzing data nationally, because there is more consistency in their collection. The transportation industry expends considerable effort collecting and cleaning up these data for accurate analysis. However, this data set also has its limitations. These data only include crashes on public roads. In addition, these reports only include data for accidents that incurred a certain level of damage to the vehicle (each state has its own reporting threshold). Finally, the data may not include information on animal species, because these reports are focused on safety in general and are not specific to WVCs. In fact, the crashes may

only be categorized as AVCs (not separating domestic and wild animals). Three national police report-based datasets were used in this review as described below.

NATIONAL CRASH DATABASES

Each state maintains its own database of crash records with different reporting thresholds, different variables describing the contributing factors, and different database structures. WVCs were analyzed from three sources:

- Fatal Accident Reporting System (FARS) includes all crashes nationally that involve a human fatality. The data from this system are likely the most consistent nationally since more detail and effort goes into reporting a fatal crash. However, the dataset is small with typically fewer than 200 AVC fatal crashes annually. From 2001 to 2005, an average of 38,493 fatal crashes occurred.[2] Hence AVCs represent roughly 0.5 percent of fatal crashes.

- The Highway Safety Information System (HSIS) includes all reported crashes from Washington, California, Illinois, Maine, Michigan, Minnesota, North Carolina, Ohio, and Utah. This is a useful source of data since some of these states report more detail on the species of animal involved in a crash. Although it contains all crashes reported, it is only for the selected states.

- The General Estimates System (GES) is a true national sample. A small random sample of police accident reports is collected from each sampling unit. A sampling unit contains one or more police jurisdictions. The values from these police reports are aggregated up to determine national estimates. Although the collection methods are rigorous to ensure randomness, this is still only a sample of all crashes, so these are estimates of national values, not true national values.

Throughout the rest of this chapter, numbers are reported from each of these three datasets. General issues and methods for analyzing these datasets are discussed here. It should be noted that national figures are analytically attractive because there is a much larger dataset, but they may mask significant differences in WVCs between local areas.

Fatal Accident Reporting System

Fatal Accident Reporting System (FARS) data include those crashes where at least one person died within 30 days of the collision from collision-related injury. Data were collected from 2001 to 2005. AVCs were identified when a crash's "first harmful event" was an animal. Note that for these events, the "most harmful event" was not always an animal. Data were downloaded from the FARS Web site (http://www-fars.nhtsa.dot.gov/)(accessed November 27, 2006). The first harmful event is the first event during a crash that causes injury or property damage. The most harmful event causes the most damage and is not always the same as the first harmful event.

Highway Safety Information System

HSIS data contain police-reported accidents for Washington, California, Illinois, Maine, Michigan, Minnesota, North Carolina, Ohio, and Utah. HSIS was developed and is maintained

by FHWA. Information can be found at http://www.hsisinfo.org (accessed January 24, 2007). This database includes all police-reported crashes for these states; therefore, it has a larger sample than the random sample in the GES dataset, but it does not contain data beyond these states. A strength of this dataset is that some of the detail collected by individual states is maintained. For example, Maine divides its AVCs into deer, bear, moose, and other.

HSIS states have different data availability. The most recent 5 years of data from each state were analyzed (table 1). Also shown in table 1 are the reporting thresholds for each state.

Table 1. Summary of HSIS data characteristics from different states.

State	Years	Thresholds	Animal Categories
California	1998–2002	Differ by municipality: from $500 to $1,000 or injury only.	Deer, livestock, other animal (except in 2001)
Illinois	1999–2003	$500 or injury	Deer, other animal
Maine	2000–2004	$1,000 or injury	Deer, bear, moose, other animal
Minnesota	2000–2004	$1,000 or injury	Deer, other animal (except 2000–2002)
Michigan	1993–1997	$400 or injury	Animal only
North Carolina	2000–2004	$1,000 or injury	Animal only
Utah	1996–2000	$750 or injury	Wild or domestic animal
Washington	2000–2004	$750 or injury	Large domestic, small domestic, wild animal

The manner in which animals are categorized also varies between states (table 1). Some states simply have a single general category of "animal" for all AVCs. One category for all animals is similar to the GES and FARS animal categorization, which can include domestic animals. When reporting on HSIS data as a whole, domestic animals were excluded (unless otherwise stated) for those states that differentiated. As such, HSIS results refer to WVCs, even though some of the states may include domestic animals within their animal classification.

Crash data can sometimes be misleading when a clear and detailed explanation of the reported value is not provided. For example, from the same source of data one could state that there were 100 crashes, or that 200 vehicles were involved in a crash (i.e., there were 100 crashes, each involving two vehicles). In this report, unless otherwise stated, crash numbers refer to number of crashes (not number of vehicles or people). When referencing the vehicle attribute, it refers to the vehicle that struck the animal (almost all crashes were single-vehicle crashes). When referencing the person attributes, it refers to the driver of that vehicle.

To compare data from states with vastly different numbers of collisions (range = 176,793 to 890,215), proportions of collisions were compared instead of raw numbers. Further, rather than using the sum of all collisions with certain characteristics (which would bias the total towards states with more collisions), the proportion of collisions within each state was summed and divided by the number of states.

General Estimates System

GES is a stratified random sample. There are actually two strata. The first stratum is geographic. There are four regions (Northeast, Midwest, South, and West) that are further categorized into 1,195 primary sampling units, each containing one or more police jurisdictions. Within these geographic areas, crash reports are sampled randomly. The second stratum is crash type (mostly in terms of severity). Crash types are divided into the following categories:

- An occupant of a vehicle that was towed after the collision is killed or severely injured—no medium or heavy trucks.
- An occupant of a vehicle that was towed after the collision is injured—no medium or heavy trucks.
- A passenger vehicle is towed after the collision (no fatalities or injuries)—no medium or heavy trucks.
- A medium or heavy truck that resulted in a vehicle being towed or an injury report.
- No vehicles were medium or heavy trucks, no vehicles were towed, and at least one person was injured.
- No person was injured.

The total number of crash reports (including those not sampled) is also known for each geographic and crash type sampling unit. Based on these sampling units, rates are determined such that each crash record is given a weight that is an estimate of the number of crashes it represents. When comparing across the crash strata mentioned above or considering total AVC numbers, the weighting factors were used. Since these weighting factors have not been published for 2005, these numbers represent 2000–2004 data. When considering variables within the AVC subsample (e.g., time-of-day distributions), straight proportions were used assuming there were random samples across nonsampling unit variables. For these numbers, 2001–2005 GES data without weights were used. The assumption regarding these proportions was not validated. Future analysis should include the most recent available data and include the weighting factors. GES data were downloaded from ftp://ftp.nhtsa.dot.gov/ges/ (accessed January 24, 2007).

Total Vehicle Miles Traveled

Researchers collected data on vehicle miles traveled (VMT) for each state. This information, coupled with the crash data described above, allowed for determination of crash rates. These rates are expressed as crashes per million VMT unless otherwise stated. These values allow researchers to compare crashes both geographically and over time to see if there is an increase in the exposure rate. VMT files were downloaded from the U.S. Department of Transportation, Bureau of Transportation Statistics (BTS) Web site at http://www.bts.gov/ (accessed January 24, 2007). Annual national VMT were available through 2004.

EVALUATION METHODOLOGIES

The goal of the remainder of this section is to summarize how WVCs (or AVCs when crash data could not be separated into domestic and wild animal) are unique from other crashes. It is difficult to normalize for all the secondary factors that may cause a certain distribution of WVCs for a given variable. The best method is to compare WVCs with non-WVCs. A proportional *t*-test or chi squared test can be completed to confirm a statistically significant difference. In the case of all reported differences, they were statistically significant.

TOTAL MAGNITUDE

Based on the HSIS data, Table 2 shows the WVCs for each of the eight states analyzed. The proportion of crashes that were WVCs in a given state ranged from 0.6 to 14.6 percent. The total number of WVCs in these eight states was 251,619 for a 5-year period (about 50,000 per year). Consider that these states comprise 16 percent of the total land area in the 50 United States and 22 percent of the rural VMT in 2004. Considering the HSIS data represent about one-fifth of the United States, the national number of reported crashes is likely to be around five times the amount reported in the HSIS states (i.e., 50,000 per year). Extrapolating the HSIS data would yield an estimate of about 250,000 WVCs per year in the United States.

GES estimates the national average of AVCs at 292,000 annually (2001–2004). This value represents 4.6 percent of all crashes annually. Based on FARS data, the total number of fatal crashes involving AVCs nationally averages 179 per year (2001–2005). From 2001 to 2005, an average of 38,493 fatal crashes occurred for all crash types.[2] Hence AVCs represent, on average, less than 0.5 percent of all fatal crashes.

Table 2. Five-year crash totals for HSIS states.

State	WVCs	All Collisions	WVCs (%)
California	5,580	890,215	0.63
Illinois	29,038	664,263	4.37
Maine	21,599	176,793	12.22
Michigan	103,962	711,482	14.61
Minnesota	21,621	415,118	5.21
North Carolina	51,764	637,994	8.11
Utah	12,449	240,381	5.18
Washington	5,606	207,133	2.71
Totals	251,619	3,943,379	6.38

As mentioned previously, carcass counts have been extrapolated to a national estimate of over one million per year. Additionally, as shown previously in figure 1, the estimated number of insurance claims per year averages about one million. Table 3 summarizes the WVC counts from these various sources.

Table 3. Total annual magnitude of WVCs from various sources.

Source	Annual WVCs
HSIS	250,000
GES	292,000
Insurance claims	1,000,000
Carcass counts	1,000,000

Marcoux conducted a survey in Michigan and found that of the people involved in a DVC, only 52 percent reported it to their insurance company.[6] This finding implies that the estimated WVCs are underreported. The carcass counts are also not likely to include all WVCs, since they are extrapolated from a mix of reported collisions and carcass counts as well as from 35 to 50 states. Considering all of these figures and the previously discussed potential underreporting, the authors recommend the following two numbers be used when discussing the magnitude of WVCs with large animals:

- The total count of WVCs each year is between one and two million.
- The number of WVCs that are reported to police and have enough property damage to warrant tracking in crash databases (e.g., greater than $400–1,000 depending on the state) totals 300,000 per year.

Keep in mind that each of these numbers represent WVCs with large animals since they are based on reported crashes or carcasses. The total magnitude of WVCs with small animals is likely much larger.

IS THE PROBLEM GROWING?

Is the number of WVCs increasing or decreasing? A previous study of HSIS data found that WVCs increased 69 percent from 1985 to 1991.[7]

Since GES data are likely the best source of national numbers, trends were examined using this data source, extending back to 1990. As shown in figure 2 and figure 3, the number of all crashes is holding relatively steady at slightly above six million, while the number of AVCs is increasing. This increase could be due to a number of different factors discussed later in this chapter such as an increase in deer population and changes in traffic volumes and speeds.

To analyze WVC trends over time, three linear regression models were used, with the independent variable being the year and the dependent variable being either the total number of WVCs, the proportion of WVCs to total crashes, or the total crash rate. An important statistic is the *t*-statistic for the coefficient of the slope, which describes the relationship between the dependant and independent variables. If the *t*-statistic is greater than two, it can be confidently concluded ($\alpha = 0.05$ or 95 percent confidence) that the slope is not zero (i.e., the rate of WVCs changing through time). Statistically a linear regression line on the total annual AVCs shows an increasing slope of 6,769 AVCs per year ($t = 7.8$, R-squared = 0.81). In addition, the proportion of AVCs to total crashes has a positive slope of 0.11 percent per year ($t = 9.4$, R-squared = 0.86).

Note that a higher *R*-squared value (which ranges from zero to one) indicates there is a linear relationship. An *R*-squared value of one results from a perfect linear relationship.

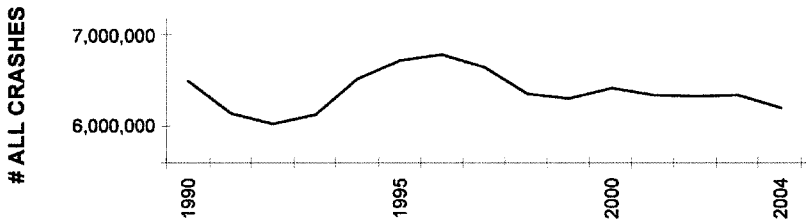


Figure 2. Graph. Total vehicle crashes.

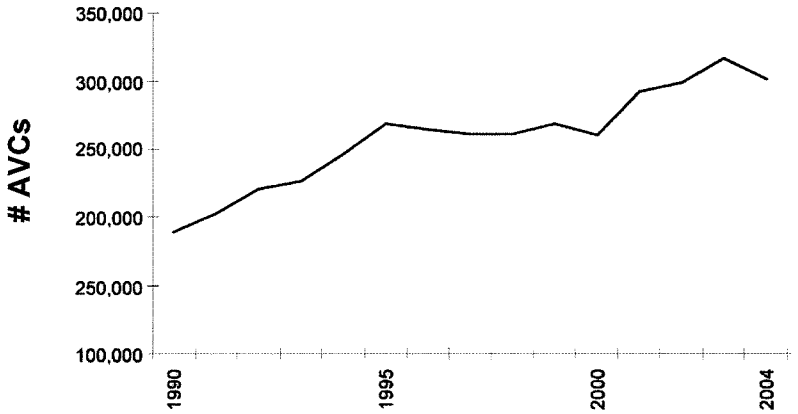


Figure 3. Graph. Total AVCs (including wildlife and domestic animals).

To ensure that the increase in WVCs over time was not due only to increases in the amount of travel (i.e., VMT), the crash rate was investigated. Figure 4 shows the crash rates each year determined by dividing GES annual numbers by VMT. The linear regression of crash rate over time has a positive slope of 0.00072 crashes per million VMT per year ($t = 2.2$, *R*-squared = 0.27). The linear relationship is weak as indicated by a low *R*-squared value. The *t*-statistic shows that the crash rate increase is statistically significant.

Statistical analysis beyond linear regression models will be considered in future stages of this topic to further assess relationships.

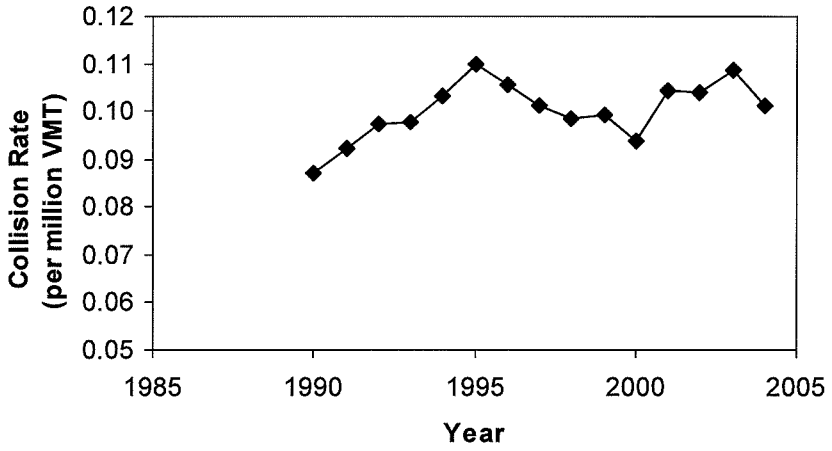


Figure 4. Graph. Annual crash rate for AVCs (GES and VMT data).

TEMPORAL DISTRIBUTIONS

For some species, there are clearly certain times of the day and times of the year when WVCs occur more frequently. For large mammals, numerous studies have shown that WVCs occur more frequently in the morning (5–8 a.m.), the evening (4 p.m.–12 a.m.), in the fall (October and November), and in the spring (May–June).[8,9,10] The peak in the spring is generally not as high as that in the fall. The daily peaks are typically explained by the fact that deer and other large animals are moving around dusk and dawn, which, combined with relatively high traffic volume in the early morning and late afternoon, results in a peak in collisions in the early morning and late afternoon and evening. The fall peak is typically explained as being related to mating season, migration, and hunting season, all of which cause animals to move around more.[11] The spring peak is explained by distribution of young and migration.

Figure 5 shows the annual AVC distribution for the three reported crash datasets. The HSIS- and GES-based AVC distributions are very similar in magnitude and shape. The FARS data do not have the sharp peak in AVCs observed in November in the other two datasets. Note that for the HSIS data most of the states followed the same basic trend. Five of the eight states had substantial peaks in proportion of AVCs in November, while two states (California and Washington) had a larger peak in October and a smaller peak in November. Utah had the least overall difference in WVCs by time of year. All states except North Carolina and Utah had minor peaks in WVCs in spring, generally in June.

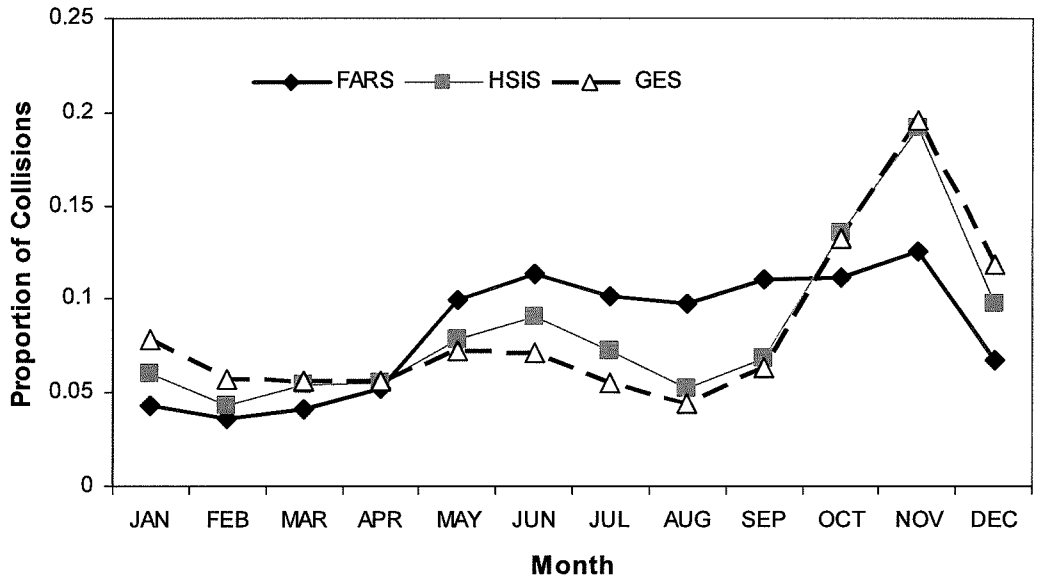


Figure 5. Graph. Annual distribution of AVCs.

Some HSIS states separated deer from other animals (WA, ME, IL, UT, and CA). For the "other animal" or domestic classifications the distribution is much more uniform throughout the year (figure 6).

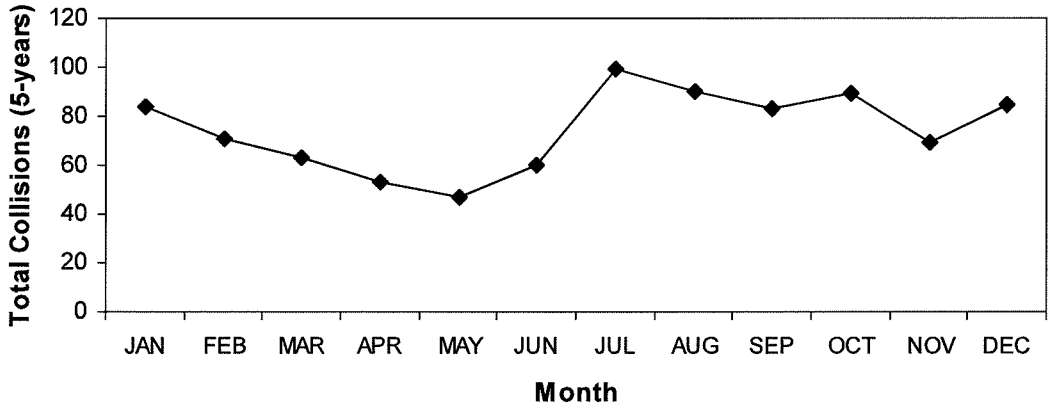


Figure 6. Graph. Annual distribution for other/domestic animal-vehicle collisions in CA, WA, IL, ME, and UT (HSIS data).

Maine was the only HSIS state to list specific wild species other than deer. For Maine, the annual distributions for bear- and moose-vehicle collisions (figure 7) do not have the major peak in November like deer (note AVCs reported in figure 5 are primarily deer). Bear-vehicle collisions are fairly uniform in the summer and nonexistent in the winter during their hibernation period.

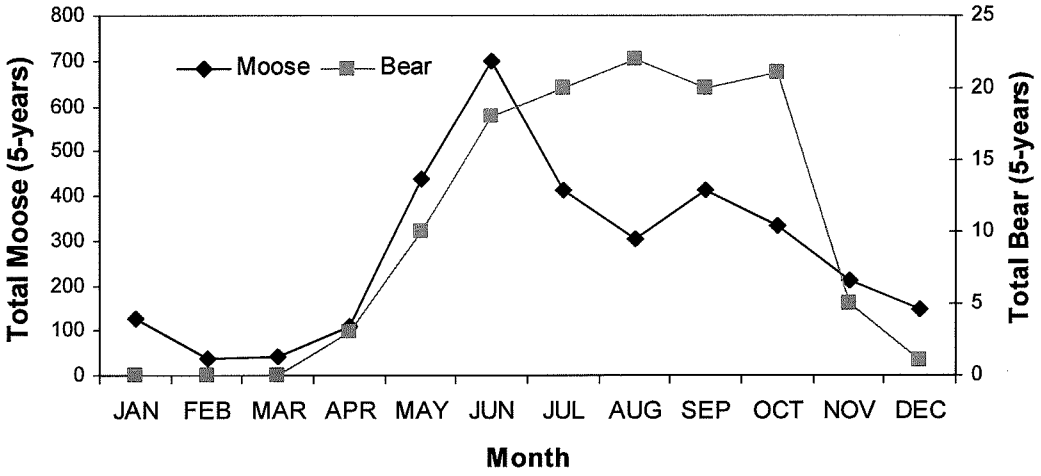


Figure 7. Graph. Annual distributions for moose and bear collisions in Maine (HSIS data).

Seasonal distributions appear to be somewhat dependent on specific geographic area. For example, in Teton County, Wyoming, WVCs were most frequent in summer months, especially in Grand Teton National Park, which has much higher traffic volumes in the summer.[12] These numbers contrast sharply with the more regional trends presented in figure 5.

For time of day, the three data sources all show the expected peaks at early morning and evening (figure 8). Wildlife, especially deer, typically move around more at dusk and dawn.

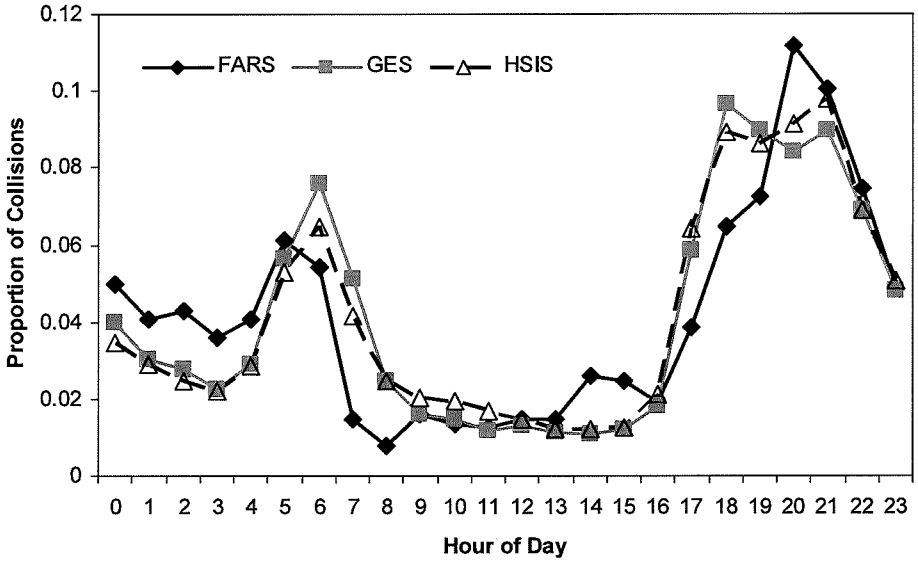


Figure 8. Graph. Time-of-day distribution.

SEVERITY

Williams and Wells looked at 147 fatal WVCs from nine different regions and found that the most common types were (1) a motorcyclist striking an animal and falling off the vehicle followed by (2) a passenger vehicle striking an animal, going off the road, and striking a fixed object or overturning. Safety measures (i.e., helmets and seat belts) were not used in 60–65 percent of the cases.[13] Jones also reported most fatal crashes involved motorcycles.[14] This conclusion was confirmed by the FARS data. On average, 30 percent of the fatal crashes involving animals also involved motorcycles. Conn and others investigated 22,498 emergency room visits where a motor vehicle collision with a large animal was identified as the cause.[15] Of these, more than one-third (8,508) were people ages 15 to 24.

In general, WVCs are less severe than other crashes. Compared to all crashes, the datasets show the proportion of crashes involving human injury is much less for WVCs. GES-based estimates of crash severity over 5 years are shown in figure 9 and figure 10 for AVCs and all crashes, respectively. Almost all AVCs resulted in no human injury (95.4 percent). This figure is consistent with the HSIS data that show 92.3 percent of crashes resulted in no human injury. There was some variability in severity values between the HSIS states, likely due to the different reporting thresholds. California showed only 87.4 percent of DVCs resulted in no injury. GES estimated fatal crashes at 608 in a 5-year period, compared to 895 in the FARS data. However, the upper confidence interval of the GES data is 1,956 fatal crashes. Note that for all crashes in this same 5-year period, FARS shows 192,463 fatal crashes.

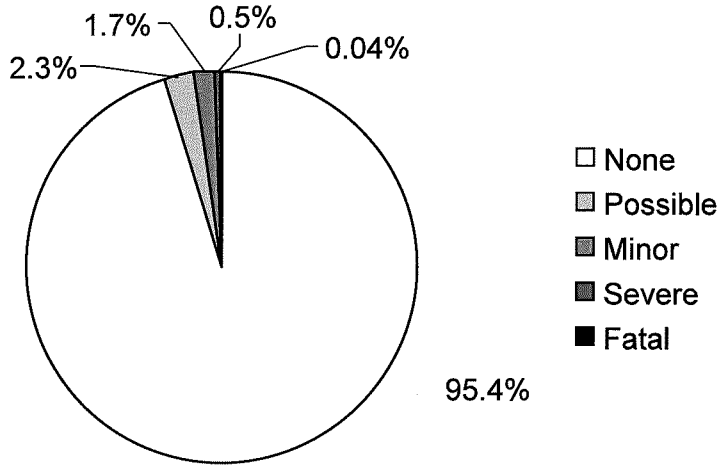


Figure 9. Graph. Severity distribution for AVCs (GES data).

Often collisions with moose and other larger animals are thought to be more fatal to humans than collisions with deer. In Newfoundland, Joyce and Mahoney found that among moose-vehicle collisions, 0.6 percent were fatal crashes and 26 percent were injury crashes.[8]

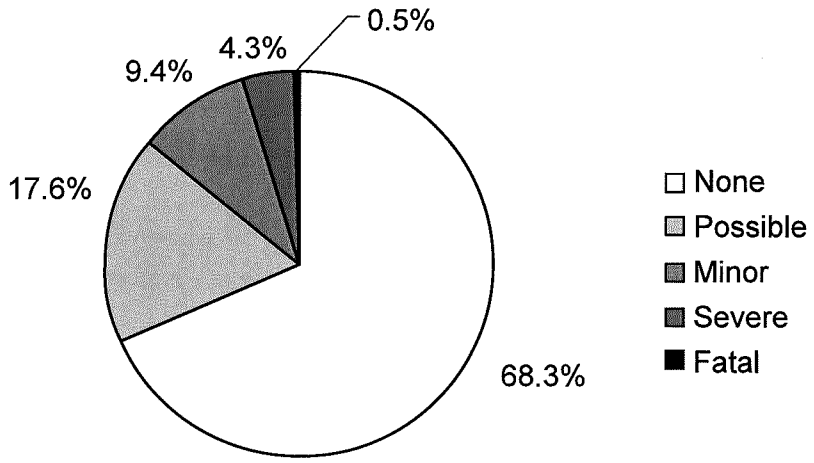


Figure 10. Graph. Severity distribution for all crashes (GES data).

From the HSIS data, domestic, livestock, and other animals had a slightly higher severity rate than WVCs, with 79.2 percent of crashes resulting in no human injury, which is lower than the 92.3 percent value for all AVCs, but still higher than the 68.3 percent value for all crashes. Moose-vehicle collisions from the Maine HSIS data show a severity profile more similar to that of all collisions (figure 11).

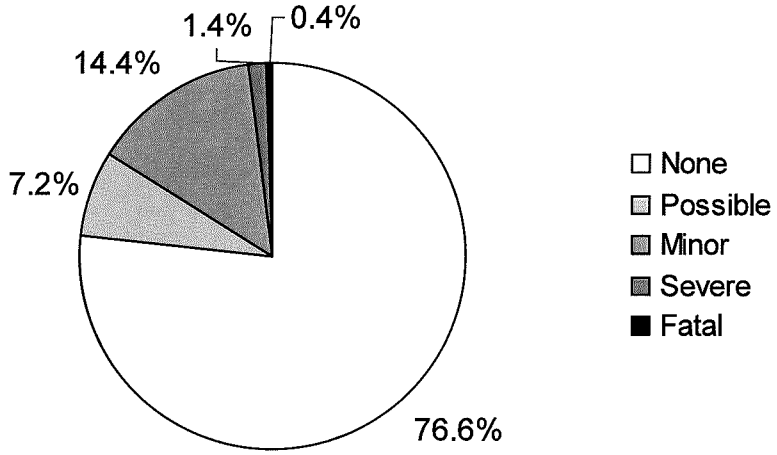


Figure 11. Graph. Severity distribution of moose-vehicle collisions in Maine (HSIS data).

FACILITY TYPE

Most studies that look at the types of roadways where WVCs occur report that they are most common on rural two-lane roads.[7] However, these results should be used with caution since a large majority of highway miles are rural, two-lane roadways.

For the GES records with number of lanes and facility types, 89.7 percent of AVCs occurred on two-lane roads. In comparison, 52 percent of all crashes occur on two-lane roads (figure 12). This is not to say that upgrading all two-lane roads would reduce WVCs. Reilly and Green found that the upgrade from two to four lanes in constructing Interstate 75 in Michigan initially resulted in a 500 percent increase in DVCs.[16] With time, the number of DVCs did steadily decrease. The initial increase could have been due to deer being unfamiliar with the new character of the roadway.

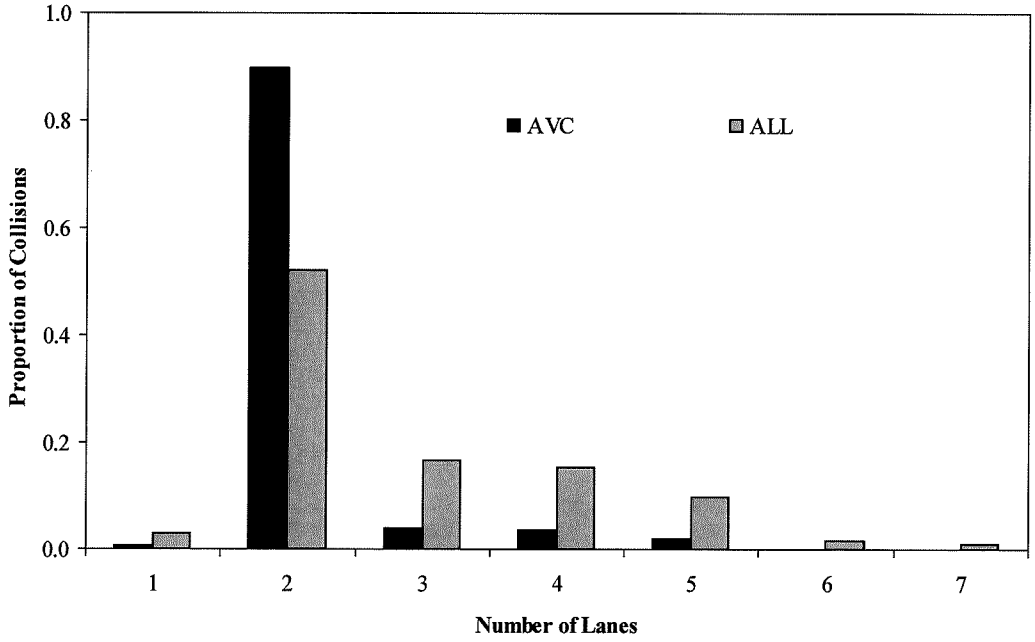


Figure 12. Graph. AVCs by number of lanes (GES data).

The majority of AVCs (91.7 percent) occurred on straight sections of roadways, compared to 85.8 percent for all crashes, according to the GES data. However, these results vary by region. In the West Region, 74.8 percent of AVCs occurred on straight roads, compared to 82.7 percent of all collisions.

TRAFFIC DENSITY AND SPEED

The impact of traffic density and speed on WVCs is complex. Predictive models of DVCs for Kansas and also for Iowa positively correlated the number of DVCs per year per mile to the number of roadway lanes and/or traffic volume.[17,18] Using traffic flow theory, Langevelde and Jaarsma modeled the probability of successful wildlife road crossings based on relevant species,

road and traffic characteristics.[19] Traffic volume has a large effect on this probability, especially for slow-moving species.[19]

Lower traffic volumes do not necessarily equate with fewer roadkills.[20] In fact, WVCs actually decrease when traffic volume increases to a high enough level that it is, in effect, a barrier (i.e., animals do not attempt to cross).[20,21,22] Several researchers have hypothesized a relationship similar to that shown in figure 13.[22,23,24]

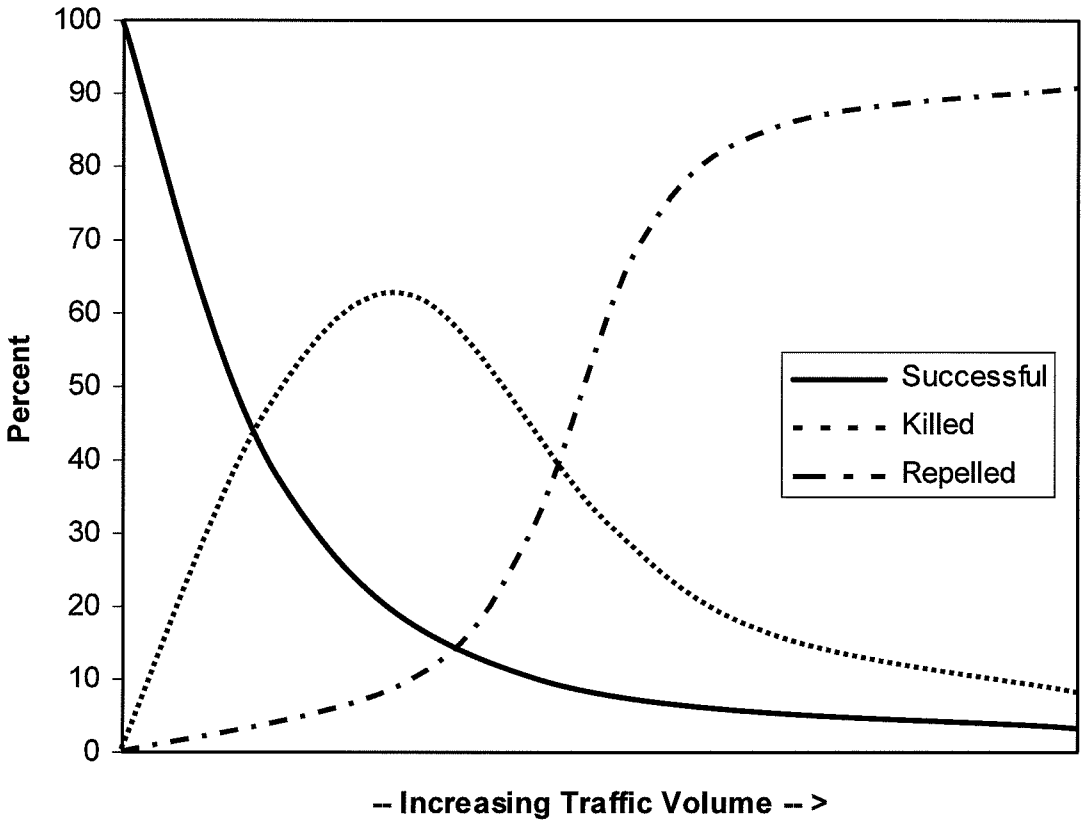


Figure 13. Graph. Theoretical relationship between traffic volume, successful wildlife crossings, and road mortality (adapted from Seiler).[23]

When analyzing the national crash data, AVCs are more likely to occur on low volume roads, as shown in figure 14. Almost one-half of WVCs in the HSIS states occurred on roadways with less than 5,000 average daily traffic (ADT).

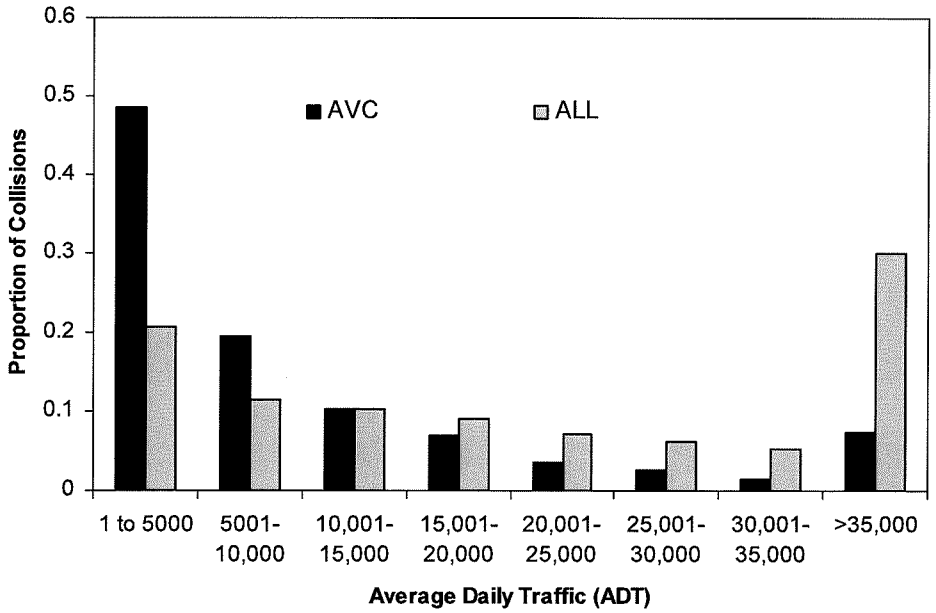
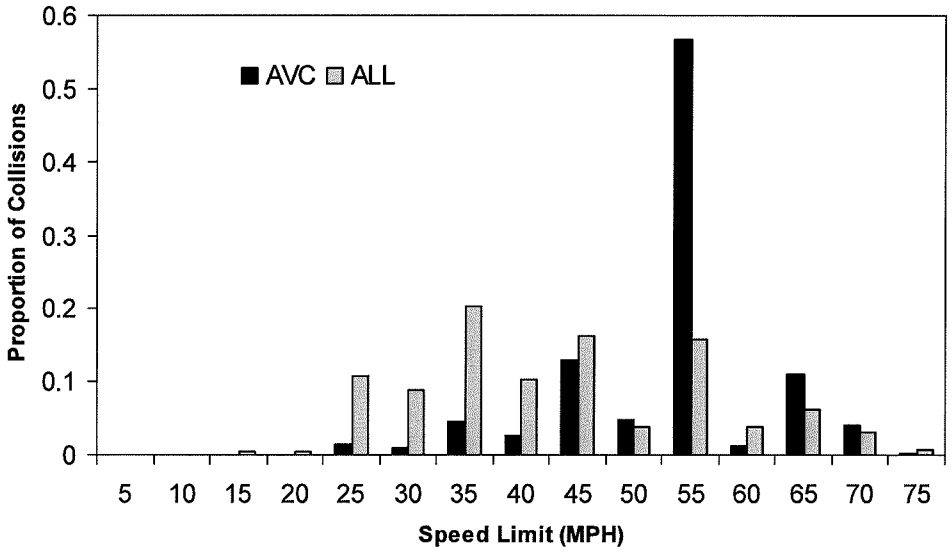


Figure 14. Graph. Crashes by ADT (HSIS data).

There are numerous reports that attempt to correlate increasing speed to increasing WVCs. Such correlations can be misleading if the author is not clear on what is being compared and what the results can suggest. For example, figure 15 indicates that AVCs occur less frequently on low-speed roadways. The initial conclusion could be that if the posted speed limit is lowered, the number of WVCs will decrease. However, the high number of AVCs on 88 km/h (55 mi/h) roadways (nearly 60 percent) is more likely a result of higher populations of wildlife on rural two-lane roadways with this design speed, rather than the 88 ki/h (55 mi/h) design speed in and of itself.

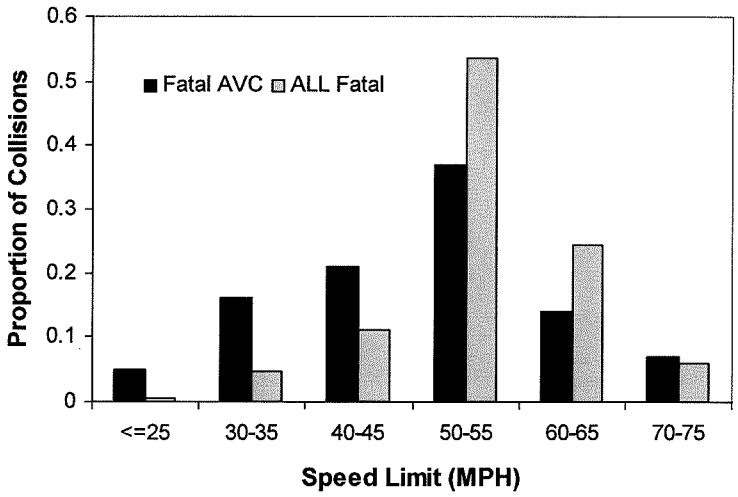


1 mi/h = 1.61 km/h

Figure 15. Graph. Distribution by posted speed limit (GES data).

Seiler found a similar trend with moose in Sweden. Moose-vehicle collisions peaked on roads with speed limits of 90 ki/h (56 mi/h) and declined at higher speeds.[25] Although an old study, Cottam found that collisions with birds also occurred more frequently on higher-speed roadways.[26] Cramer and Portier found that Florida panther WVCs increased with an increase in posted speed and traffic flow.[27]

As shown in figure 16, the likelihood of fatal AVCs occurring on 88 ki/h (55 mi/h) roadways is lower than the likelihood of a non-AVC fatal crash on a roadway with the same speed limit. This relationship is opposite of the distribution for all AVC crashes discussed above. There are numerous possible explanations for this. One hypothesis is that motorcycles, which account for a large proportion of fatal AVC crashes, typically travel on lower-speed roadways. However, there has been insufficient research to verify what accounts for the difference in the distribution of speeds for fatal AVCs.



1 mi/h = 1.61 km/h

Figure 16. Graph. Distribution of fatal crashes by posted speed limit (FARS data).

WEATHER

WVCs are more likely to occur in dry weather, perhaps due to the fact that animals are less likely to move around during inclement weather. Carbaugh found there were fewer deer sightings during precipitation.[28] Ninety-five percent of fatal AVCs occurred during clear weather compared to 88 percent of all crashes. The proportion of accidents in clear weather is similar for GES (92 percent AVC and 85 percent all) and HSIS (92 percent of WVCs 83 percent of all).

These results reinforce those of other research that show collisions with large animals typically occur on straight, dry roads.[29]

ANIMAL SPECIES

Data regarding animal species affected by WVCs vary considerably by state. Williams and Wells characterized 147 fatal WVCs from nine states in different regions of the United States between 2000 and 2002.[13] Seventy-seven percent of these WVCs involved deer; other types of animals included cattle, horse, dog, bear, cat, and opossum.

Of the eight HSIS states, six differentiated WVCs by some categorization scheme based on animal type (table 1). Illinois and Minnesota recorded DVCs and "other animal" collisions, although Minnesota only made this differentiation in 2003 and 2004. In both these states, deer made up more than 90 percent of the WVCs. California differentiated among deer, livestock, and other, except in 2001, when the species were not recorded. Using 1998–2000 and 2002 data only, deer represented 54 percent of AVCs (figure 17). Livestock are clearly not wild, but "other animal" could be wild or domestic. Non-animal represents WVC collisions in which an animal was involved but not struck (i.e., the driver swerves to avoid a deer and collides with a guardrail).

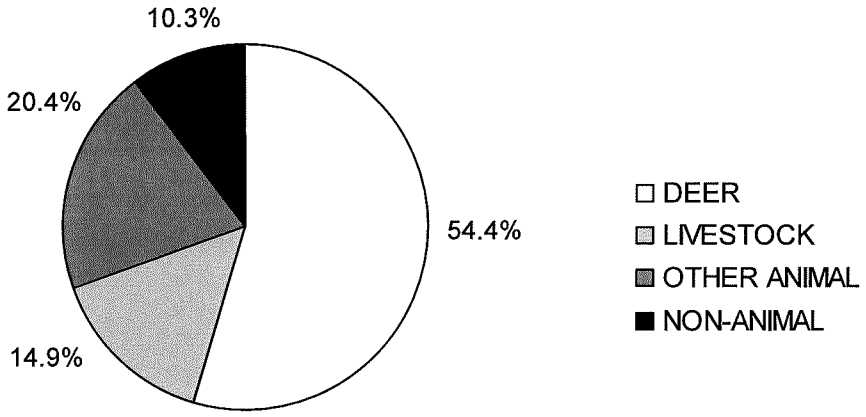


Figure 17. Graph. Animal species involved in collisions in California (HSIS data).

In Maine, 81 percent of AVCs were attributable to deer and 15 percent attributable to moose (figure 18). Maine also recorded whether collisions occurred with bears and other animals.

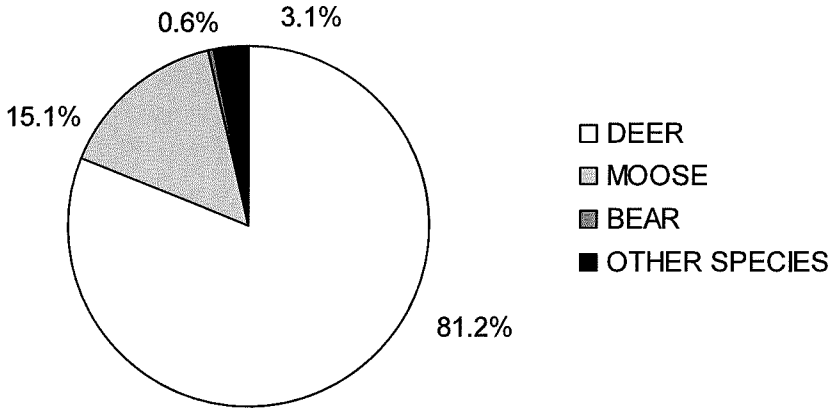


Figure 18. Graph. Animal species involved in collisions in Maine (HSIS data).

Rather than differentiating by species, Utah and Washington divided their reported AVCs into wild and domestic species. Washington further divided domestic species into large (cattle, horses, etc.) and small (dog, cat, etc.) domestics (figure 19). Washington reported a preponderance of collisions with wild animals. In Utah, over the five years of study, 84 percent of all AVCs were due to collisions with wild animals rather than domestic animals, a slightly lower percent of wild animal collisions than reported in Washington.

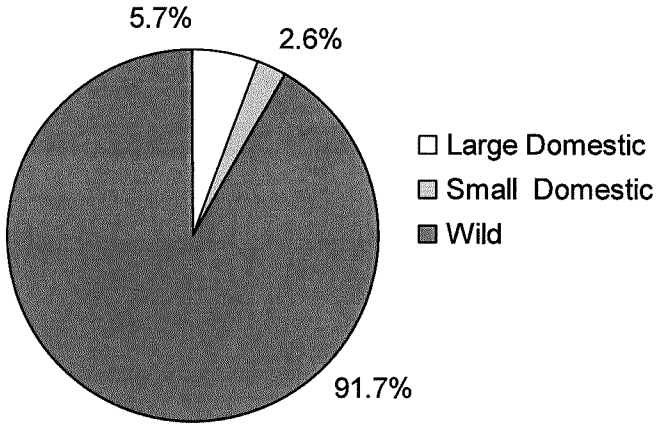


Figure 19. Graph. Animal species involved with collisions in Washington (HSIS data).

LANDSCAPE ADJACENT TO ROADS

Of all recorded accidents in the United States, the vast majority involve deer, especially white-tailed deer (*Odocoileus virginianus*). While deer and DVCs may be widespread, their occurrence is not randomly distributed across the landscape. White-tailed deer-vehicle collisions are typically associated with mixed landscapes that provide cover (forests, shrub land) as well as food (more open areas with grasses, herbs, crops, but also young trees).[30,31] A high heterogeneity and diversity of the landscape, proximity to cover, and the occurrence of edge habitat (transitions from cover to more open habitat), riparian habitat, and shrub land are strongly associated with the presence of white-tailed deer and white-tailed deer-vehicle collisions. (See references 30, 31, 32, 33, 34, 35, 36, 37, and 38.)

Research results are mixed on the relationship between building density and WVCs, showing either a negative or positive association. In general there are fewer collisions when the density of buildings increases. (See references 25, 28, 31, 37, 39, and 40.)

Mule deer (*Odocoileus hemionus*)-vehicle collisions are sometimes associated with seasonal migration corridors.[41,42,43] Seasonal migration of mule deer typically occurs in mountainous and heavy snowfall areas.[44] Furthermore, mule deer-vehicle collisions have been associated with large drainages and heavy cover.[45,46] Mule deer tend to avoid sites with human disturbance and deep snow.[47,48] Nonetheless, mule deer can adapt to an urban or suburban environment.[46,49]

The relationship between slopes and DVCs is uncertain. Carbaugh found that deer favored steep declines and inclines and rarely used level areas.[28] By contrast, Malo and others found that lateral embankments, especially with guardrail, negatively correlated with DVCs.[39] Alexander and Waters found that slopes less than five degrees were optimal for wildlife movement, but that west to south facing slopes were also indicative of locations with wildlife movement.[50] Pellet found that on a section of Interstate 90 near Bozeman, MT, as the absolute mean slope increased up to 19.5 percent, ungulate vehicle collisions decreased; while further increases in slope led to an increase in collisions.[51]

NUMBER OF VEHICLES AND COLLISION TYPE

Almost all WVCs are single-vehicle crashes (HSIS 98.5 percent, GES 99 percent). However, FARS data indicated a slightly lower percentage than the HSIS and GES data sources; only 85.6 percent of fatal AVCs were single-vehicle crashes. The proportion of FARS AVCs is lower than the other datasets (which include nonfatal crashes); however, this value is still much higher than the proportion for all FARS crashes, of which 56.9 percent are single-vehicle crashes. From the FARS data it can be seen that aside from collisions with animals, the two highest collision types for AVCs were hitting another vehicle or overturning (figure 20), which reinforces the hypothesis that swerving to avoid a WVC may result in a higher-severity collision.

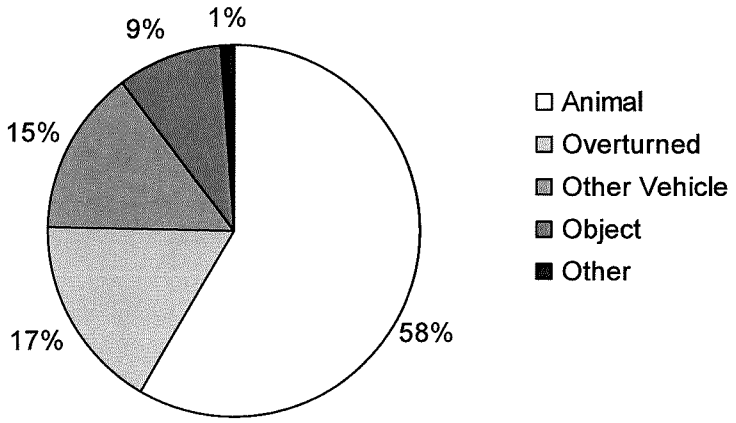


Figure 20. Graph. Fatal AVCs by collision type (FARS data).

DEER POPULATION DENSITY

A relationship between deer population density and DVCs has been documented in several studies.[52,53,54] Over the last century deer population size has increased strongly in most regions in the United States.[55] For example, in Virginia the white-tailed deer population size increased from an estimated 25,000 animals in 1931 to 900,000 by the early 1990s.[55] In Wisconsin, pre-hunting population size estimates for white-tailed deer increased from 1,152,000 in 1993 to 1,643,000 in 2004, but the estimated population size varied strongly between 1993 and 2004.[56] In Iowa population size estimates for white-tailed deer increased from 500–700 in 1936 to 360,000 in 2004.[54] In Wisconsin, the deer population estimates between 1993 and 2004 were poorly correlated with the number of DVCs.[56] In Iowa, deer population indices were closely correlated to the number of road-killed deer, both increasing by about a factor of 2.3 between 1985 and 2004.[54] The increase has been especially strong since the 1960s.[55,57] The increase in deer abundance is correlated with the number of DVCs, at least across relatively large areas, but this correlation has not been analyzed at a national level.[53,54,58]

The relationship between deer population density and the number of DVCs seems intuitive, but this is not necessarily the case.[59,60] A comprehensive review by Knapp, Putman and suggests that a reduction of the population size across a relatively wide area can be effective in reducing DVCs. (See references 52, 53, 54, 58, 61, and 62.) On the other hand, a reduction in population

over a large area does not necessarily result in a decrease in DVCs, and the reduction in population can be difficult to achieve and maintain, as is discussed further in chapter 7. Very few data exist on the effectiveness of population reduction programs in reducing WVCs, but one field test showed that a deer population reduction program in Minnesota reduced winter deer densities by 46 percent and DVCs by 30 percent.[52]

DRIVER CHARACTERISTICS

GES and HSIS data showed very little difference in the proportion of male drivers involved in WVCs versus all crashes. According to the FARS data, however, 81.8 percent of drivers involved in AVCs were male, compared to 74.8 percent in all crashes.

The national rate of alcohol involvement in all collisions was 7.76 percent (GES crashes where alcohol involvement was known and recorded). Comparatively, only 0.4 percent of AVCs involved alcohol. This observation does not, of course, mean that being intoxicated decreases a driver's chance of being involved in an AVC. This observation is likely due to some correlation between alcohol-related crashes and some other factor.

Probably the most unexpected finding in comparing crash distributions of WVCs to all crashes was the difference in accident distribution by driver age (note that the same trend was found with FARS and GES data, but only HSIS data are shown in figure 21). The peak in the number of crashes (all types combined) for younger drivers (i.e., age 16–25), seen in figure 21, is typically explained by inexperience and more risky driving behavior. Specific attributes of younger drivers include less skill at detecting hazards, less ability to conduct some driving tasks automatically, being easily distracted, less skill in performing emergency maneuvers, less perception of risk, and overestimation of driving abilities.[63] For middle-age drivers, the chances of being involved in a crash are fairly constant across this age group but less than that of younger age groups (figure 21). As driver age increases, the number of drivers decreases, resulting in reduced exposure (in terms of VMT), explaining the reduction in the total number of crashes (figure 21).

The unexpected finding is that, in contrast to the distribution for all crashes, WVC crashes have no pronounced spike for young drivers (figure 21). This suggests that the chance of being involved in a WVC does not decrease with experience. Another possible explanation is that young drivers drive less on the types of roadways where WVCs occur (i.e., low flow, two lane), resulting in relatively few WVCs for this age group.

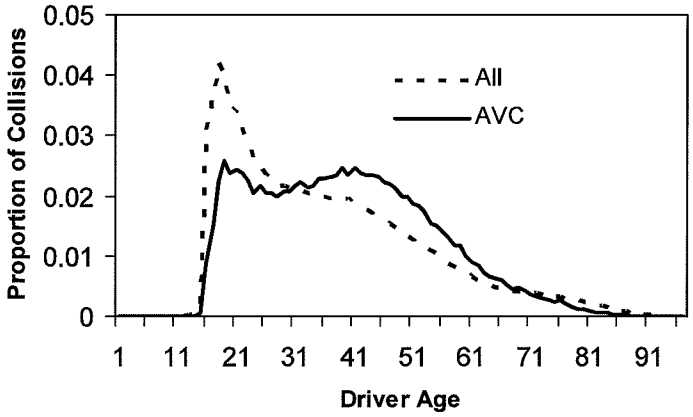


Figure 21. Graph. Age distribution for all crashes and AVCs (HSIS data).

To further investigate the relationship between age and WVCs, the National Household Travel Survey and U.S. Census data were combined to estimate a VMT breakdown by age group.[64,65] This VMT was used to determine a crash rate by age category for the GES data. Young drivers (age 15–19) had a crash rate 3.7 times higher than middle-age drivers (age 25–54) for all crashes. For AVCs, younger drivers still had a higher crash rate than middle- age drivers (2.1 times as high), but it is clearly not as large an increase as for the typical crash.

It should be noted that although age may not play as much of a role in being involved in a WVC, it does play a role in being injured. As noted previously, Conn and others found that persons between ages 15 and 24 were by far the highest category of emergency room injuries attributed to WVCs.[15]

SUMMARY

This review of the national crash databases showed that AVCs have become more important, in both absolute and relative numbers. The total number of WVCs is increasing at a rate of approximately 6,800 more WVCs per year. Deer populations have also continued to increase in many areas within the United States. The review of reported crashes for large animals showed that WVCs are more commonly or typically as follows:

- On rural, two-lane, low-flow, high-speed roadways.
- During early morning and late evening hours.
- Within spring and fall months.
- Lower-severity crashes (high-severity WVCs are more commonly motorcycle crashes).
- Comparative in proportion of crashes for the younger and medium-age driver categories.
- In locations with high wildlife populations, especially deer.

- With deer (mule deer and white-tailed deer combined).
- In areas with many transitions from cover to more open habitat, riparian habitat, shrub land (for white-tailed deer) and large drainages and known seasonal migration corridors (for mule deer).
- Near forested cover and drainages.
- On dry, straight roadways.
- Single-vehicle collisions.

This review also showed that the availability of consistent and detailed WVC data is limited, the data do not always distinguish between species or species groups, and the data suffer from severe underreporting. Furthermore, reliable WVC data for small or medium size species or threatened or endangered species do not exist on a national level.

CHAPTER 3. ECONOMIC IMPACTS OF WILDLIFE-VEHICLE COLLISIONS

This chapter describes the costs associated with WVCs. It focuses on impacts that can be converted to monetary values. There are other impacts associated with WVCs that may not be easily quantifiable. Nonetheless, the cost estimates that are presented are an important component in justifying potential mitigation measures to reduce WVCs.

METHODS

Western Transportation Institute (WTI) researchers estimated the costs for WVCs in two ways. First, they estimated the costs for the average WVC based on property damage, human injuries and human fatalities. Secondly, they estimated the costs for species-specific WVCs for deer, elk, and moose-vehicle collisions (*Alces alces*). For this second analysis, the parameters included were vehicle repair costs, costs associated with human injuries and fatalities, towing, accident attendance and investigation, the monetary value of the animal that was killed in the collision (based on hunting fees and other recreational values), and the cost of disposal of the animal carcass.

AVERAGE ANIMAL-VEHICLE COLLISION

The total estimated cost of the average AVC based on property damage, human injuries, and human fatalities is $6,126 (table 4). More than 95 percent of all AVCs result in property damage only (table 4), at an average cost over all collisions of $2,451. While human injuries and fatalities occur in less than 5 percent of all collisions, their associated costs per collision are substantially higher, driving up the cost of the average AVC to the $6,126 value.

For the analyses described above, 1994 USDOT estimates of motor vehicle accident costs were used, corrected for the Gross Domestic Product Deflator through the fourth quarter in 2006.[66,67] The 1994 USDOT cost estimates relate to all types of motor vehicle accidents, including, but not exclusively, AVCs. The severity categories for human injuries, including a "possible human injury" are based on police reports at the scene of the accident. The 1994 USDOT cost estimates factor in that some of these "possible human injuries" later show to be injuries indeed, while others are not. The distribution of AVCs across the maximum severity categories is based on the data presented in figure 9 in chapter 2 of this report and specifically relates to AVCs.

Table 4. Estimated costs for property damage, human injuries, and human fatalities for the average AVC.

Maximum Severity	Cost ($)	Distribution of Collisions (%)	Contribution to Cost of Average AVC ($)
Property damage only	2,570	95.37	2,451
Possible human injury	24,418	2.34	572
Evident human injury	46,266	1.75	809
Incapacitating/severe human injury	231,332	0.47	1,083
Human fatality	3,341,468	0.04	1,210
Total		1.00	6,126

DEER-, ELK-, AND MOOSE-VEHICLE COLLISIONS

Based on a review of the literature, the probability that a collision with a deer, elk, or moose would result in property damage, a human injury, and a human fatality was estimated. In addition, estimates were made of the amount of property damage (vehicle repair costs) as a result of a collision with these three species.

The species-specific cost estimates were made using the same base cost estimates and categories for human injuries as in table 4. Since it was not possible to distinguish among the three injury categories when calculating the species-specific probabilities that a collision would result in a human injury, the relative frequency of each of the three injury categories was determined using the values in table 4. This approach produced the following values: 51.4 percent of all human injuries involved possible human injuries, 38.4 percent of all human injuries involved evident human injuries, and 10.3 percent of all human injuries involved incapacitating or severe human injuries.

VEHICLE REPAIR COSTS

In Nova Scotia, the percentage of collisions involving white-tailed deer that resulted in property damage was estimated at 90.2 percent—3,524 collisions with property damage out of 3,905 collisions.[68] In Utah this percentage was estimated at 94 percent.[3] There were no similar data available for elk or moose. For this analysis the percentage of collisions resulting in property damage was assumed to be 92 percent for collisions with deer, 100 percent for collisions with elk, and 100 percent for collisions with moose. Property damage (repair costs for vehicles) has been estimated by a number of studies:

- Romin and Bissonette estimated the value at $1,200 ($1,881 for deer in Utah and Vermont) in 1992.[3]

- In British Columbia, the costs for deer collisions with passenger vehicles were estimated at Can$1,222.[69]

- The cost for deer collisions on average for different regions in the United States in 1993 were estimated at $1,577.[4]

- In New Mexico, the average vehicle repair cost of an elk-vehicle collision was estimated at $3,448, based on seven collisions.[70]

- Vehicle repair costs resulting from a collision with a moose in north central British Columbia can be as high as Can$25,000, but they averaged Can$5,150 in 1999.[71]

- In British Columbia, the estimated average claim for a DVC was Can$1,222 and a moose-vehicle collision was Can$3,358.[69]

- Other studies in British Columbia estimated moose-vehicle collisions at Can$2,200 in 2000 and Can$2,800 in 2001.[68,72]

- An average value of $2,300 was reported for the United States in 2002.[73]

Based on these various values, it was assumed for this analysis that the average vehicle repair costs as a result of AVCs were $2,000 for deer, $3,000 for elk, and $4,000 for moose. Combined with the percentage chance that a collision indeed results in property damage (see earlier), the vehicle repair costs for an average AVC with each species were estimated at $1,840 (deer), $3,000 (elk), and $4,000 (moose).

HUMAN INJURIES

AVCs can cause human injuries. (See references 4, 15, 29, 68, and 74.) In the United States, AVCs were estimated to result in 26,647 human injuries per year (average for 2001–2002).[15] An estimated 22,498 of these human injuries resulted from collisions with larger animals, mostly with deer (86.9 percent). An estimated 12.2 percent were the result of collisions with horses (*Equus* sp.) and bovines (*Bos* sp.). Elk, moose, and bear (*Ursus* sp.) accounted for the remaining 0.8 percent.[15]

The percentage of white-tailed deer-vehicle collisions resulting in human injuries was estimated at 1.3 percent in Finland; 3.8 percent in the U.S. Midwest; 4 percent in Ohio, 4 percent across the U.S., 7.7 percent in Ohio; and 9.7 percent in Nova Scotia. (See references 4, 53, 62, 68, and 75.)

The percentage of moose-vehicle collisions resulting in human injuries was estimated at 9.9 percent in Finland, 11.2 percent in Sweden, 18 percent in Newfoundland and Labrador, 21.8 percent in Newfoundland, 23 percent in Maine (figure 11, chapter 2), 20 percent in rural Alaska, and 23 percent in Anchorage, AK. (See references 68, 75, 76, 77, 78, and 79.) The ratio of moose-vehicle collisions to human injuries was estimated at 1:0.201 in Newfoundland and 1:0.304 in Anchorage, AK.[79,80] The ratios are higher than the percentages, because more than one person may be present in a car, and multiple people may be injured as a result of one collision. For this analysis it was assumed that an AVC resulted in an average of 0.05 human

injuries for deer, 0.10 human injuries for elk, and 0.20 human injuries for moose. When these proportions are combined with the relative frequency for each of the three injury categories (51.4 percent for possible human injuries, 38.4 percent for evident human injuries, and 10.3 percent for incapacitating or severe human injuries), it results in the cost estimates for human injuries by species presented in table 5. The costs of human injuries by species type are $2,702 (deer), $5,403 (elk), and $10,807 (moose) for each collision. Note that the costs in table 4 and table 5 cannot be directly compared. The costs in table 4 are for all AVCs, regardless of the species, while the costs in table 5 relate to specific wildlife species. In addition, for table 4 the chances that a reported AVC results in a human injury are based on GES data (table 8), while for table 5 these chances are based on a species-specific review of the literature.

Table 5. Costs for types of human injuries for the average deer-, elk-, and moose-vehicle collision.

Type of Human Injury	Deer	Elk	Moose
Possible	$627	$1,254	$2,508
Evident	$887	$1,775	$3,550
Incapacitating/severe	$1,187	$2,374	$4,749
Total	$2,702	$5,403	$10,807

HUMAN FATALITIES

While rare, AVCs can cause human fatalities. (See references 4, 13, 68, and 74.) The percentage of white-tailed deer-vehicle collisions resulting in human fatalities was estimated at 0.009 percent in Ohio (14 collisions with human fatalities from 143,016 collisions), 0.029 percent in North America, 0.03 percent in the U.S. Midwest (33 collisions with human fatalities from 125,608 collisions), and 0.05 percent in Nova Scotia (2 collisions with human fatalities from 3,905 collisions).[53,62,68]

White-tailed deer are the most common species involved in fatal WVCs. A study that used data from nine states (Colorado, Georgia, Minnesota, Missouri, North Carolina, Ohio, Pennsylvania, South Carolina, and Wisconsin) showed that 77 percent of these fatal accidents involved white-tailed deer.[13]

The percentage of moose-vehicle collisions resulting in human fatalities was estimated at 0 percent in Anchorage, AK (0 fatalities from 519 collisions), 0.26 percent in Newfoundland (14 fatalities from 5422 collisions), 0.36 percent in Newfoundland (6 collisions with human fatalities from 1662 collisions), 0.45 percent in Newfoundland (3 fatalities from 661 collisions), 0.43 percent in Maine (figure 11, chapter 2); 0.5 percent in Sweden, and 0.50 percent in rural Alaska. (See references 8, 68, 76, 78, 79, and 80.)

For this analysis it was assumed that an AVC resulted in an average of 0.0005 (deer), 0.0020 (elk), and 0.0040 (moose) human fatalities. When these proportions are combined with the cost listed in table 4, it results in a cost estimate for human fatalities of $1,671 (deer), $6,683 (elk), and $13,366 (moose) for each collision. Note that these estimates cannot be directly

compared with those in table 4. The costs in table 4 are for all AVCs, regardless of the species, while the cost estimates in this paragraph relate to specific wildlife species. In addition, for table 4 the chances that a reported AVC results in a human fatality are based on GES data (table 8), while the chances for the cost estimates in this paragraph are based on a species-specific review of the literature.

TOWING, ACCIDENT ATTENDANCE, AND INVESTIGATION

Not all WVCs require the towing of a vehicle and attendance or investigation by medical personnel, fire department personnel, or police. When they do, the cost for these efforts was estimated to vary between Can$100 and 550.[69] Note that the cost for the actual medical assistance is included in the cost estimates for human injuries calculated earlier. For this analysis it was assumed that the cost of towing and accident attendance or investigation is $500, but these services are only required in 25 percent (deer), 75 percent (elk), and 100 percent (moose) of the collisions. These assumptions result in an average cost for towing, accident attendance, and investigation of $125 (deer), $375 (elk), and $500 (moose) per AVC.

MONETARY VALUE OF ANIMALS

Animals usually die immediately or shortly after having been hit by a vehicle. In Michigan, Allen and McCullough estimated that a minimum of 91.5 percent of all white-tailed deer that were hit by a vehicle died at the scene or shortly thereafter.[81] In Newfoundland, 88.5 percent of all moose collisions resulted in the death of the animal (4,800 moose fatalities out of 5,422 collisions). For this analysis, it was assumed that an AVC always resulted in the eventual death of the animal, regardless of the species.

The monetary value of wildlife has many different components, including license fees, costs associated with hunting (e.g., materials, transport, lodging, meals), and recreational wildlife viewing. Hunting license fees in British Columbia were Can$15–125 for deer, Can$25–200 for elk, and Can$25–200 for moose, for residents and non-residents, respectively.[72] The net return to the economy of British Columbia from hunting was estimated at Can$1,270–7,450 for deer, Can$3,250–3,290 for elk, and Can$1,250–1,680 for moose.[72] The total net return to the economy of British Columbia from recreational wildlife viewing was estimated at Can$174,000,000 per year.[72] There were an estimated 681,000 large mammals present in British Columbia, including black bears (*Ursus americanus*), grizzly bears (*Ursus arctos*), caribou (*Rangifer tarandus*), mule deer, and black-tailed deer (*Odocoileus hermionus columbianus*), white-tailed deer, elk, moose, and bighorn sheep (*Ovis canadensis*).[72] From this information, an average value for recreational wildlife viewing per large mammal was estimated at Can$255.

In New Mexico, the minimum estimated income to the state as a result of hunting was estimated at $250 for each deer and $500 for each elk, excluding hunter expenditures and associated economic benefits.[70] In Utah, Romin and Bissonette estimated the economic value of a deer at $1,313 in 1992.[3] Bissonette and Hammer estimated the value of deer in Utah in 1999 at $2,420.[82] Based on this information, it was assumed that the total monetary value of each animal was $2,000 (deer), $3,000 (elk) and $2,000 (moose).

REMOVAL AND DISPOSAL COSTS OF DEER CARCASSES

In Canada, the clean-up, removal, and disposal costs for animal carcasses were estimated at Can$100 for deer, Can$350 for elk, and Can$350 for moose.[72] In Pennsylvania, the average for deer carcass removal and disposal in a certified facility was $30.50 per deer for contractors and $52.46 per deer for the Pennsylvania Department of Transportation in 2003–2004 (Jon Fleming, Pennsylvania Department of Transportation, personal communication). For this analysis, it was assumed that the removal and disposal costs of animal carcasses were $50 (deer), $100 (elk), and $100 (moose).

OTHER COSTS

Examples of costs that are not easily quantifiable and that were excluded from these analyses are the costs associated with emotional distress of people involved in WVCs, the expenses involved with conservation efforts for threatened or endangered species, the costs of the distress of injured animals, the costs associated with the rehabilitation of injured animals, and the cost of cultural values impacted by wounded animals (e.g., native Americans or other groups in society). Wildlife rehabilitators in Connecticut estimated that 36 percent of all reptiles and amphibians, 6 percent of all birds, and 12 percent of all mammals admitted to wildlife rehabilitation centers in Connecticut between 1996 through 2005 suffered from wounds inflicted by vehicles (Laurie Fortin, State of Connecticut, Department of Environmental Protection, personal communication). The total number of individuals (all species groups combined) that suffered from wounds inflicted by vehicles was 896 per year. At an average cost of $150–200 per individual medical examination and treatment (visits to veterinarian, X-rays, medication, etc.), the yearly wildlife rehabilitation costs in Connecticut are estimated at $134,400–179,200 (Laura Simon, Connecticut Wildlife Rehabilitators Association, personal communication).

SUMMARY

The cost of WVCs is summarized in table 6. Bear in mind that this analysis is based on a series of assumptions and estimates that may need to be modified as more and better data become available. A national estimate of vehicle collisions with moose or elk is unavailable. However, based on a total estimate of one million DVCs per year in the United States, the estimated total cost associated with WVCs is calculated to be $8,388,000,000 (per year in the United States). Note that collisions with smaller animal species (smaller than deer) and domesticated species (e.g. livestock) were not included in this calculation.

Table 6. Summary of estimated costs of a WVC for a deer, elk, and moose.

Description	Deer	Elk	Moose
Vehicle repair costs per collision	$1,840	$3,000	$4,000
Human injuries per collision	$2,702	$5,403	$10,807
Human fatalities per collision	$1,671	$6,683	$13,366
Towing, accident attendance and investigation	$125	$375	$500
Monetary value animal per collision	$2,000	$3,000	$2,000
Carcass removal and disposal per collision	$50	$100	$100
Total	$8,388	$18,561	$30,773

CHAPTER 4. IMPACTS TO WILDLIFE

Roads and traffic can negatively affect wildlife in various ways, including habitat loss, reduced habitat quality, reduced habitat connectivity (and associated potential demographic and genetic consequences), and direct road mortality. (See references 83, 84, 85, and 86.) This chapter focuses on the effects of direct road mortality on wildlife only, specifically for threatened and endangered species.

As previously stated, in most cases, an animal that has been hit by a vehicle dies immediately or shortly after the collision. For example, in Michigan, Allen and McCullough estimated that a minimum of 91.5 percent of all white-tailed deer that were hit by a vehicle died at the scene or shortly thereafter.[81] In Newfoundland, 88.5 percent of all moose collisions resulted in the death of the animal (4,800 moose fatalities out of 5,422 collisions). Many different wildlife species representing a wide variety of species groups have been observed as roadkill, sometimes in massive numbers. Seiler provided a review of estimates of the number of road-killed animals.[23] The combined number of road-killed amphibians, birds, ungulates, and other vertebrates runs in the multiple millions per year for most of the countries that were reviewed. In the United States the total number of road-killed vertebrates was estimated at 365 million per year.[87] The number of DVCs in the United States was estimated to exceed 500,000 per year, around 538,000 per year, and greater than 1,000,000 per year.[3,4,45]

The number of WVCs and animal carcasses is often underestimated (as previously discussed in chapter 2); researchers have calculated the underestimation by 10.3 percent, 25 percent, 50 percent, 77.5 percent, and 87.9 percent. (See references 4, 68, 72, and 88.) These estimates for underreporting apply especially to deer, as this species is involved in the vast majority of all reported AVCs or large WVCs in North America; for example, 80 percent in Saskatchewan, and 81.4 percent in Maine.[68,89] Underreporting may have various causes, including infrequent carcass checks, poor visibility of the carcass from the road, mutilation of the carcass by traffic to the point that the species can no longer be identified or that little to none of the carcass remains, decomposition, (illegal) removal by humans other than the data collectors, and scavengers.[90]

While deer are the species of primary interest from a safety perspective, their survival probability is typically not a concern. Species most affected in their population survival probability seem to be species that have relatively low population density, large home ranges, travel long distances, are long lived, and have a relatively low reproduction rate. (See references 85, 91, 92, and 93.)

Roads and traffic can reduce population densities for some species such as different frogs and toads, the western European hedgehog (*Erinaceus europaeus*), and the desert tortoise (*Gopherus agassizii*).[94, 95, 96] For some species, the survival probability of local or regional populations can be impacted too, especially if the species concerned also suffer from other human-related disturbances such as large-scale intensive agriculture and urban sprawl.[97,98] The effect of road mortality on the population viability of a species can not always be separated from other effects associated with roads and traffic, but road mortality is believed to have affected the population survival probability for multiple species representing different species groups: amphibians (moor frog (*Rana arvalis*)), (leopard frog (*Rana pipiens*); spotted salamander (*Ambystoma maculatum*)), reptiles (timber rattlesnakes (*Crotalus horridus*)), (land and large bodies pond

turtles including the box turtle (*Terrapene ornata*)), mammals (western European hedgehog), (Eurasian badger (*Meles meles*)), (otter (*Lutra lutra*)), (ocelot (*Leopardus pardalis*)), (Florida panther (*Felis concolor coryi*)), (Iberian lynx (*Lynx pardinus*)), (Florida Key deer (*Odocoileus virginianus clavium*)). (See references 91, 92, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, and 110.)

THREATENED AND ENDANGERED SPECIES

This section reviews federally listed threatened and endangered animal species in the United States for which direct road mortality is among the major threats to the survival of the species or certain populations of that species. The threatened and endangered species were not reviewed with regard to other effects associated with roads and traffic such as habitat loss, reduced habitat quality, and the barrier effect of transportation infrastructure. Note that the list in this chapter (table 7) has no regulatory status and that it does not replace potential consultation with the appropriate agencies about the impact of road improvement projects on local endangered species. In addition, because the required data were often difficult to access, and since only limited time was available for this effort, the list in this chapter is not necessarily complete.

METHODS

All threatened and endangered animal species (clams, snails, crustaceans, arachnids, insects, fishes, amphibians, reptiles, birds, and mammals) in each of the 50 states and Washington, DC, were combined into one list. If different populations of the same species were listed, they were treated separately.[111] Species (or populations) were identified for which direct road mortality is among the major threats to the survival probability of the species. Species that are aquatic were not reviewed with regard to vehicle collisions. Mortality as a result of collisions with trains and off-road vehicles was also excluded from the review. This review focused solely on the effect of direct mortality resulting from vehicle collisions (e.g., cars and trucks) on paved roads (e.g., asphalt or concrete).

The following sources were used to evaluate whether direct road mortality is a major threat to the survival probability of threatened and endangered species: (1) documents that provided a rationale for the listing of threatened and endangered species (*Federal Register* publications), (2) the 2006 International Union for Conservation of Nature and Natural Resources Red List of Threatened and Endangered Species, (3) other sources, including publications on individual species or species groups and expert opinions (appendix A).[112] If an expert opinion was the sole source of information that direct road mortality is among the major threats to the survival of a certain species, additional quantitative information was sought out on the importance of road mortality before the species was added to table 7. In addition, speculations alone about the potential impact of direct road mortality were not sufficient for a species to be listed in this chapter.

The list presented in this chapter is not necessarily complete because the required information was difficult to access and the time available for this effort was limited. Furthermore, some species have been listed for decades and circumstances have changed or more and better knowledge about the threats to individual species has become available since the original listing documents were published. For these reasons one cannot only rely on the original listing

documents. Other sources have to be included in determining whether the survival probability of a species is substantially impacted by road mortality.

Even though the information available was carefully evaluated, the process of including and excluding species from the species listed in this chapter was at least partially subjective. Because of the diverse and inconsistent nature of the sources and data available, the inclusion or exclusion from the list could not be based on a simple definition. The inclusion or exclusion of the species listed relied, at least to a certain extent, on expert judgment that is open to debate. Furthermore, just as the status of species and circumstances have changed since the original listing documents were published (discussed above), the status and circumstances will continue to change and the list presented in this chapter will become less applicable over time.

RESULTS

For the 21 species listed in table 7, direct road mortality is considered a major threat to the survival of the species. The table includes three amphibian species, seven reptile species, three bird species, and eight mammal species. A brief discussion for each species follows table 7.

Table 7. Threatened and endangered species in the United States for which direct road mortality is among the major threats to the survival probability of the species.[111]

Species Group	Species Name	Sources Justifying the Inclusion of the Species Concerned in this Table		
		Federal Listing Documents	International Union for Conservation of Nature and Natural Resources	Other Source(s)
Amphibians	California tiger salamander (*Ambystoma californiense*), C. CA, S. Barb., Son. county	[113]	[112]	[114,115,116] Dave Johnston, California Department of Fish and Game, California, personal communication
Amphibians	Flatwoods salamander (*Ambystoma cingulatum*)	[117]	[112]	Bruce Means, Coastal Plains Institute and Land Conservancy, Tallahassee, FL, personal communication, John Palis, Palis Environmental Consulting, Jonesboro, IL, personal communication
Amphibians	Houston toad (*Bufo houstonensis*)	Threats not discussed	[112]	[118]
Reptiles	American crocodile (*Crocodylus acutus*)	[119]	Threats not discussed	[120,121]
Reptiles	Desert tortoise (*Gopherus agassizii*), except in Sonoran Desert	[122]	Threats not discussed	(See references 96, 123, 124, and 125.)
Reptiles	Gopher tortoise (*Gopherus polyphemus*), W of Mobile/Tombigbee Rs.	[126]	Threats not discussed	[125,127,128]
Reptiles	Alabama red-bellied turtle (*Pseudemys alabamensis*)	Collisions not listed as a threat	Threats not discussed	[125,129] D. Nelson, Dep. of Biol. Sc., Univ. S. AL, personal communication, Matthew J. Aresco, Nokuse Plantation, Bruce, Florida, personal communication
Reptiles	Bog turtle (Muhlenberg) northern population (*Clemmys muhlenbergii*)	[130]	Threats not discussed	
Reptiles	Copperbelly water snake (*Nerodia erythrogaster neglecta*)	[131]	Not listed	[132]

Table 7. Threatened and endangered species in the United States for which direct road mortality is among the major threats to the survival probability of the species—continued.

Species Group	Species Name	Sources Justifying the Inclusion of the Species Concerned in this Table		
		Federal Listing Documents	International Union for Conservation of Nature and Natural Resources	Other Source(s)
Reptiles	Eastern indigo snake, eastern indigo (*Drymarchon corais couperi*)	Collisions not listed as a threat	Not listed	[133,134,135] Bruce Means, Coastal Plains Institute and Land Conservancy, Tallahassee, FL, personal communication; John Palis, Palis Environmental Consulting, Jonesboro, IL, personal communication
Birds	Audubon's crested caracara (*Polyborus plancus audubonii*), FL pop.	[136]	Threats not discussed	[137]
Birds	Hawaiian goose (*Branta sandvicensis*)	Threats not discussed	[112]	[138] K. Misajon, NPS, personal communication
Birds	Florida scrub jay (*Aphelocoma coerulescens*)	[139]	[112]	[140]
Mammals	Lower Keys marsh rabbit, (*Sylvilagus palustris hefneri*)	Collisions not listed as a threat	Threats not discussed	[141,142]
Mammals	Key deer (*Odocoileus virginianus clavium*)	Threats not discussed	Threats not discussed	[143]
Mammals	Bighorn Sheep, Peninsular CA pop. (*Ovis canadensis*)	[144]	Threats not discussed	
Mammals	San Joaquin kit fox (*Vulpes macrotis mutica*)	Threats not discussed	[112]	[145]
Mammals	Canada lynx (*Lynx canadensis*), lower 48 states	[146]	Collisions not listed as a threat	[147] Alison Michael, U.S. Fish and Wildlife, personal communication; Phil Delphey, U.S. Fish and Wildlife Service, personal communication
Mammals	Ocelot (*Leopardus pardalis*)	Collisions not listed as a threat	Collisions not listed as a threat	[107,148]
Mammals	Florida panther (*Felis concolor coryi*)	Threats not discussed	Collisions not listed as a threat	[149]
Mammals	Red wolf (*Canis rufus*), except where XN	Collisions not listed as a threat	[112]	

Amphibians

The California tiger salamander (*Ambystoma californiense*) is affected by habitat loss due to urbanization and agriculture, unnatural hydrology, predation by nonnative species (bullfrogs, crayfish, various fish species), reduced availability of burrows as a result of rodent control programs, vehicle collisions, reduced food availability through the use of pesticides for mosquito control, hybridization with nonnative tiger salamanders, and storm water road runoff (Dave Johnston, California Department of Fish and Game, CA, personal communication). (See references 112, 113, 114, 115, and 116.)

The flatwoods salamander (*Ambystoma cingulatum*) was listed because of habitat loss and habitat alteration.[117,150] However, direct mortality (road mortality during migration, capture by bait collectors) is also a potential or a major threat to this species (Bruce Means, Coastal Plains Institute and Land Conservancy, Tallahassee, FL, personal communication; John Palis, Palis Environmental Consulting, Jonesboro, IL, personal communication).[112,117] At one location where a substantial population decline has been observed, road mortality was not considered substantial. In this case, habitat loss and habitat degradation (agriculture, silviculture, urbanization, and changes in hydrology, predation by nonnative fish species) are thought to be the primary cause of the decline.[151] Silviculture is the cultivation and management of forest trees or woodlands for producing timber and other wood products.

The Houston toad (*Bufo houstonensis*) is affected by habitat loss and habitat alteration, mostly through urbanization, recreational development, and agriculture.[112,118] However, direct road mortality through increased habitat fragmentation by road construction has also been identified as a major threat to the survival probability of the species.[112,118] Other threats include predation by nonnative species (e.g., Brazil fire ants).[112]

Reptiles

The American crocodile (*Crocodylus acutus*) is affected by changes in hydrology and consequent changes in salinity levels.[121] In addition, direct mortality of adult American crocodiles is considered higher than the population can sustain.[121] Of the deaths recorded between 1971 and 2001, the majority were hit by cars.[119,120,121] Warning signs and fences were installed along the major highways throughout crocodile habitat in south Florida.[119] However, it appears that some or all of the planned underpasses may not have been built (U.S. Highway 1) and that some of the fencing that was installed (State Route 905) was not flush with the ground so that American crocodiles could enter but not exit the right of way. Some of these fence sections have now been removed (Frank Mazzotti, Department of Wildlife Ecology and Conservation, Fort Lauderdale Research and Education Center, Davie, FL, personal communication).

The desert tortoise (figure 22) is affected by habitat loss (agriculture, landfills) and habitat degradation (e.g., through off-road vehicle use, overgrazing, invasive plant species). (See references 96, 123, 152, and 153.) Substantial direct mortality occurs on highways as well as off highways (nonintentional and intentional crushing by off-road vehicle operators, trampling of their burrows by off-road vehicles and livestock, shooting). (See references 96, 122, 123, 124, 125, 152, and 153.) Other mortality causes are disease, drought, mining, wildfires, garbage and

litter, handling by humans, collection by humans, and predation by common ravens (*Corvus corax*). (See references 96, 123, 125, 152, 154, and 155.)



Figure 22. Photo. Desert tortoise (copyright: Marcel Huijser).

The gopher tortoise (*Gopherus polyphemus*) is affected by habitat loss (urbanization, agriculture, silviculture, mining) and habitat degradation (silviculture, fire suppression, nonnative plant species).[126,127,128] Collection by humans and road mortality also affected the species substantially. (See references 125, 126, 127, and 128.) Furthermore, the species is affected by predation, including by nonnative fire ants.[128] Fences and culverts were installed along a section of Highway 63 in Green County, south of Leakesville, MS (Matthew J. Aresco, Nokuse Plantation, Bruce, FL, personal communication; Claiborne Barnwell and Chuck Walters, Mississippi Department of Transportation, personal communication). The aim of the mitigation measures is to reduce gopher tortoise road mortality and to allow for gopher tortoises to cross under the road (Claiborne Barnwell and Chuck Walters, Mississippi Department of Transportation, personal communication) (figure 23). Highway 63 has 24.1 km (15 mi) of road length with gopher tortoise fencing, and, because of the nature of the terrain, there is only one culvert that was specifically designed for the gopher tortoise (between Lucedale and Leakesville, MS) (Chuck Walters, Mississippi Department of Transportation, personal communication). At the site of the culvert, the fence stretches out about 914 m (3,000 ft) to either side of the culvert (Chuck Walters, Mississippi Department of Transportation, personal communication). Some of the fencing was installed as early as 1998, and along those road sections the number of reported road-killed gopher tortoises was reduced from one to two per year to zero (Chuck Walters, Mississippi Department of Transportation, personal communication).



Figure 23. Photo. Fences lead gopher tortoises towards a culvert along Highway 63 in Green County, south of Leakesville, MS (copyright: Chuck Walters, Environmental Division, Mississippi Department of Transportation).

The Alabama red-bellied turtle (*Pseudemys alabamensis*) is affected by egg predation, human disturbance, and road mortality (David Nelson, Department of Biological Sciences, University of South Alabama, personal communication; Matthew J. Aresco, Nokuse Plantation, Bruce, FL, personal communication).[125,129,156] The small population size and low recruitment rates of the species make recovery a difficult process. A weekly road mortality survey along the Mobile Bay Causeway (6.5 mi from Spanish Fort to Mobile, AL) between 2001 and 2004 reported 324 Alabama red-bellied turtle carcasses (David Nelson, Department of Biological Sciences, University of South Alabama, personal communication) (figure 24 and figure 25).[129] In a typical year, 12–15 adult females, most of them with eggs, are found dead on the Mobile Bay Causeway (David Nelson, Department of Biological Sciences, University of South Alabama, personal communication). In addition, several dozen juveniles and a few males are killed by vehicles each year as well (David Nelson, Department of Biological Sciences, University of South Alabama, personal communication).



Figure 24. Photo. A section of the Mobile Bay Causeway that has relatively many road-killed Alabama red-bellied turtles (copyright: Marcel Huijser).



Figure 25. Photo. Road-killed Alabama red-bellied turtle (copyright: Marcel Huijser).

The northern population of the bog turtle (*Clemmys muhlenbergii*) is affected by habitat degradation and fragmentation from agriculture and development, habitat succession due to invasive exotic and native plants, and illegal trade and collecting.[130] In addition, roads

contribute "significantly" to mortality, especially where roads are adjacent to or within wetlands.[130]

The copperbelly water snake (*Nerodia erythrogaster neglecta*) is affected by habitat loss and habitat fragmentation, primarily because of agriculture, drainage and damming of wetlands, coal mining, channelization, damming and diversion of streams and rivers, and residential and commercial development.[131] In addition, predation by pets and vehicle-caused mortality are a concern.[131,132] Traffic mortality may account for mortality of 14–21 percent of the population per year.[132] The species seems especially vulnerable as it frequently crosses overland to different wetland sites.[132]

The eastern indigo snake (*Drymarchon corais couperi*) is affected by habitat loss due to development, collection and commercial trade, intentional killing, vehicular traffic, and residual pesticide exposure.[135,157] In addition, gopher tortoise burrows that are gassed to kill rattlesnakes also unintentionally kill indigo snakes.[157] Bolt reported that road mortality was the highest cause of death in a study where 81 individuals were followed, some for more than three consecutive years.[133] At least 15 of the 38 known mortalities (39 percent) in the field were due to vehicles. In that study, twice as many males were killed on the road as females (M. Rebecca Bolt, The Dynamac Corporation, Kennedy Space Center, FL, personal communication). In another study, of the 31 indigo snakes documented, 5 were found dead on a road (16 percent of total number of individuals followed), accounting for 55 percent of all known mortalities.[134]

Birds

The crested caracara in central Florida (*Polyborus plancus audubonii*) is affected by habitat alteration for agriculture and housing, illegal killing, and vehicle collisions.[136,137] In a 3-year study, 52 percent of all fledgling mortality (14 out of 27 deaths) was caused by vehicle collisions.[137] The crested caracara spends substantial time close to roads as it searches for and feeds on road-killed animals (Dan Smith, Western Transportation Institute, Montana State University, personal communication).

The Hawaiian goose, or nene (*Branta sandvicensis*), is affected by habitat loss, predation by the nonnative small Indian mongoose (*Herpestes auropunctatus*), dogs, and perhaps rats and cats.[112] Poaching and roadkills are also important causes of mortality (Kathleen Misajon, National Park Service, personal communication).[112,138] Road mortality is the most common known cause of mortality in adults.[158] The species may also be affected by diseases and parasites, inbreeding depression, loss of adaptive skills in captive-bred birds, and dietary deficiencies.[112]

Haleakala National Park reported 35 road-killed Hawaiian geese between 1973 and 2006, and Hawai'i Volcanoes National Park reported 33 road-killed Hawaiian geese between 1996 and 2006 (Kathleen Misajon, National Park Service, personal communication). The population size of the Hawaiian goose fluctuated between 140 and 200 between 1996 and 2006 (Kathleen Misajon, National Park Service, personal communication). In Hawai'i Volcanoes National Park, five adult Hawaiian geese have been killed on the road in 2006 between January 1 and August 28, out of a total of 160 individuals (Kathleen Misajon, National Park Service, personal communication).

In Hawai'i Volcanoes National Park, the Hawaiian goose is attracted to roads because of feeding by park visitors, especially around parking areas (Kathleen Misajon, National Park Service, personal communication) (figure 26). This practice habituates the birds to roads and cars, and it encourages them to spend more time on and alongside roads, increasing their exposure to vehicles. Furthermore, some road sections in the park split roosting habitat from feeding habitat. When they have young, Hawaiian geese walk between roosting and feeding sites for 3–4 months and cross the road frequently, mostly at dawn or dusk, with relatively low visibility (Kathleen Misajon, National Park Service, personal communication). Pairs with goslings are basically pedestrian until the goslings fledge at 3–4 months of age.

Permanent warning signs have been installed in known Hawaiian goose kill areas (Kathleen Misajon, National Park Service, personal communication) (figure 27). In addition, temporary warning signs can be installed at new or unexpected locations. Nonetheless, all five individuals that were killed by vehicles between January 1 and August 28, 2006 were within signed crossing zones (Kathleen Misajon, National Park Service, personal communication). There are also indirect effects of roadkills to the Hawaiian goose population. For example, mates are left without partners, often for at least one breeding season, resulting in one less nesting attempt that year (Kathleen Misajon, National Park Service, personal communication). In addition, goslings without one or both parents have substantially reduced survival probability (Kathleen Misajon, National Park Service, personal communication).



Figure 26. Photo. "Do Not Feed Nene" sign (copyright: Hawai'i Volcanoes National Park, National Park Service).

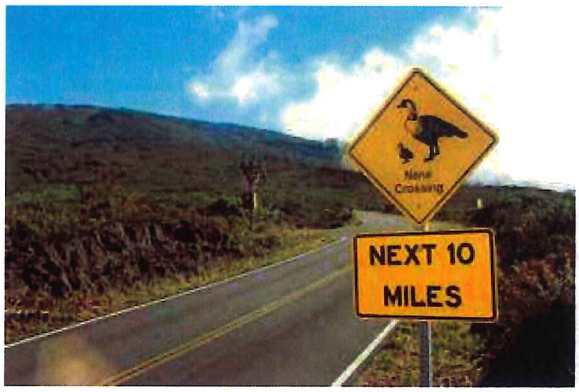


Figure 27. Photo. Hawaiian goose (nene) warning sign (copyright: Haleakala National Park, National Park Service).

The Florida scrub jay (*Aphelocoma coerulescens*) is affected by habitat loss (housing developments, citrus-groves) and reduced habitat quality (disrupted fire regimes, human

disturbance), predation by nonnative species (feral cats) and roadkill. (See references 112, 139, 140, and 159.) Annual mortality rates of the Florida scrub jay have been recorded to be 65 percent higher in road territories compared to nonroad territories.[140] Furthermore, roadside territories are a population sink, and the high mortality rate appears to be caused by vehicle collisions rather than other factors associated with a roadside environment.[140]

Mammals

The Lower Keys marsh rabbit (*Sylvilagus palustris hefneri*) is or has been affected by wetland drainage for residential, commercial and military purposes, habitat destruction associated with road building, hunting, predation by feral house cats, road mortality, mowing practices, and off-road vehicle use.[117,160] In a combination of a field and modeling study, almost one-third of all mortalities were caused by vehicle collisions, and modeling showed that theoretical removal of road mortality would eliminate the chance of extinction for the Big Pine metapopulation.[141] Dispersing subadult males seem especially vulnerable to traffic mortality.[117]

The Florida Key deer (*Odocoileus virginianus clavium*) is affected by vehicle collisions, habitat loss, and human disturbance.[110,143] Vehicle collisions account for more than 50 percent of the total deer mortality, mostly on U.S. Highway 1.[143]

The bighorn sheep, peninsular California population, (*Ovis canadensis*) is affected by a range of issues including disease, low recruitment, habitat loss, habitat degradation, habitat fragmentation, residential and commercial development and high predation rates.[144] This population, especially small groups that have low recruitment, is also threatened by road mortality.[144]

The San Joaquin kit fox (*Vulpes macrotis mutica*) is threatened by habitat conversion (agriculture, urban development, industrial development), habitat fragmentation, loss of prey species (e.g., eradication of prairie dog towns), predation (coyotes, bobcats, nonnative red foxes, and domestic dogs), and vehicle mortality.[112,145,161] In the San Joaquin Valley of California, habitat conversion for agriculture has slowed, but habitat loss, reduction of habitat quality, and habitat fragmentation are still a primary threat. Road mortality varies between studies: 20 out of 225 adult deaths (9 percent), 11 out of 142 juvenile deaths (8 percent), 1 out of 60 deaths (2 percent), 1 out of 22 deaths (5 percent), 2 out of 49 deaths (4 percent), 2 out of 17 deaths (12 percent), 15 out of 23 adult deaths (65 percent), and 6 out of 12 juvenile deaths (50 percent).[145] After predation, vehicle collisions are likely to be the second most common cause of mortality.[145]

Canada lynx (*Lynx canadensis*) is likely impacted by urbanization and forestry practices (including fire suppression) and trapping.[162,163] In addition, its population size fluctuates with the availability of its main prey species, the snowshoe hare (*Lepus americanus*).[163] In the United States, road mortality may limit the reestablishment of the Canada lynx in Wisconsin and Michigan.[146] A total of 218 adult lynx were released between 1999 and 2006, and there were 80 known mortalities as of June 30, 2006.[147] Starvation was a substantial cause of mortality in the first year of the releases only. About 31.3 percent of the known mortalities were human induced (including collisions with vehicles or shooting by humans).[147] Malnutrition and disease or illness accounted for 21.3 percent of the deaths, while 32.5 percent of the deaths were from unknown causes.[147] Closer and more recent analyses showed that road mortality accounted for a

minimum of 44 percent (11 out of 25) of human-caused mortalities (Alison Michael, U.S. Fish and Wildlife, personal communication). This percentage may be higher as this estimate only included confirmed vehicle-caused mortality and excluded suspected vehicle-caused mortality (Alison Michael, U.S. Fish and Wildlife, personal communication). In Maine, 11 road-killed Canada lynx have been reported since 1999; nine on two-lane logging roads that are also accessible to the public and two on paved public roads.[164] Recent data from Minnesota show that Canada lynx have died from shooting, trapping, collisions with trains, and road mortality (Phil Delphey, U.S. Fish and Wildlife Service, personal communication). Road mortality on paved highways amounted to 17 percent (5 out of 30) of all known mortalities since the species was listed in 2000 (Phil Delphey, U.S. Fish and Wildlife Service, personal communication).

The ocelot is affected by habitat loss (loss of dense thorn shrub habitat), mortality vehicle collisions, and genetic erosion.[107,148,165] Vehicle collisions constituted 35 percent of all mortality.[148]

The Florida panther is affected by habitat loss (agriculture, urbanization), habitat fragmentation, road mortality, and loss of genetic diversity .[166,167,168] Road mortality is substantial, 25 out of 73 deaths were caused by vehicles.[149]

The red wolf (*Canis rufus*) went extinct in the wild by 1980 and was reintroduced in 1987 in North Carolina.[112] After reintroduction, the species was affected by hybridization with coyotes (*Canis latrans*) .[112,169,170] Direct mortality (vehicle collisions, shooting) can be substantial.[112]

Other Species

In addition to the species listed in table 7, the authors of this report recognize that other federally threatened and endangered species may be substantially affected by road mortality too. However, species that had insufficient data available, at least to the authors of this report at the time of publication, were excluded from table 7.

Summary

This chapter identified 21 federally listed species from four species groups (amphibians, reptiles, birds and mammals) for which direct road mortality is among the major threats to the survival of the species. However, road mortality is typically only one of the major threats to these species. Habitat loss (e.g., due to agriculture, urbanization, mining, and changes in hydrology), reduced habitat quality (e.g., due to agricultural and silviculture practices such as livestock grazing, logging, fire suppression, introduction of nonnative plant species, and water contamination with pollutants, and the use of pesticides, in general), habitat fragmentation (e.g., due to roads or other unsuitable habitat), competition and predation by nonnative species, other sources of natural and unnatural mortality (e.g., off-road vehicles, poaching, direct killing or collection by humans, disease), and low recruitment and loss of genetic diversity due to small populations also threaten the survival of the species listed in this chapter. This implies that a substantial reduction in road mortality is not necessarily sufficient for the recovery of the species listed in this chapter. For successful species recovery, including mitigation for effects related to roads and traffic, it is advisable to use an integrated approach.[171]

CHAPTER 5. MITIGATION METHODS THAT ATTEMPT TO INFLUENCE DRIVER BEHAVIOR

This broad category of WVC mitigation strategies includes those that attempt to help drivers avoid a WVC by changing their behavior. The specific mitigation measures reported on in this chapter, by broad category based on their intent, consist of the following categories:

- Public information and education.
- Improvement in driver attentiveness using warning signs by:
  - Standard signs.
  - Large, nonstandard signs.
  - Seasonal signs.
  - Animal detection systems.
- Improvement of driver attentiveness with in-vehicle warning systems by:
  - In-vehicle warning linked to roadside animal detection systems.
  - In-vehicle warning linked to on-board animal detectors.
- Increase in visibility to drivers by:
  - Roadway lighting.
  - Vegetation removal.
  - Wider striping.
  - Reflective collars for animals.
  - Reduced height of snow banks.
- Reduction in traffic volumes on roadways by:
  - Reduction in traffic volume on road network.
  - Temporary road closures.
- Reduction of average speeds on roadways by:
  - Reduction of the posted speed limit.
  - Traffic calming/reduction of design speed.
  - Posting of advisory speed limits.
- Wildlife crossing guards.

The mitigation measures presented in the report are what might be considered by planners as possible mitigation measures. FHWA is not recommending any of these measures by including them in this report. The majority of the mitigation measures presented have been used in practice

or at least tried as a case study, the exceptions being in-vehicle roadside animal detection linked to on-board computer warning and reduction in traffic volume on the road network.

PUBLIC INFORMATION AND EDUCATION

Increasing roadway safety via public information and driver education seeks to reduce death and serious injury on roadways by increasing motorists' awareness of the impacts, causes, and high-risk locations of WVCs, as well as to give drivers advice on the best actions to take to avoid crashes with animals. These WVC reduction efforts are implemented through general messages in the media, videos, brochures, posters, and bumper stickers. Often these activities work in concert with roadside messages at specific high-risk locations or in specific seasons of high wildlife migration or movement. Public information and driver education efforts are thought to work best when conducted in concert with other WVC reduction techniques.[172,173]

The most common WVCs in the United States involve deer. DVC education and information efforts can be divided into two categories. In one category are efforts that provide information describing DVC significance, such as the local rates of DVCs or locations of roadway segments with high rates of DVCs. In the second category are efforts that provide information on DVC avoidance, namely, actions drivers can take to avoid wildlife if they appear on or near the roadway.[53]

Many transportation professionals and researchers have discussed driver education and public information campaigns as a means to help reduce WVCs or have conducted research to incorporate their findings into motorist education efforts. (See references 29, 38, 70, 174, 175, and 176.) However, there are no known studies indicating the statistical effectiveness of driver education or public information/awareness efforts that have directly, by themselves, decreased the incidence rates of WVCs.[176]

A national phone survey indicated driver respondents believe WVCs are a serious problem, and more than 97 percent believe driver education and media information to the general public would be helpful in reducing WVCs.[175] Respondents to a survey in Michigan (1,653 questionnaires) are receptive to receiving more information on what actions to take to reduce their probability of being involved in a WVC. They indicated newspapers as the preferred medium, although they also chose eight other avenues of receiving information.[177] In British Columbia a survey of 1,882 licensed drivers indicates respondents strongly (81 percent) believe wildlife warning signs reduce WVCs.[178]

Public information and driver education, combined with other WVC reduction activities must work in concert to effectively reduce crashes and increase safety. Given a receptive audience for information, campaigns have great potential to tap into a public that seeks to more fully understand the dangers of WVCs, the actions drivers can take to avoid accidents, and the locations of high-risk roadways.

Many states have developed safety campaigns to increase public awareness. For example, the Maine Department of Transportation's Safety Office has a public information campaign to increase awareness of WVCs. They have developed a video, brochures, and crash maps for moose and deer at: http://www.maine.gov/mdot/safetyoffice/maine-crash-data.php (accessed

January 25, 2007). The Iowa Departments of Transportation, Public Safety, and Natural Resources in conjunction with insurance agencies and local law enforcement have developed the "Don't Veer for Deer" campaign. Public information maps, brochures, Public Service Announcements, and a poster can be found at http://www.dps.state.ia.us/commis/gtsb/deercrashes/index.shtml (accessed January 25, 2007).

The "Colorado Wildlife on the Move" Campaign reached more than three million people through television, magazines, and other media and included 58,000 driver safety tip sheets and 500 posters distributed in welcome centers, national parks, and Enterprise Rent-A-Car offices in 85 cities and 175 locations.(179)

As a result of a local outreach campaign in Montana, survey respondents who had heard or seen information on WVCs increased from 21 to 33 percent.(173)

Case Studies and Contacts

Two relevant case studies relating to public information and education are the "Drivers for Wildlife" program in Jasper National Park and the program to reduce bird collisions at the NASA Kennedy Space Center.

The Parks Canada Drivers for Wildlife program in Jasper National Park combines public education, which includes bumper stickers (see figure 28) and roadway billboards (see figure 29, with two digital signs that record speed and advise drivers to slow down in the high-risk wildlife zone. The number of road-killed animals along park highways decreased by about 15 percent after the first 10 months of the public education and roadside sign program; however, the signs were given the most credit for the reduction of WVCs.(172)

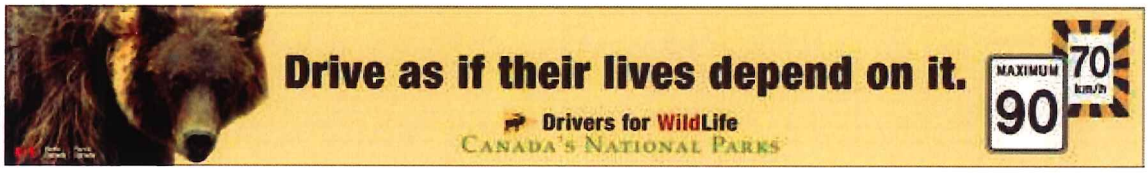


Figure 28. Photo. Example of bumper sticker for a driver awareness campaign to reduce WVCs in Jasper National Park, Canada (source: Parks Canada).

For information about Jasper National Park's campaign, contact Brenda Shepherd, Park Ecologist, Jasper National Park, (780) 852-6232, brenda.shepherd@pc.gc.ca.

In July of 2005, the space shuttle Discovery hit a vulture during take-off. Initially NASA formed an "Avian Abatement Team" to address this safety issue. The program has been expanded to include prevention of roadkill (which attracts the birds) in concert with the Merritt Island National Wildlife Refuge, which is a 140,000-acre overlay of the Kennedy Space Center. The refuge provides a buffer zone for NASA.



Figure 29. Photo. Roadside billboard along highway in Jasper National Park, Canada (source: Parks Canada).

The Kennedy Space Center has developed a Web site with a video, materials, posters (see figure 30), stickers and updates on the latest roadkill statistics at: http://environmental.ksc.nasa.gov/projects/roadkill.htm (accessed January 25, 2007).

The Web site includes a link to the FHWA's Critter Crossings Web site at: http://www.fhwa.dot.gov/environment/wildlifecrossings/index.htm (accessed January 25, 2007).

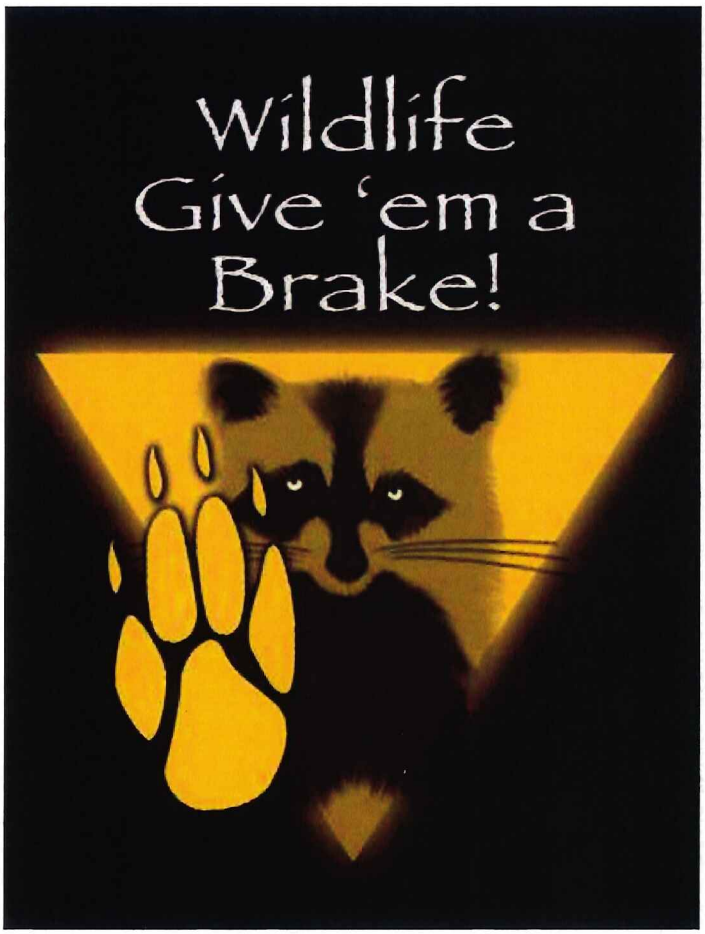


Figure 30. Photo. Poster created by NASA's John F. Kennedy Space Center as part of its RoadKill Prevention Program (source: NASA).

Direct Benefits

The Iowa Department of Transportation's Don't Veer for Deer campaign appears to be demonstrating benefits. Since implementation of this program the number of fatalities resulting from deer-car collisions dropped 60 percent in 2005, from 10 in 2003 to 4 in 2005, according to their Web site (http://www.dps.state.ia.us/commis/pib/Releases/2006/10-05-2006_Deer.htm).[180] The long-term effect requires further study.

The reduction in severity (i.e., number of fatalities) is a positive benefit, but no campaigns identified the direct level of correlation between public information and driver education efforts and the reduction of WVCs.

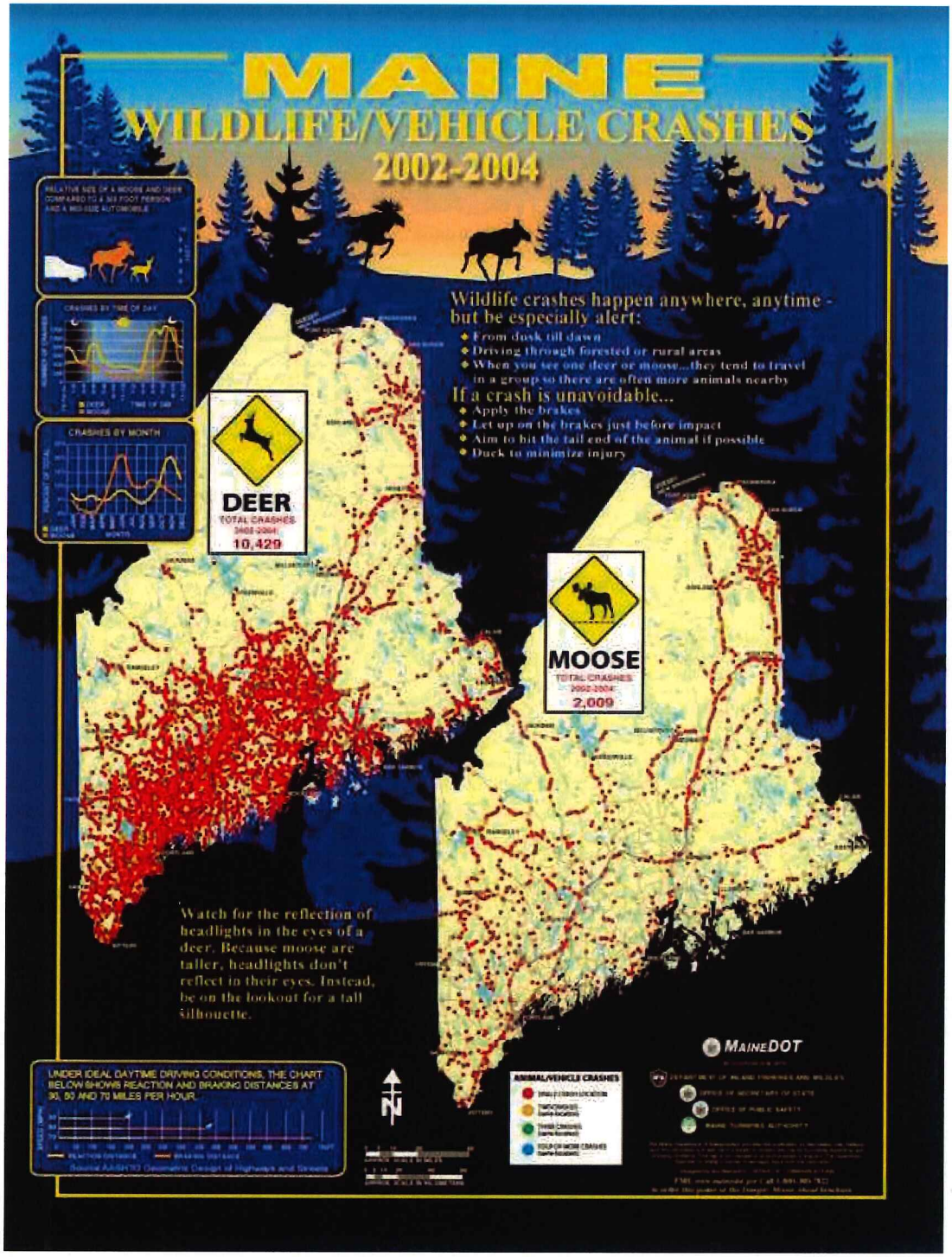


Figure 31. Photo. Poster produced by the Maine Department of Transportation (source: Maine Department of Transportation).

Indirect Benefits

Many driver education and public information campaigns summarize and display crash data maps related to WVCs. This spatial information can also be used for focusing limited resources to roadside mitigation methods for the most problematic areas within a state, county, or metropolitan area.

Undesirable Effects

No undesirable effects were identified in the literature review.

Costs

For statewide public information campaigns, costs were low compared to other mitigation methods. Maine has spent about $6,500 for its moose and deer crash maps and moose safety brochures. This investment provided an adequate outreach supply to last for about three years (Duane Brunell, Maine Department of Transportation, personal communication). In Colorado, the "Wildlife on the Move" Campaign cost $16,335. Most expenses were in two categories: (1) printing of publications (a little more than $10,000) and (2) contract labor for outreach (a little more than $4,500) (Monique DiGiorgio, Southern Rockies Ecosystem Project, personal communication). Costs for the Don't Veer for Deer campaign in Iowa were negligible (Michael Pawlovich, Iowa Department of Transportation, personal comment).

Guidelines

Given that drivers are open to receiving more educational information to help reduce WVCs, it may be most cost effective to focus driver education and public information efforts toward 18- to 45-year-olds, as they are involved in the highest numbers of AVCs (see figure 32). In a study in Kent County, MI, registered drivers between the ages of 30 and 39 had the highest number of DVCs.[181] If public campaigns or local education programs can be focused for specific age groups, 30- to 45-year-olds should be targeted. Note that figure 32 also suggests that drivers do not benefit from driving experience where AVCs are concerned. Campaigns directed at younger drivers, who have higher AVC crash rates, may also be studied.

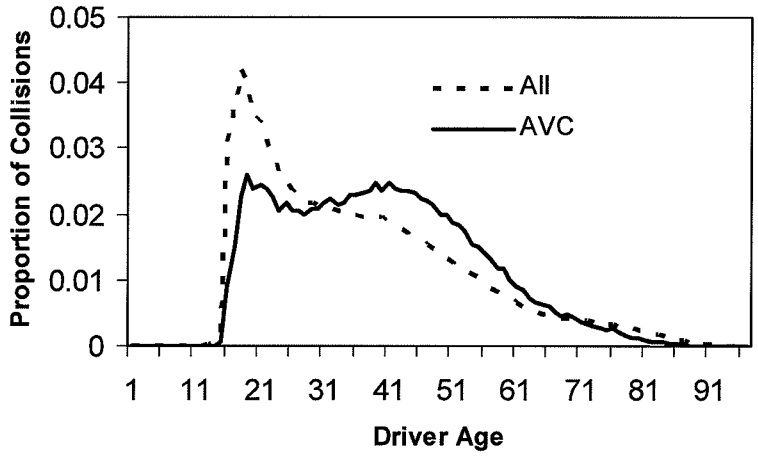


Figure 32. Graph. Driver age distribution for all crashes and AVCs (HSIS data).

ROADWAY WARNING SIGNS

Roadway wildlife warning signs are perhaps the most commonly applied WVC mitigation measure.[85,182] The signs alert the drivers to the potential presence of wildlife on or near the road and urge them to be more alert, to reduce the speed of their vehicle, or a combination of both. These signs attempt to prevent a collision or to reduce the severity of a collision if one does occur by lowering vehicle speeds at impact (figure 33).

Since the effectiveness of warning signs depends on driver response, it is critical that warning signs are reliable (i.e., the driver is warned when there is a high chance of WVC). The warning signs discussed below (standard warning signs, large or enhanced warning signs, seasonal wildlife warning signs, and animal detection systems) should be placed in road sections that exceed a certain minimum risk of WVC. The current location selection process can typically be improved upon.[53,183,184] Seasonal wildlife warning signs need to be in place during those periods of the year that animals cross the road most frequently. Animal detection systems (if used) need to be connected to reliable sensors used for the detection of large animals on or near the road.

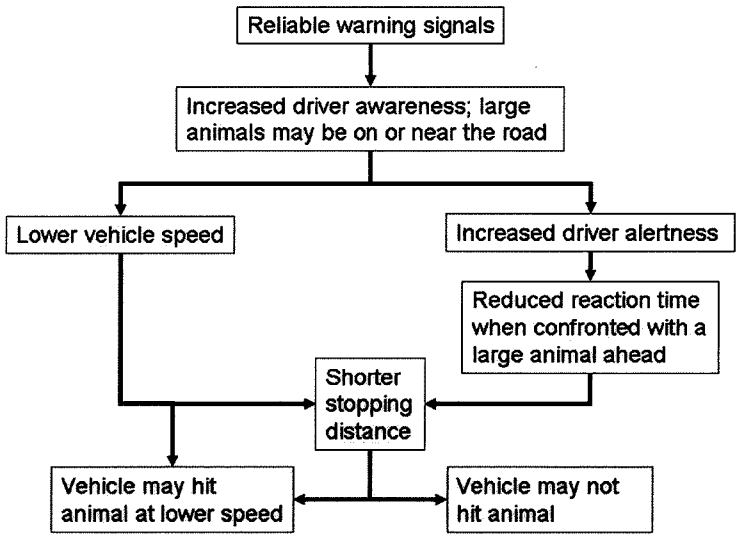


Figure 33. Flow chart. Warning signs and driver response.

Driver awareness and response are influenced by the type of warning sign.[185,186,187] Large and graphic signs, flags attached to wildlife warning signs, permanently flashing lights on top of or around wildlife warning signs, and messages displayed on variable message signs are designed to attract the attention of the driver and invoke response to a greater extent than standard wildlife warning signs. Seasonal wildlife warning signs are designed to deliver a more time specific warning message to drivers; they are only displayed during certain times of the year when the risk is much higher, for example during the seasonal migration of certain species. Animal detection systems are even more time specific in their operation; the warning signals are only activated after a large animal has been detected on or near the road.

Driver response is split into two components: increased alertness and lower vehicle speed. Increased alertness can lead to a reduction in driver reaction time. Driver reaction time to an unusual and unexpected event can be reduced from 1.5 s to 0.7 s if drivers are warned.[188] Assuming a constant vehicle speed of 88 km/h (55 mi/h) before and after warning signals have been presented to a driver, increased driver alertness could reduce the stopping distance of the vehicle by 21 m (68 ft). This reduction in reaction time and stopping distance, however, has not been specifically tested with respect to the presence of large animals in rural areas, let alone for warning signals that may apply to road sections of many miles rather than a point or short road section. Lower vehicle speed allows for more reaction time, and should a collision still happen, it is likely to be less severe.[189] At relatively high speed even small reductions in vehicle speed matter because the relation between vehicle speed and the risk of a severe accident is exponential; small reductions in vehicle speed result in a disproportionate decrease in the risk of a severe accident.[189]

STANDARD WILDLIFE WARNING SIGNS

The standard deer warning sign in the United States is a diamond-shaped panel with a black deer symbol on a yellow background, sometimes accompanied by text signs that indicate the length of the road section to which the sign applies (figure 34).



Figure 34. Photo. Standard deer warning sign along Montana Highway 83 (copyright: Marcel Huijser, WTI).

Meyer investigated the effectiveness of standard deer warning signs in Kansas by comparing the accident data before and after sign installation.[190] After taking all available accident data before sign installation and other road and landscape parameters into consideration, there was no evidence that the presence of the deer warning signs had resulted in fewer DVCs.[190] Rogers also concluded that the number of DVCs had not reduced as the result of the installation of deer warning signs.[38] Furthermore, the installation of standard camel crossing signs in Saudi Arabia did not result in reduced vehicle speed.[191] Finally, in a driving simulator study, a standard deer warning sign resulted in an average vehicle speed of 123.2 km/h (76.6 mi/h), just over the posted speed limit of 120.7 km/h (75 mi/h).[192] This result shows that a standard deer warning sign was unable to reduce the average vehicle speed to the posted speed limit or lower.

Case Studies and Contacts

For information about the study on the effectiveness of deer warning signs in Kansas, contact: Eric Meyer, University of Kansas, Civil, Environmental & Architectural Engineering Department, 1530 West 15th Street, Room 2150, Lawrence, KS 66045-7609 (he is currently affiliated with Meyer Intelligent Transportation Services, (785) 843-2718, emeyer@insighthawks.com).

Direct Benefits

Based on the available data, standard deer warning signs are concluded to be ineffective in reducing WVCs, in general, and DVCs, in specific.

Most authors doubt the effectiveness of standard warning signs, but only two studies were found that had investigated the effectiveness, confirming the existing doubts. (See references 9, 38, 58, 182, 185, 190, and 193.)

Indirect Benefits

No indirect benefits were identified in the literature review.

Undesirable Effects

As a general rule, unnecessary signs should be removed as they may distract drivers and require maintenance. However, standard warning signs may be required to reduce liability in case of WVCs.[194]

Costs

One study estimated costs at $94 (note not adjusted for inflation) per sign.[185] USA Traffic Signs reports the following costs: $55 (61 by 61 cm (24 by 24 inches)), $62 (76 by 76 cm (30 by 30 inches)), $85 (91 by 91 cm (36 by 36 inches)).[195]

Guidelines

The *Manual on Uniform Traffic Control Devices* (MUTCD) provides guidance on animal warning signs. The standard warning sign (figure 34) is known as W11-3. The MUTCD is very specific in the sign dimensions, colors, etc. However, the manual only provides general guidance on when to use these signs:

> "Nonvehicular signs [this includes animal warning signs] may be used to alert road users in advance of locations where unexpected entries into the roadway or shared use of the roadway by pedestrians, animals, and other crossing activities might occur."[196]

See Knapp and Yi for a discussion on guidelines for the installation of standard deer warning signs.[183]

LARGE, NONSTANDARD WILDLIFE WARNING SIGNS

Large or enhanced animal warning signs may take many forms. They can be larger than the standard wildlife warning signs, include graphic images of a vehicle hitting wildlife, and have permanently activated flashing amber warning lights, light emitting diodes (LEDs), or red flags attached to the signs (figure 35 and figure 36).

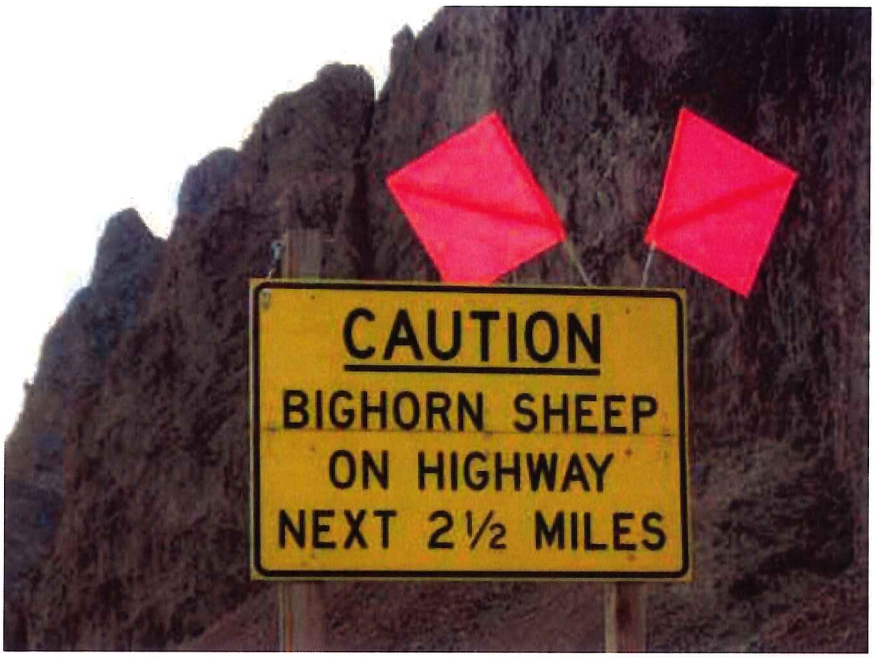


Figure 35. Photo. Large enhanced warning sign for bighorn sheep along State Highway 75 in Idaho (copyright: Marcel Huijser, WTI).

Lighted animated deer crossing signs reduced vehicle speed by 4.8 km/h (3.0 mi/h) compared to the same signs when they were turned off.[185] The presence of deer carcasses as a "supplement" to the signs resulted in a much greater reduction in vehicle speed: 12.6 km/h (7.9 mi/h) (lights turned off) and 10.0 km/h (6.2 mi/h) (lights turned on).[185] Despite the successful speed reduction of the lighted animated signs, they did not result in a reduction of DVCs.[185]

Hammond and Wade conducted an experiment in a driving simulator and exposed drivers to standard deer warning signs and enhanced deer warning signs that had a flashing light on top of a standard deer warning sign.[187] The average vehicle speed with standard deer warning signs was 99.6 km/h (61.87 mi/h) (SD = 5.16). The enhanced sign with the lights turned off resulted in similar speeds of 99.5 km/h (61.80 mi/h) (SD = 4.80), but the enhanced sign with the lights turned on resulted in significantly lower vehicle speed of 95.9 km/h (59.55 mi/h) (SD = 4.66), a reduction of 3.7 km/h (2.32 mi/h).[187]

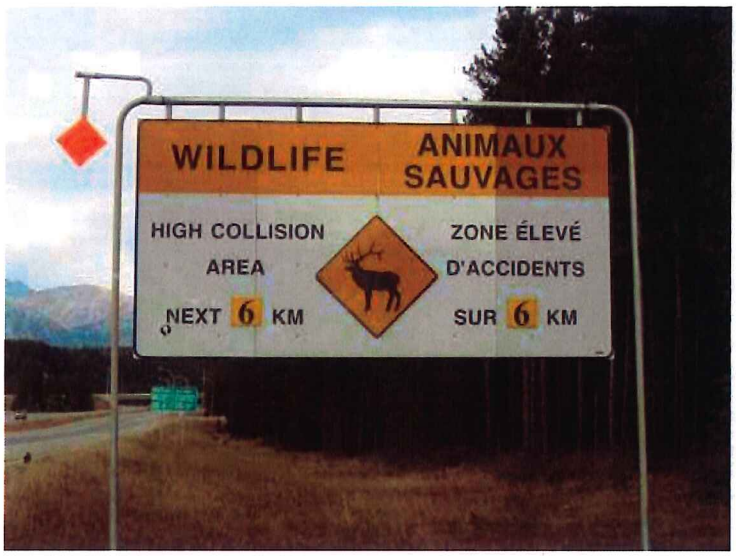


Figure 36. Photo. Large enhanced elk warning sign along the Trans-Canada Highway in Banff National Park, Canada (copyright: Marcel Huijser, WTI).

Enhanced camel warning signs in Saudi Arabia resulted in a significant reduction of vehicle speed whereas standard camel warning signs did not.[191] The standard warning signs were triangular where all sides were 110 cm (43 inches), with a red border and white interior with black camel silhouette, and did not have diamond reflective material. The enhanced signs were signs that were larger than the standard warning signs, had diamond reflective material, had a yellow camel on a black background, and/or were accompanied by the text message "camel-crossing" and a reduced advisory speed limit. The enhanced signs reduced vehicle speed by 3–7 km/h (2–4 mi/h).[191]

Hardy and others found that wildlife advisory messages posted on permanent and portable dynamic message signs (DMS) can reduce vehicle speeds.[173] The greatest effect occurred during "dark" conditions, when the number of AVCs is higher.

Stanley and others conducted experiments with a driving simulator and found that enhanced wildlife warning signs resulted in lower vehicle speeds and earlier braking when drivers were confronted with a deer in the simulated environment.[192]

Case Studies and Contacts

For information about a driving simulator study with enhanced deer warning signs, contact Curtis Hammond and Michael G. Wade, University of Minnesota, Division of Kinesiology, 1900 University Ave SE, Minneapolis, MN 55455; (612) 625-2051, chammond@umn.edu; (612) 626-2094, mwade@umn.edu.

For more information about a field test with enhanced camel warning signs in Saudi Arabia, contact Ali Al-Ghamdi and Saad AlGadhi, Civil Engineering Department, College of

Engineering, King Saud University, P.O. Box 800, Riyadh 11421, Saudi Arabia, +966-1-4677019, (fax +966-1-4673366), asghamdi@ksu.edu.sa.

For information about wildlife advisory messages posted on permanent and portable DMS, contact Amanda Hardy, Western Transportation Institute, (406) 994-2322, ahardy@coe.montana.edu.

For information about a driving simulator study with enhanced deer warning signs, contact Laura Stanley, Virginia Polytechnic Institute & State University, Blacksburg, VA 24060, (540) 808-5140, lstanley@vtti.vt.edu.

Direct Benefits

The only study identified that directly looked at sign impact on WVCs, rather than the impact on driver response, suggests that large or enhanced wildlife warning signs are not effective in reducing WVCs in general or DVCs specifically.[185] Nonetheless, the observed reduction in vehicle speed (3–7 km/h (2–4 mi/h)) suggests that the signs may be somewhat effective after all, perhaps reducing the severity of the crash in terms of property damage, human injuries and human fatalities. Only limited data are available on this subject.

Indirect Benefits

No indirect benefits were identified in the literature review.

Undesirable Effects

Uniform warning signs across the United States are desirable so that drivers learn and understand what different signs represent (known as "driver expectancy"). While nonstandard signs may draw attention, a potential downside is that it takes drivers longer to interpret the sign, simply because it is nonstandard.

Costs

One cost estimate reported in the literature was $2,000 (note: not adjusted for inflation) per sign.[185]

Guidelines

It should be noted that many nonstandard animal warning signs deviate from the MUTCD. Although some states have adopted alternative signs into their state manual on traffic control, care should be taken when the MUTCD is not followed exactly. It may degrade driver expectancy and could open the State DOT to liability issues.

See Knapp and Yi for a discussion of guidelines for the installation of nonstandard deer warning signs.[183]

SEASONAL WILDLIFE WARNING SIGNS

Seasonal wildlife warning signs are only present at certain times of the year when animals cross the road most frequently, such as during a seasonal migration (figure 37).



Figure 37. Photo. Seasonal deer migration sign in Utah (copyright: Marcel Huijser).

Sullivan and others erected temporary warning signs with (1) reflective flags and (2) permanently flashing amber lights in locations that were known to be used by mule deer (*Odocoileus hemionus*) during their seasonal migration.[43] The number of DVCs was reduced by 51 percent (range 41.5–58.6 percent for individual test areas) compared to control areas. The signs reduced the percentage of speeders from 19 percent to 8 percent during their first season of operation, but the effect was less pronounced in the second season, perhaps due to driver habituation.[43]

Rogers investigated the effect of enhanced deer warning signs (black on yellow sign showing a deer and a car symbol, combined with a black on orange sign stating "HIGH CRASH AREA") on the number of DVCs.[38] The signs were deployed between October and January (the peak of DVCs) for three consecutive years. Rogers found no effect of the seasonal signs on the number of DVCs.[38]

Case Studies and Contacts

For information about a field study on the effectiveness of seasonal warning signs in Utah, Nevada and Idaho, contact Todd L. Sullivan, Jack H. Berry Institute, Department of Forest, Range and Wildlife Sciences, Utah State University, Logan, UT. (Current address: USDA/APHIS Wildlife Services, 5107 Austin Ellipse, Moody Air Force Base, GA 31699).

Direct Benefits

Seasonal deer warning signs may reduce DVCs; however, more studies on their effectiveness are required.

Indirect Benefits

No indirect benefits were identified in the literature review.

Undesirable Effects

The signs reportedly are subject to vandalism and theft.[43]

Costs

Sullivan and others reported a cost of $268 per 1,609 m ($435 per mi).[43]

Guidelines

See Knapp and Yi for a discussion of guidelines for the installation of seasonal deer warning signs.[183]

ANIMAL DETECTION SYSTEMS

Animal detection systems use sensors to detect large animals that approach the road. Once a large animal is detected, warning signals are activated to inform the drivers that a large animal may be on or near the road at that time (figure 38). The warning signals are extremely time specific. Huijser and others listed more than 30 locations in North America and Europe that have had an animal detection system installed, and they describe the experiences with installation, operation and maintenance, reliability, and effectiveness.[197] Since August 2007, a number of additional locations were equipped with an animal detection system, including along SR 260 near Payson, AZ (David Bryson, Electrobraid Fence Ltd., personal communication; Norris Dodd, Arizona Game and Fish Department, personal communication). An animal detection system combined with electric fencing was used at these locations.



Figure 38. Photo. Animal detection system along Highway 191 in Yellowstone National Park, MT (copyright: Marcel Huijser, WTI).

Two broad categories are commonly used in animal detection systems: area-cover systems and break-the-beam systems. Area-cover systems detect large animals within a certain range of a sensor. Area-cover systems can be passive or active. Passive systems detect animals by only receiving signals. The two most common systems are passive infrared and video detection. These systems require algorithms that distinguish between, e.g., moving vehicles with warm engines and moving pockets of hot air and movements of large animals. Active systems send a signal over an area and measure its reflection. The primary active area-cover system is microwave radar. Break-the-beam sensors detect large animals when their body blocks or reduces a beam of infrared, laser, or microwave radio signals sent by a transmitter to a receiver. Other less common detection systems include a system that depends on radio-collared animals and receivers placed in the right of way, and a system that uses seismic sensors to detect vibrations in the soil as large

animals approach.[197] Most of these systems have or had problems with the reliability of the sensors, although some of the manufacturers seem to have overcome these problems.[197]

The effectiveness of animal detection systems has been investigated with regard to a potential reduction in vehicle speed and a potential reduction in AVCs. Once a driver is aware that a large animal may be on or near the road ahead, the driver may lower the speed of the vehicle. Previous studies have shown variable results: substantial decreases in vehicle speed (greater than or equal to 5 km/h (3.1 mi/h)), minor decreases in vehicle speed (less than 5 km/h (3.1 mi/h)), and no decrease or even an increase in vehicle speed. (See references 42, 187, 198, 199, 200, and 201.) This variability of the results appears to be related to various conditions, namely, type of warning signal and signs, whether the warning signs are accompanied with advisory or mandatory speed limit reductions, road and weather conditions, whether the driver is a local resident, and perhaps also cultural differences that may cause drivers to respond differently to warning signals in different regions.[197]

Kistler, Romer and Mosler-Berger, and Mosler-Berger and Romer have reported on the number of AVCs before and after seven infrared area-cover detection systems were installed in Switzerland (table 8). (See references 198, 202, 203, and 204.) These systems reduced the number of AVCs by 82 percent on average (1-sided Wilcoxon matched-pairs signed-ranks test, $P = 0.008$, $n = 7$).[197] All seven sites showed a reduction in collisions after an animal detection system was installed, and three of the seven sites did not have a single collision after system installation (as of 6–7 years after installation). The data relate to collisions with roe deer (*Capreolus capreolus*) and red deer (*Cervus elaphus*), and collisions that occurred during the day when the systems were not active were excluded from the analyses.

While the data on the effectiveness of animal detection systems are encouraging, animal detection systems should still be regarded as an experimental mitigation measure rather than a measure that will reduce WVCs on short term with a high degree of certainty.[197]

Table 8. Collisions with large animals before and after detection system installation in Switzerland.

	Before Installation			After Installation			Reduction	
Location	Coll. (*N*)	Yrs.	Coll./ yr	Coll. (*N*)	Yrs.	Coll./yr	Coll./yr	%
Warth	14	7	2.00	3	10	0.30	1.70	85.00
Soolsteg	8	11	0.73	1	6	0.17	0.56	77.08
Val Maliens	7	3	2.33	6	5	1.20	1.13	48.57
Marcau	12	4	3.00	6	5	1.20	1.80	60.00
Schafrein	26	8	3.25	0	6	0.00	3.25	100.00
Duftbächli	18	8	2.25	0	6	0.00	2.25	100.00
Grünenwald	6	8	0.75	0	7	0.00	0.75	100.00
Average Reduction								**81.52**

Case Studies and Contacts

For a general overview of technology, reliability and effectiveness, contact Marcel Huijser, Western Transportation Institute, P.O. Box 174250, Bozeman, MT 59717-4250, (406) 543-2377, mhuijser@coe.montana.edu.

For information about a field study on the effectiveness of animal detection systems, contact Christa Mosler-Berger, Wildtier Schweiz, Strickhofstrasse 39, 8057 Zürich, Switzerland, wild@wild.unizh.ch.

For more information about the animal detection system and wildlife fencing along State Route 260 in Arizona, contact Norris Dodd, Wildlife Research Biologist, Arizona Game and Fish Department, Research Branch, P.O. Box 2326, Pinetop, AZ 85935, (928) 368-5675, doddnbenda@cybertails.com.

Manufacturer: Terry Wilson, Sensor Technologies and Systems, Inc., 8900 East Chaparral Road Scottsdale, AZ 85250, (480) 483-1997, (fax (480) 483-2011), terry_wilson@sensor-tech.com, http://www.sensor-tech.com/ (accessed January 25, 2007).

Manufacturer: Calonder Energy AG's representative in USA: Willy Bärchtold, Swiss Army Vehicles, 1436 Van Asche Drive, Fayetteville, AR 72704, (479) 521-0056, cars@sav.ms.

Direct Benefits

The only available data on the effectiveness of animal detection systems show a reduction in collisions with large animals of 82 percent.[197] This percentage may change as more data become available.

Indirect Benefits

Animal detection systems do not restrict animal movements when deployed over long distances.

Undesirable Effects

Animal detection systems can reduce collisions with large animals, but the presence of poles and equipment in the right of way is a potential hazard to vehicles that run off the road.[197]

Costs

Estimated costs of these systems are $40,000–96,000 per km ($65,000–154,000 per mi) (excluding installation costs) (unpublished data, Marcel Huijser, Western Transportation Institute, Montana State University).[197] The costs for the equipment will be higher if the road section concerned has curves or slopes, or if the line of sight in the right of way is blocked by objects.

Guidelines

It should be noted that many animal detection systems use signs that deviate from the MUTCD. Some states have adopted alternative signs into their state manual on traffic control. Care should be taken when the MUTCD is not followed exactly. It may degrade driver expectancy and could open the State DOT to liability issues.

See Huijser and others for considerations for planning and design.[197]

IN-VEHICLE WARNINGS: ROADSIDE ANIMAL DETECTION SYSTEM LINKED TO ON-BOARD COMPUTER WARNING SYSTEM

The concept of an animal detection system that is linked to an on-board computer warning system is described in Huijser and others.[197] The technology would be designed to warn a driver through a warning signal inside the vehicle that an animal is on or near the roadway within a certain distance from the vehicle. This technology is not currently deployed. This information should be provided just before drivers get to the area covered by the animal detection system. Road signs and highway advisory radio messages are the most obvious ways to deliver this information to the driver. When approaching the animal detection system, a driver may be confronted with an activated warning signal indicating that a large animal has been detected and is present on or near the road at that time. In the future the information about the purpose and the location of the animal detection system may also be delivered to an on-board computer inside the vehicle. This procedure would require a two-way GPS-based communication system. The most essential part of the concept is that the warning signal from the animal detection system is delivered to the on-board computer as soon as the vehicle gets within a certain radius of the animal detection system and if a large animal has been detected.

Case Studies and Contacts

No case studies and contacts are available, as this technology has not yet been deployed.

Direct Benefits

This mitigation measure has not been specifically investigated. However, the effectiveness can be expected to be similar to that of animal detection systems, i.e., 82 percent reduction in collisions with large animals.[197] This percentage is likely to change as data become available.

Indirect Benefits

Animal detection systems do not restrict animal movements when deployed over long distances.

Undesirable Effects

Animal detection systems can reduce collisions with large animals, but the presence of poles and equipment in the right of way is a potential hazard to vehicles that run off the road.[197]

Costs

Estimated costs for these systems are $40,000–96,000 per km ($65,000–154,000 per mi) (excluding installation costs), plus additional costs for the on-board computer and communication system (Marcel Huijser, unpublished data, Western Transportation Institute, Montana State University).[197] The costs for the equipment will be higher if the road section concerned has curves or slopes, or if the line of sight in the right of way is blocked by objects.

Guidelines

See Huijser and others for considerations for planning and design.[197]

IN-VEHICLE WARNINGS: ON-BOARD ANIMAL DETECTORS

On-board animal detectors (typically infrared detectors) inform drivers when a large animal (or human being) is detected within a certain range from the sensors attached to the vehicle. (See references 205, 206, 207, and 208.) The range should be sufficient to allow for the driver to stop the vehicle before impacting the detected animal. The system could potentially detect large animals anywhere; it would not depend on the installation of any roadside equipment. However, it is uncertain whether these on-board detectors are still in production.

Case Studies and Contacts

For design concept, contact Masaki Hirota, Nissan Motor Co., Ltd., 1 Natsushima-cho, Yokosuka Kanagawa 237-8523, Japan, m-hirota@mail.nissan.co.jp.

Direct Benefits

Because this concept is still in the design phase, no direct benefits were identified in the literature review. However, the benefits would be expected to be similar to animal detection systems.

Indirect Benefits

The system would not only detect large animals but potentially also humans (e.g., pedestrians, bicyclists).

Undesirable Effects

Vehicle-based systems only inform drivers in vehicles equipped with such a detection system. Drivers in other vehicles will not benefit.

Costs

A reported cost for these detectors is $2,250 per vehicle.[53]

Guidelines

See Hirota and others for design concept.[207]

INCREASE VISIBILITY OF ANIMALS TO DRIVERS

A driver's ability to avoid a collision with an animal may be determined in a split second. Once drivers see a road hazard, it may take 0.7 to 1.5 s (depending on whether the hazard was anticipated or unexpected) to move their foot from the accelerator to the brake.[188] Depending on vehicle speed and when an animal crossing the road is first seen, a collision may occur before the driver even has the chance to brake. The sooner drivers see an animal in the road, the better their chances of responding quickly to avoid a collision. Roadway lighting and vegetation removal have been used in an attempt to increase visibility to provide as much time and space possible for drivers to see and respond to animals in or near the roadway.

INCREASE VISIBILITY OF ANIMALS TO DRIVERS: ROADWAY LIGHTING

Most WVCs occur between dusk and dawn when light, and thus visibility, is limited (see Section on Causes and Factors of WVCs: Temporal Distributions). (See references 9, 10, 38, 75, 78, 79, 209, 210, and 211.) The drab coloring of most wildlife species increases the probability that a driver may not see an animal in the dark. Even the most attentive driver would have difficulty seeing a dark-colored moose on a dark road at night in time to avoid a collision. Garrett and Conway characterized moose-vehicle collision occurrences in Anchorage, AK, finding these incidents were 2.6 times more likely to occur during periods of darkness; further, 61 percent of collisions that occurred during dark periods occurred where there were no streetlights illuminating the road.[79] Lavsund and Sandegren found the risk of moose-vehicle collisions in Sweden was six times higher during hours of darkness compared to daylight conditions.[76] It has been hypothesized but not well documented that lighting may help drivers see animals and avoid such collisions in nondaylight hours.

Numerous reviews of WVC mitigation measures mention use of roadway lighting in attempts to reduce WVCs. (See references 3, 9, 68, 74, 176, 212, 213, 214, 215, and 216.) Most of these reviews either do not provide support that highway lighting is effective or conclude that highway lighting is ineffective. Reed and Woodard found that highway lighting was not effective in reducing DVCs in Colorado.[217] L-P Tardiff and Associates, Inc. cited a study by Miller indicating that lighting was ineffective for mitigating WVCs (no further information was provided and the report was unavailable at the time that this review was drafted).[68,218] Alternatively, one review states, "Lighting has been used on numerous occasions and has been shown to be effective in high crash locations because it gives drivers a longer reaction time" but does not cite any specific studies to support that claim.[215] Knapp classifies the use of roadway lighting as a method that is "not generally used and rarely studied for safety impacts" and cites that the American Association of State Highway Transportation Officials regard this measure as "experimental."[176]

Despite discrepancies in the tested effectiveness of highway lighting, the practice of using highway lighting has been recommended in certain situations. Garrett and Conway recommend the installation of streetlights, encouraging drivers to upgrade older vehicles' headlights with halogen bulbs, and keeping the lenses of the lights free of dirt and debris to increase the chance of seeing a moose in time to avoid a collision.[79] Thomas also suggests that roadway lighting be considered for reducing moose-vehicle collisions in Alaska.[78]

Given the paucity of information on the efficacy of lighting to reduce WVCs, there is a need to further explore the usefulness of this approach. If recommendations to install lighting are pursued, quantitative studies with experimental designs should be employed to further understand the effect that lighting and increased visibility may have on WVCs.

Reed and Woodard conducted a five-year study in Colorado that involved alternately turning roadside lights on and off for one-week periods to quantify the effect on DVCs, observed deer crossings of the highway at night, and vehicle speeds.[217] Lighting did not affect DVCs or driver speeds; however, drivers did significantly reduce speeds when a deer decoy was present (this practice was discontinued due to concerns about abrupt driver responses to the decoy, creating a potential safety concern for other motorists). Lighting did not disrupt deer crossing behaviors, although it appeared that a greater proportion of deer crossed in the lighted areas compared to prior to the study and when the lights were off.

A four-year study of the installation of roadway lighting, fencing, one-way gates and bridge modifications along 11.5 km (7.1 mi) of the Glenn Highway near Anchorage, AK, revealed a 70 percent decrease in moose-vehicle collisions overall.[213,219,220] The entire area was lighted, while about 5.5 km (3.4 mi) of the road had fencing, one-way gates, and modified bridges. The lighted area with fences reduced moose-vehicle collisions by 95 percent, while the areas with lighting but without fencing reduced moose-vehicle collisions by 65 percent. However, it was not clear if the 65 percent reduction in moose collisions was the result of moose avoiding the lighted areas or the result of increased motorist visibility.[213,219,220]

Case Studies and Contacts

For information about roadway lighting and fencing to reduce WVCs, contact Biota Research and Consulting, Inc., info@biotaresearch.com.

Direct Benefits

Reduction of moose-vehicle collisions by 65 percent was found in Alaska, but it is not clear if this was due to increased visibility or moose avoiding the lighted area.

Indirect Benefits

Griffith found that highway lighting reduced all "property damage only" (i.e., no human injury) crashes at night.[221] The typical method for comparisons for before/after installation is a reduction in the ratio of nighttime crash rates to daytime crash rates. Griffith found this ratio reduced by 32 percent for all property damage only crashes. However there was no reduction in injury or fatal crashes.

Undesirable Effects

An undesirable effect of roadway lighting is the impact on a driver's vision after leaving the lighted area. While driving through the lighted area, a driver's eyes will become accustomed to the light. Afterward, it may take some time before the driver's eyes readjust to less light.

Some sensitive species (e.g., Canada lynx, mountain lions (*Felis concolor*), bears, and gray wolves (*Canis lupus*) may avoid light, which may result in an unintentional barrier effect for lighted areas.[222] In addition, roadway lighting may temporarily blind certain species as their eyes are adapted to darkness, potentially increasing their vulnerability to traffic.[212]

Costs

Mode and others noted that in 2001, $1.3 million was dedicated to lighting three miles of the Glenn Highway in Alaska to improve motorist visibility of moose.[223] Hedlund and others state that roadway lighting is expensive but did not provide any figures to illustrate the estimated expense.[214] L-P Tardiff and Associates, Inc. mention Miller's report, which states that highway lighting is expensive, but again, no figures accompanied that statement.[68,218]

Guidelines

For guidelines on highway lighting, refer to the *Roadway Lighting Handbook* and Addendum.[224,225]

INCREASE VISIBILITY OF ANIMALS TO DRIVERS: VEGETATION REMOVAL

Visibility may be improved by reducing roadside vegetation that may obscure wildlife approaching the road. In a study of DVC mortalities in east central South Dakota, Gleason and Jenks found that deer were killed more often than expected in areas adjacent to shelterbelts with canopy vegetation.[226] Puglisi and others found that DVC occurrences were less common where wooded areas were more than 23 m (25 yds) away from a highway in Pennsylvania.[32]

Clearing vegetation from roadsides resulted in a 20-percent reduction in moose-vehicle collisions in Sweden.[76] In a study examining the effect of scent marking, intercept feeding and forest clearing, analyses demonstrated that forest clearing resulted in a 49-percent reduction in collisions.[227] While it is recognized that the results may not translate to a highway setting, the clearing of vegetation across a 20- to 30-m (70- to -100-ft) swath on each side of a Norwegian railway reduced moose-train collisions by 56 percent (+/-16 percent).[228]

Thomas states that vegetation clearing is one of the most commonly applied measures to reduce moose-vehicle collisions; recommendations from that report include that vegetation clearing should be applied in an effort to reduce moose-vehicle collisions in Alaska.[78] Distance between the roadway and forest cover has been shown to be negatively correlated to DVCs in Illinois; recommendations from that study included removing vegetation to provide an open width of the road corridor of at least 40 m (131 ft) in areas where DVCs are particularly high.[30] Based on results from predictive models, Seiler notes that moose-vehicle collisions in Sweden were more common on roads that cross through clear cuts and young forests and suggests collisions with moose may be reduced by 15 percent in areas where the distance between forest cover and the road exceeds 100 m (300 ft).[25]

In addition to affecting visibility, roadside vegetation management may be directed to reducing the attractiveness of roadside forage to animals. While vegetation management to increase visibility and reduce the draw of animals to the right of way may be complementary goals in

some cases, Putman and others summarize the potentially conflicting outcomes of reducing vegetation along roadways:

"The management of roadside vegetation—and specifically, the clearance of woodland or scrub from a margin at the road edge—may have benefits both in increasing driver awareness of deer at the roadside, and increasing visibility of oncoming traffic to the deer themselves. In addition, removal of such vegetation and the cover that it provides may also reduce the probability of deer approaching so close to the road edge in the first place. The method and timing of removal of such vegetation may however be critical. While the removal of vegetation within transportation corridors may help improve driver and animal visibility, simple cutting of encroaching shrub and tree growth may at the same time increase the subsequent attractiveness of these cut-over areas as foraging sites by deer. Such measures might thus actually result in an increase in the number of deer utilizing the roadside—ultimately increasing the risk of accident."[58]

For further discussion of vegetation issues, see also the section titled "Influence Species Composition or Minimize Nutritional Value of Vegetation in Right of Way" in chapter 6.

Case Studies and Contacts

No contacts for this mitigation measure were identified in the literature review.

Direct Benefits

Jaren et al. and others conducted an eight-year study of the effect of vegetation removal on moose-train collisions in Norway and found that clearing vegetation across a 20- to 30-m (70- to 100-ft) swath on each side of the railway reduced moose-train collisions by 56 percent (+/-16 percent).[228] Lavsund and Sandegren showed that clearing of vegetation along transportation corridors resulted in a 20-percent reduction in moose-vehicle collisions in Sweden.[76]

Indirect Benefits

Reducing the number of large trees near roads may result in fewer collisions with these stationary obstructions.[214]

Undesirable Effects

Removal of brushy species of vegetation or canopy may result in fresh growth of attractive forage that draws grazing animals to the right of way, potentially counteracting the potential safety gains of better visibility with increased probability of drivers encountering wildlife.[74]

Costs

Vegetation removal requires long-term maintenance commitment and may involve expenses to acquire right of way in order to manage vegetation as desired. Jaren and others calculated that if collisions are reduced by at least 50 percent as a result of removing vegetation, then the costs of vegetation removal treatment would be economically beneficial if applied in areas where more than 0.3 per km (0.48 per mi) moose-train collisions occur.[228] Andreassen and others estimate forest clearing for 18 km (11.2 mi) costs $500 per km ($800 per mi) or $9,000 per year, showing

that the number of moose saved using this technique could result in a profit of $1,080.[227] Andreassen and others state that forest clearing may be more economical compared to scent marking and supplemental feeding, stating that the initial cutting is the main expense.[227]

Guidelines

Thomas provides a summary of a variety of vegetation clearing methods used in Alaska including hydroaxing, hand clearing, steam clearing, and spray inhibitors.[78]

The timing and effect of vegetation clearing depends on the vegetation and climate at the roadway site and needs to be carefully evaluated.

INCREASE VISIBILITY OF ANIMALS TO DRIVERS: WIDER STRIPING

Drivers may see a break in the painted highway striping (particularly if it is wide) when an animal crosses it, even if the animal itself is difficult to distinguish due to color, background, or lighting conditions, and thus be warned of its presence on the highway. In addition, wide striping may make the driver perceive a narrower roadway, potentially resulting in lower vehicle speed (see later section on traffic calming and reducing design speed).

Wide striping was used along Rt. 4 in Phillips, ME, and along Rt. 6/15 in Shirley, ME.[229] The Rt. 6/15 road section in Shirley also had temporary optical markers (TOMs) installed. TOMs are small yellow reflective tags which are typically used as a substitute for striping during roadway construction activities. When a large animal, e.g., a moose, enters the roadway, the absence of light reflecting off the TOMs obstructed by the animal may result in a visual break for drivers, and thus a warning.[229] No evaluation or results of these installations were found.

Case Studies and Contacts

Contacts for the case studies mentioned above could not be identified.

Direct Benefits

No direct benefits were identified in the literature review.

Indirect Benefits

No indirect benefits were identified in the literature review.

Undesirable Effects

No undesirable effects were identified in the literature review.

Costs

No costs were identified in the literature review.

Guidelines

No guidelines were identified in the literature review.

INCREASE VISIBILITY OF ANIMALS TO DRIVERS: REFLECTIVE COLLARS FOR ANIMALS

One of the mitigation measures under consideration at a location in Canada is to put collars with reflective tape on a number of animals to increase their visibility to drivers. Free ranging wood bison (*Bos bison*) were reintroduced in northeast British Columbia. Their number has grown to about 100 individuals. The bison spend about 90 percent of their time on or near a 150-km (31-mi)-long section of the Alaska Highway near the Yukon border because of the attractive vegetation in the right of way and because the disturbance associated with the right of way may provide a shelter from predators. They are typically found in large groups, and a number of serious bison-vehicle collisions have taken place.

Case Studies and Contacts

For information about the proposal to put collars with reflective tape on bison, contact Conrad Thiessen, Wildlife Biologist, Peace Region, Ministry of Environment, 400-10003 110 Ave., Fort St. John, British Columbia, V1J 6M7 Canada, phone: (250) 787-3287, fax: (250) 787-3490, Conrad.Thiessen@gov.bc.ca

Direct Benefits

No direct benefits were identified in the literature review.

Indirect Benefits

No indirect benefits were identified in the literature review.

Undesirable Effects

It requires considerable and continuous effort to have a certain minimum number of bison (or any other species, including deer) equipped with collars with reflective tape. In addition, capturing and handling activities are likely to cause stress and risk of injury and death for the animals involved.

Costs

No costs were identified in the literature review.

Guidelines

No guidelines were identified in the literature review.

INCREASE VISIBILITY OF ANIMALS TO DRIVERS: REDUCE HEIGHT OF SNOWBANKS

Garrett and Conway suggested reducing the height of snow berms in order to increase drivers' visibility of moose on the side of the road.[79] They acknowledge this practice would be impractical and expensive to employ on all streets, and thus this might be better applied in particular areas with high rates of moose-vehicle collisions.

Case Studies and Contacts

No contacts were identified in the literature review.

Direct Benefits

No direct benefits were identified in the literature review.

Indirect Benefits

No indirect benefits were identified in the literature review.

Undesirable Effects

No undesirable effects were identified in the literature review.

Costs

No costs were identified in the literature review.

Guidelines

No guidelines were identified in the literature review.

REDUCE TRAFFIC VOLUME ON ROAD NETWORK

The increase in the number of WVCs (chapter 2) is associated with factors such as new highway construction, increased traffic volumes and speeds, wildlife population distribution, and wildlife abundance.[58,230] As mentioned in chapter 2 in the section titled "Is the Problem Growing," the average crash rate (number of crashes per vehicle mile traveled) has held fairly constant for WVCs; but the total number of VMT and thus the total WVCs have increased. The relationship between the number of WVCs and traffic volume on a single roadway, however, is confounded by changes or differences in wildlife population size and relatively great data variability.[74]

No original studies were located that tested the effectiveness of permanently lowering traffic volume on highways or permanently lowering road density of paved roads as a mitigation measure for reducing WVCs. Literature reviews by Danielson and Hubbard, D'Angelo and others, Putman and others, and Knapp did not address this potential mitigation measure on either the local or landscape scale. (See references 58, 61, 176, and 231.)

Some modeling efforts found a relationship between traffic volume and WVCs and suggest reduced traffic volumes as a potential solution to WVCs.[17,19,20] The modeling effort only identified a relationship between roads with a certain traffic volume and the presence of WVCs; it did not prove a causal relationship. Jaarsma and Willems for example, suggest implementing traffic calming on the more minor rural roads in order to shift the traffic onto a few major highways.[20] A similar number of studies found that higher volumes on roadways reduced the number of WVCs (see section in chapter 2 on traffic density and speed). As presented in a later section on "Undesired Effects," lower densities may actually increase crash rates.

Citing road mortality as one of the reasons, Friends of the Earth is campaigning for a 10-percent reduction in overall road traffic levels in the UK by 2010, as compared to 1990 levels.[232] However, it is unclear how to feasibly achieve this reduction.

Case Studies and Contacts

Reducing traffic volume has not been attempted directly as a mitigation measure for reducing WVCs. However, Catharinus Jaarsma has done extensive modeling on possible impacts (see description in previous paragraphs): Catharinus Jaarsma, Land Use Planning Chair, Wageningen University, the Netherlands.

Direct Benefits

Some modeling studies suggest reduced traffic volumes will result in decreased WVCs, although other studies found the opposite result. The relationship between road mortality, traffic volume and animal density, and mobility warrants further study.[22]

Indirect Benefits

Numerous indirect benefits can be suggested such as reduced energy demand, reduced pollution, etc. However, one should keep in mind the more holistic picture. For example, traffic calming measures may shift traffic to more major highways, but this would actually require drivers to travel further to get where they are going, ultimately increasing fuel use and emissions.

Undesirable Effects

Lower traffic volumes do not necessarily equate with fewer roadkills.[20] As noted above, this method may actually increase the number of WVCs. Additionally, limiting traffic on a roadway may have adverse economic impacts.

Costs

No costs were identified in the literature review.

Guidelines

No guidelines were identified in the literature review.

TEMPORARY ROAD CLOSURES

During periods of high animal movement, roads could be temporarily closed. Several temporary closures have been implemented for the reduction of WVCs. Some low-volume paved roads are closed seasonally during the night. In Delaware Water Gap National Recreation Area, the River Road is closed annually during the night (6 p.m. to 6 a.m.) in March and April when there is a forecast calling for rain with temperatures greater than 10 °C (50 °F). This allows multiple amphibian species to cross the road during their seasonal migration.[233,234] In the Shawnee National Forest, the LaRue Road at the base of the bluffs adjacent to LaRue Swamp is closed day and night from March 15 to May 15 and September 1 to October 30 to allow amphibians and reptiles, including several snake species, to conduct their seasonal migration.[235] In East Brunswick, NJ, the Beekman Road is closed several nights in the spring to allow spotted salamanders to cross the road during their seasonal migration.[236]

Case Studies and Contacts

For information on road closure in the LaRue-Pine Hills in the Shawnee National Forest, contact: Mississippi Bluffs Ranger District, 521 North Main Street, Jonesboro, IL 62952, (618) 833-8576.

Direct Benefits

Although the magnitude of impacts on WVCs has not been documented in the literature, it is clear that while a road is closed to traffic, there will be no WVCs.

Indirect Benefits

Like the previous section, numerous indirect benefits can be suggested such as reduced energy demand, reduced pollution, etc. (assuming that drivers do not just take an alternative route).

Undesirable Effects

Closing roads may have adverse economic impacts and accessibility issues. Road closures may require people to reroute, actually requiring drivers to travel further to their destination, ultimately increasing fuel use and emissions.

Costs

No costs were identified in the literature review.

Guidelines

No guidelines were identified in the literature review.

REDUCE VEHICLE SPEED

For areas with high WVC frequency, reducing vehicle speed is occasionally suggested as a mitigation strategy. Before discussing the methods and implications of this strategy, it is

important to understand the different types of speeds associated with the design and operation of a highway:

- The **design speed** is "a selected speed used to determine the various geometric design features of the roadway."[1] Certain minimum design standards are used for different design speeds. A higher design speed typically means higher minimums for curve radius, lane widths, shoulder widths, clear zone widths, and other design parameters. Higher design speeds also mean lower maximums for the number of access points (e.g., intersections, driveways, or interchanges) per mile.

- After a road is built, a spot speed study is done. **Operating speed** is determined as "the speed at which drivers are observed operating their vehicles during free-flow conditions. The 85th percentile of the distribution of observed speeds is the most frequently used measure of the operating speed associated with a particular location or geometric feature."[1] Speed studies are typically done before speed limit signs are installed, or speed limit signs are covered during the study. The theory assumes that drivers are the best judge of a safe driving speed of a roadway and 85 percent of the people will travel at reasonable speeds.

- The enforceable **posted speed limit** is the maximum legal speed at which a vehicle is allowed to travel. These are typically set near the operating speed (85th percentile speed).

- When a portion of the roadway has characteristics where the design speed is less than that of the rest of the road, an **advisory speed** can be posted. For example an advisory speed sign in the Netherlands is located at a gap in exclusionary wildlife fencing (figure 39). Advisory speeds are lower than the posted speed limit and are not enforceable other than by using basic "reasonable and prudent" laws.



Figure 39. Photo. Advisory speed sign in The Netherlands located at a gap in exclusionary wildlife fencing (copyright: Marcel Huijser).

Under typical circumstances, the design speed, operating speed, and posted speed should be almost equal for a given roadway. With this in mind, there are effectively three ways to reduce vehicle speed: (1) reduce the posted speed, (2) reduce the design speed through traffic calming or redesign, and (3) post an advisory speed.

REDUCE VEHICLE SPEED BY REDUCING THE POSTED SPEED LIMIT

This mitigation entails reducing the posted speed. The ability to do this depends on who owns the roadway (state, county, city), as well as the legislation and guidelines governing those agencies. Once approval for the reduced speed is obtained, this mitigation is implemented by replacing the existing speed limit signs.

One location where posted vehicle speeds were reduced to mitigate WVCs is in Jasper National Park in Alberta, Canada, on the Yellowhead Highway. This roadway is a rural two-lane highway in a national park, with 3.7-m (12-ft) lane widths, and 3-m (10-ft) shoulders.[237] Passing sight distance exists for most of the length. Passing sight distance is defined as "determined on the basis of the length needed to complete normal passing maneuvers in which the passing driver can determine that there are no potentially conflicting vehicles ahead before beginning the maneuver."[1]

Prior to the mitigation, the speed limit for the roadway was 90 km/h (56 mi/h). Traffic in 1998 was 1.2 million vehicles per year with a high percentage of trucks, buses, and recreational vehicles. The area includes grizzly bear, white-tailed deer, mule deer, bighorn sheep, and elk.

In 1991, the speed limit was reduced from 90 km/h (56 mi/h) to 70 km/h (43 mi/h) on three sections of the road; 2.5, 4, and 9 km (1.5, 2.5, and 5.6 mi) in length. Bertwistle reported that on average, 5,475 speeding tickets are issued each year (although he was not specific as to if these were in the 70 km/h (43 mi/h) zones or on the highway as a whole). Even with the speed limits and enforcement, a speed study in 1995 at two of the speed reduction locations showed that less than 20 percent of the vehicles obeyed the 70 km/h (43 mi/h) speed limit. Bertwistle reported that bighorn sheep collisions actually increased in the reduced speed zones and decreased in the control areas (the 90 km/h (56 mi/h) areas). Elk collisions were monitored at one reduced speed location and both the control and the reduced speed zones had increases in elk vehicle collisions. Bertwistle stated that there was a relationship between reducing the posted speed and the frequency of elk-vehicle collisions; however, the data presented in the paper appear to be inconclusive.

A report by Biota Research and Consulting, Inc. summarizes WVCs in the Jackson, WY area.[213] On a particular 1.4-km (0.9-mile) stretch of highway, the authors suggest highway lighting as a solution, because even with the posted speed limit reduced to 56 km/h (35 mi/h), drivers continue to strike and kill deer. The report does not state whether or not there was a decrease in WVCs from the posted speed limit reduction.

Often reduced speed zones are tied to other mitigation methods. A variable speed limit is associated with an animal detection system in Switzerland. (This system is described in the section on Animal Detection Systems earlier in this chapter.) Advisory speeds have also been used in conjunction with gaps in exclusionary fencing in The Netherlands, as previously mentioned (figure 39).

Case Studies and Contacts

For further information on the reduced speed limits in Jasper National Park, contact Jim Bertwistle, Warden, Jasper National Park, Alberta, Canada, (403) 852-6155.

Guidelines

If reduced speed zones are implemented, the following design considerations are recommended:

- Consider additional signing in advance of the reduced speed zones to inform motorists of the intent and hazard present. In Jasper National Park the signs stated "Slow Down for Wildlife."

- Reduced speed zones will have limited effectiveness without consistent visible enforcement, especially if the posted speed is significantly below the operating speed or design speed.

Direct Benefits

The effect of reducing vehicle speed on WVCs is unclear. However, for all crashes, reducing vehicle speeds will generally reduce the frequency of severe crashes (i.e., human injury or fatality).[238]

Indirect Benefits

Indirect benefits cited in the literature include

- Fines collected from regular enforcement.
- Increased fuel economy: West and others showed that for a mix of vehicle types, fuel efficiency peaked at about 88 km/h (55 mi/h).[239]
- Reduced emissions: the exact relationship is unclear but they are closely related to fuel efficiency.
- Reduced injury severity of crashes.

Undesirable Effects

Extreme caution should be taken in reducing the posted speed limit excessively below the operating speed. Such a reduction can set up a situation where motorists are encouraged to break the law and leads to speed dispersion (the spread of vehicle speeds). Instead of a tight distribution of speeds for vehicles on the road, there tends to be two speed groups: one group of vehicles will travel at the posted speed limit and another will travel at the operating speed. It has been shown that speed dispersion increases crash rates even if average speeds decrease. Solomon and Cerrelli found that vehicles traveling close to the average speed had the lowest crash involvement rates.[240,241] Crash involvement rate not only increased for faster vehicles, but also for slower vehicles. Garber and Gadiraju found a similar U-shaped relationship, where the further the posted speed was from the design speed, the higher the crash rate for the roadway.[242] Speed dispersion is particularly an issue on two-lane rural roads (where WVCs occur most often), because it increases the number of vehicles passing in unsafe situations.

Costs

Costs include the following:

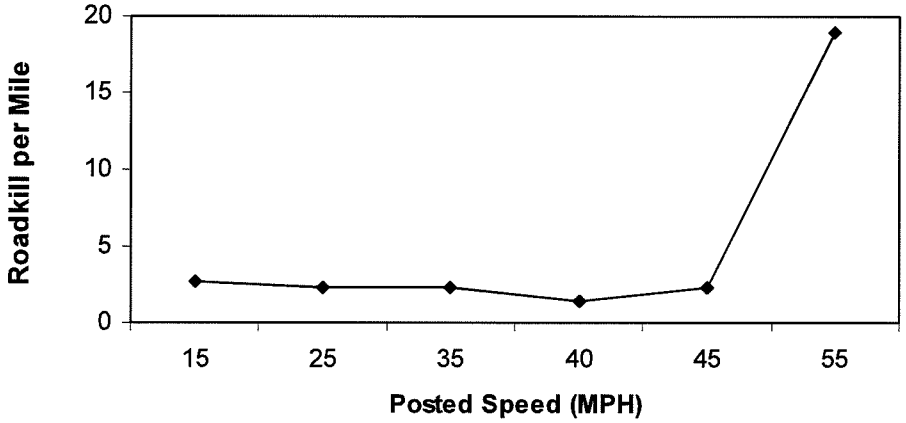
- The initial cost of replacing speed limit signs.
- The cost of regular enforcement.
- Additional costs in increased travel time need to be considered.
- Potential increase in head-on and other collisions due to speed dispersion.

REDUCE VEHICLE SPEED BY TRAFFIC CALMING/REDUCING DESIGN SPEED

Reducing the design speed of a road may be more effective in reducing vehicle speed than reducing the posted speed limit. A lower design speed typically relates to sharper horizontal and vertical curves, narrow lane widths, narrow or no shoulders, and narrow clear zones (i.e.,

obstructions such as trees closer to the roadway). In addition to the basic highway geometrics, there are numerous traffic calming methods used to slow vehicles down. These are typically used in residential neighborhoods or on a highway approaching a town, and rarely on major highways where most WVCs occur. Traffic calming treatments include speed bumps/humps, traffic circles, curb extensions, sidewalk extensions, raised medians, and rumble strips.

Gunther and others showed that in Yellowstone National Park, roads with higher posted speed limits had higher WVC occurrences.[243] His primary evidence is shown in figure 40, where an 88 km/h (55 mi/h) roadway has significantly higher roadkill per mile than roadways with lower posted speed limits. Notice, however, that WVC frequencies do not increase until 88 km/h (55 mi/h) speed limit. The 88 km/h (55 mi/h) road (U.S. 191) used by Gunther in this analysis is not an interior roadway and experiences much higher traffic over the year than the other roads considered. Gunther did show that internal roadways that were reconstructed with higher design speeds did see an increase in roadkill.



1 mi/h = 1.61 km/h

Figure 40. Graph. Roadkill by posted speed limit in Yellowstone.[243]

Below are three examples of traffic calming applications for wildlife:

One example is shown in figure 41 where speed bumps are used to reduce vehicle speed for Cassowaries (*Casuarius casuarius*), a large bird species in Queensland, Australia. The top sign originally displayed a warning for a speed bump, but was vandalized with a black marker to look like a dead bird.



Figure 41. Photo. Speed bumps used to reduce WVCs in Australia (copyright: Marcel Huijser). (Please disregard graffiti on signs.)

A second example is the installation of four "slow points" on a road in Tasmania that experienced a dramatic increase in collisions with eastern quolls (*Dasyurus viverrinus*) and Tasmanian devils (*Sarcophilus laniarius*) after the road section in a national park was widened and sealed and modal speed increased by 20 km/h (12.4 mi/h).[244] In addition, after the initial widening the population size of the two species declined substantially and the eastern quoll population became extinct. The slow points consisted of concrete barriers with a "Give Way" sign that constricted traffic to a single lane in the center of the road in or close to locations that had a concentration of roadkill.[244] The tight curves and the merging of traffic forced vehicles to slow down. After the installation of the slow points, the median vehicle speed in the center of the road section dropped by about 20 km/h (12.3 mi/h) (17–35 percent reduction), while vehicle speed at the outer two slow points close to the park boundary and wildlife zone boundary was only reduced by 1–7 percent. In addition, road mortality became more sporadic; the eastern quoll population became reestablished and was at 50 percent of its size before the road was widened and sealed two years after the installation of the slow points.[244] Furthermore, there was some indication that Tasmanian devil population was recovering as well.

A third example is the installation of (1) rumble strip patches along a road in south Florida in combination with (2) a black-on-yellow warning sign that reads "PANTHER CROSSING NEXT X MI" that has (3) a permanently activated flashing amber light installed on top of the warning sign. These mitigation measures are designed to increase driver alertness and to reduce vehicle speed to reduce collisions with the Florida panther.

Case Studies and Contacts

Although this mitigation has not been implemented directly, Kerry Gunther has done extensive modeling on potential impacts of design speed reductions: Kerry Gunther, Bear Management Office, Yellowstone National Park, kerry_gunther@nps.gov.

For more information on the slow points installed in Tasmania, contact Menna Jones, Department of Zoology, University of Tasmania, GPO Box 252-5, Hobart, Tas. 7001, Australia, E-mail: Menna.Jones@utas.edu.au.

Direct Benefits

Direct benefits of this measure in reducing WVCs are inconclusive.

Indirect Benefits

Lower speeds may reduce the number of fatal crashes and improve the overall safety of the roadway.

Undesirable Effects

Certain traffic calming measures have maintenance issues with snow removal. Also, the economic impacts of longer travel times should be considered.

Costs

No costs were identified in the literature review.

Guidelines

For further information on typical traffic calming measures and design guidelines, refer to the FHWA/ITE report on "Traffic Calming: State of the Practice" available at: http://www.ite.org/traffic/tcstate.htm (accessed January 25, 2007).

REDUCE VEHICLE SPEED BY POSTING ADVISORY SPEED SIGNS

Advisory speeds are typically only used in conjunction with other mitigation methods (primarily roadway warning signs). The results of those implementations are not revisited here, as they are discussed in other sections.

WILDLIFE CROSSING GUARDS

In some cases, individuals will direct traffic in areas where animals cross the roadway. This situation often occurs in national parks where mini-traffic jams (referred to as "animal jams") occur as vehicles stop on the highway to view wildlife. In some cases, this traffic control is conducted by park staff. In other situations, it may be the work of volunteers. For example, a story in *USA Today* on September 24, 2006, by Mick Cochran told of the volunteer group calling itself the Bugle Corps in Rocky Mountain National Park that manages traffic along the park's roads during the Rocky Mountain elk (*Cervus elaphus nelsoni*) rutting (breeding) season.[245]

Case Studies and Contacts

Most local technical assistance program (LTAP) centers offer flagger training and certification. Contact information for LTAP centers is located at: http://www.ltapt2.org/ (accessed January 25, 2007).

Direct Benefits

No direct benefits were identified in the literature review.

Indirect Benefits

When vehicles stop to view wildlife, it creates an unsafe situation with vehicles weaving around the stopped vehicles and pedestrians walking along roadways. This mitigation measure may reduce vehicle-vehicle and vehicle-pedestrian collisions.

Undesirable Effects

Staff or volunteers that manage traffic are exposed to potential injury from inattentive motorists.

Costs

Costs include training costs and the cost of the time spent by the individuals managing traffic. Costs of safety vests and stop/yield paddles (mandatory) are minimal.

Guidelines

Volunteers or staff should be trained in traffic control.

Note that the application of this mitigation measure is typically in national parks or other protected areas where wildlife may be habituated to people, traffic, and roads. In addition, the measure is typically only deployed when traffic volume is relatively high and when staff or volunteers are available.

CHAPTER 6. MITIGATION METHODS THAT SEEK TO INFLUENCE ANIMAL BEHAVIOR

These WVC reduction strategies are designed to change where, how, and when wildlife cross roads by modifying the animals' behavior without the use of major structures on or along the roadway. The specific mitigation measures reported on in this chapter are as follows:

- Deer reflectors and mirrors.
- Audio signals in right of way or attached to vehicles.
- Olfactory repellents.
- Deer flagging models.
- Hazing.
- Deicing alternatives.
- Intercept feeding.
- Influence species composition or minimize nutritional value of vegetation in the right of way.
- Remove carcasses along transportation corridors.
- Increase median width.

DEER REFLECTORS AND MIRRORS

Deer mirrors and reflectors are roadside installments intended to act as visual wildlife repellents. Mirrors directly reflect vehicle headlights off the roadway and into the surrounding right of way.[61] Reflectors beam colored reflected light from headlights into roadside habitat (Swareflex, D. Swarovski & Co., Wattens, Austria, http://www.swareflex.com/ (accessed January 26, 2007)) or onto the roadway itself (Strieter-Lite, Strieter Corp., Rock Island, IL, http://www.strieter-lite.com/).[246]

Most studies testing the effectiveness of mirrors and/or reflectors on reducing WVCs found that they had (1) no effect, (2) mixed results, or (3) inconclusive results. (See references 38, 59, 247, 248, 249, 250, 251, and 252.) Differences in experimental design and in the variety of models tested confound the comparison of results.[231] However, Schafer and Penland did find a significant reduction (88 percent) in WVCs using Swareflex reflectors in Washington State.[211] Pafko and Kovach found in Minnesota that reflectors reduced rural incidences by 50–97 percent, but suburban metropolitan WVC incidences increased.[250]

The Strieter-Lite company suggests there is scientific proof that their reflectors do work (78–90 percent reduction in DVCs) and that reflective luminance (brightness) is not a major factor, because wild animals have acute night vision.[253,254] Sivic and Sielecki conducted a spectrometric evaluation of Swareflex and Strieter-Lite wildlife warning reflectors and noted operational implications of low light reflection intensities.[255] Reflectors require suitable placement, alignment maintenance, and regular cleaning; however, in a roadside application it is impossible to keep reflectors clean at all times.[72,254,256] Possible reasons why reflectors and mirrors do not result in fewer roadkill include improper installation, lack of maintenance (no replacement of missing reflectors or realigning them after they became out of alignment), and dirty mirrors/reflectors (especially in winter).

Utah DOT discontinued use of reflectors due to an increase in deer kills and difficulty in keeping reflectors clean; high installation and maintenance/cleaning costs were also factors.[256] Thirty-nine percent of Swareflex reflectors used in Wyoming showed deterioration after 3 years.[248] In British Columbia, reflectors were prone to theft and vandalism.[72] Where mirrors and reflectors work in reducing WVCs, it may be a result of driver behavior, particular site characteristics, or rural versus suburban landscapes.[250,251,257]

Mirrors and reflectors are addressed in several literature reviews and annotated bibliographies. (See references 58, 61, 176, 231, 248, 258, and 259.) Knapp and others summarized 10 studies, five of which concluded that roadside reflectors did not appear to impact DVCs, two of which concluded that they did, and three reached inconclusive or mixed results.[53]

Studies testing the influence of reflectors on animal behavior found little or no evidence of avoidance.[59,246,257] A study of Strieter-Lite wildlife warning reflectors in four colors (red, white, blue-green, and amber) found them to be ineffective at altering white-tailed deer behavior so that DVCs might be prevented.[246] Interestingly, data indicated that deer increased negative behavioral responses toward vehicles in the presence of reflectors.[246] Ramp and Croft, however, found Swareflex reflectors produced a weak fleeing response in kangaroos.[260] Ujvari and others found that deer initially responded to reflectors with alarm and flight but then became habituated to the light reflection.[261] D'Angelo and others recommend that future development of deer-deterrent devices for WVC mitigation be based on empirical knowledge of deer senses and behavior.[246]

Case Studies and Contacts

For information on a couple of the reflectors that are available, contact Swareflex Reflectors, D. Swarovski & Co., Wattens, Austria, www.swareflex.com, and Strieter-Lite, Strieter Corp., Rock Island, IL, http://www.strieter-lite.com/ (accessed January 26, 2007).

For information on effectiveness of reflectors on animal behavior, contact Gino D'Angelo, Daniel B. Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA 30602, (706) 227-6867, gid4895@owl.forestry.uga.edu.

Direct Benefits

Roadside reflectors and mirrors are categorized as "tried" (as defined by AASHTO Safety Strategy Groups) and "used with conflicting safety analysis results" in a critical evaluation of DVC crash countermeasures.[176]

Indirect Benefits

This mitigation approach allows for animal movements at grade and allows animals to change where they cross over time.

Undesirable Effects

Deer have been documented to move toward vehicles in the presence of reflectors.[246]

Costs

A manufacturer advertises total cost of installation with reflectors, posts, equipment, and labor to be $4,000–6,000 per km ($7,000–10,000 per mi). The average life of reflectors is 12.5 years, so costs amount to $169–199 per km ($272–320 per mi) per year. Maintenance cost per mile per year is $500 ($300 per km per year) (Strieter-Lite, Strieter Corp., Rock Island, IL, http://www.strieter-lite.com/).[262] In British Columbia, reflectors cost approximately $10,000 per km ($16,000 per mi) to install along both sides of a highway, and maintenance costs range in the order of $500–1,000 per km ($800–1,600 per mi) annually.[72]

Guidelines

The manufacturers have installation guidelines. Regular maintenance, e.g., cleaning of the reflectors, may be needed.

AUDIO SIGNALS IN RIGHT OF WAY OR ATTACHED TO VEHICLE (DEER WHISTLES)

Audio animal warning devices are intended to alert wildlife of oncoming traffic. Sav-A-Life Deer Alert (Sav-A-Life Industries, New York, New York, http://www.sav-a-life.com/ (accessed January 26, 2007)) and Game Tracker's Game Saver, marketed as vehicle-mounted ultrasonic animal warning devices, elicited no response in 150 groups of free-roaming mule deer in with/without trials.[263] Behavioral observations of captive kangaroos in response to the Shu Roo, a vehicle-mounted ultrasonic kangaroo deterrent, did not differ in the on or off position.[264]

Many literature reviews and annotated bibliographies deem audio repellants ineffective in terms of modifying animal behavior for the goal of WVC reduction.(See references 58, 61, 74, 176, 216, 231, 265, and 266.)

A roadside wildlife warning system utilizing high-frequency sounds has been developed (International Road Dynamics, Inc., (IRD) Saskatoon, Saskatchewan, Canada, http://www.irdinc.com/ (accessed January 26, 2007)).[267] Results from a study were not conclusive, and the system is no longer in service (Rob Bushman, IRD Inc., personal

communication). While it is recognized that the results may not apply to highways, a wildlife warning system was installed along a railroad in Poland.[268] The system is activated when trains approach.[268] The effectiveness of this system has not been evaluated.

Another roadside wildlife warning system was developed by Firma Günter Josef Folda in Austria.[269] Headlights from approaching cars activate equipment that is integrated with the poles and reflectors that delineate the roadway (Edward Mulka, JAFA Technologies, Inc., personal communication). Once activated, the equipment emits a high-pitched alarm sound along with a supplemental blue light strobe light (Edward Mulka, JAFA Technologies, Inc., personal communication).[269,270] Unconfirmed data from Austria (between the cities of Nassereith and Imst in the Gurgltal on the Miemingerstraße road) indicate that the equipment may reduce WVCs by 85–93 percent.[270] The equipment is encased in a weather-resistant box and is powered by solar cells, batteries, or both (Edward Mulka, JAFA Technologies, Inc., personal communication).[270] The equipment weighs less than a pound and can be mounted on trees or small poles. The equipment can be directed such that the sound and strobe emitter face away from the road in the direction of wildlife that may be in the process of approaching the road (Edward Mulka, JAFA Technologies, Inc., personal communication).[270]

A study of fallow deer (*Dama dama*) behavioral responses to acoustic road markings showed that while behavioral responses differed initially, deer became completely indifferent to the acoustic stimuli within 10 days.[271]

In a comparison of whistle acoustic frequencies and intensities and deer hearing abilities, Scheifele and others determined closed-end whistles produced frequencies of ~3.3 kHz with little variation with changes in air pressure, while open-end whistles emitted frequencies of ~12 kHz with significant variation depending on air pressure.[272] Deer hearing sensitivity is estimated to be between 2 kHz and 6 kHz.[272,273] Taking into consideration the masking effect of road and car noise, however, deer are not likely to be able to hear the whistles.[263,272] Recordings made during dynamic drives found that the Shu Roo signal was not detectable above the noise of four vehicles traveling at different speeds, yielding no difference whether the device was turned on or off.[264] Further, if whistles were audible in combination with vehicle and road noise, there is no evidence that they affect animal behavior and habituation to these sounds is possible. (See references 263, 264, 271, 272, and 274.)

Case Studies and Contacts

Contacts for some audio signal manufacturers are:

- Sav-A-Life Industries, New York, NY, http://www.sav-a-life.com.
- Rob Bushman, International Road Dynamics, Inc., http://www.irdinc.com/search.
- WIWASOL-II. Firma Günter Josef Folda, Perkonigweg 3, 9311 Kraig, Austria, Phone: +43 (0) 664 2301980, Fax: +43 (0) 720 555870, Email: office@wildwarner.at http://www.wildwarner.at/pages/31alhomepag.html. Distributor USA: Edward A. Mulka, JAFA Technologies, Inc., 213 Hooton Road, Mt. Laurel, NJ 08054, Tel/Fax: (856) 802-9095, Cell: (856) 278-1597, E-mail: emulka@jafatech.com, http://www.jafatech.com/.

Direct Benefits

Deer whistles are categorized as "tried" (as defined by AASHTO Safety Strategy Groups) and "used with conflicting safety analysis results" in a critical evaluation of DVC crash countermeasures .[176]

The effectiveness of the IRD system is inconclusive. Maintenance staff anecdotally felt the system was effective, but the data were inconclusive, possibly since not enough data were collected. Currently the IRD system is not in use.(Rob Bushman, IRD Inc., personal communication).

The effectiveness of the WIWASOL-II system may be 85–93 percent, but these results are currently unconfirmed.[270]

Indirect Benefits

This approach accommodates unrestricted animal movements at grade.

Undesirable Effects

Audio signals may frighten animals away in areas where there may be interest in establishing or improving habitat connectivity across a highway.

Costs

The Sav-A-Life Deer Alert individual vehicle-mounted devices cost $23.50 each.

For a test installation of a roadside-based audio signal system along a 6-km (3.7-mi)-long road section, the costs were about €19.000.[270]

Guidelines

If auditory warnings are used, their frequency must be within the auditory range of the species, and they must not be drowned out by the surrounding road and vehicle noise.

OLFACTORY REPELLENTS

Olfactory repellents involve odorous chemical or organic compound applications along roadways to act as deterrents for wildlife.

A literature review of capsaicinoids, synthesized animal odors, other animal products, garlic, particulates, soaps, thiram, bittering agents, natural predator excretions, and putrescent egg determined the latter two hold the most potential for keeping ungulates away from roadways but have not been field tested.[176,275] An experimental study and literature review found olfactory repellents did not prove effective as area repellents for large-scale application on travel corridors, making them unsuitable for use in reducing WVCs.[276] Other literature reviews that addressed effectiveness in terms of reducing WVCs have determined that olfactory repellents have not been adequately tested, show only limited effectiveness, or are impractical because of the need to

repeat applications, especially after precipitation events. (See references 22, 58, 61, 176, 216, 277, and 278.) Future development of olfactory repellent measures requires further study of wildlife behavioral responses on a range of species and of the potential for animal habituation.[176,260,279]

Experimental scent marking using Duftzaun (HAGOPUR GmbH, Landsberg am Lech, Germany), a mixture of bear, gray wolf, Eurasian lynx (*Lynx lynx*), and human components, showed an 85 percent reduction in moose-train collisions in Norway, but results were questionable given that short treatment distances (500 m (1,640 ft)) yielded small and variable samples sizes for the number of collisions.[227]

Captive trials of Wolfin® (Pro Cell Biotenik, Hornefors, Sweden), a synthetic scent repellent, showed no repellency of caribou or black-tailed deer.[280,281] The repellent Plant Plus (Roe Koh and Associates Pty. Ltd., Mornington, Victoria, New Zealand), a synthetic canine predator odor, had aversive effects on one species of marsupial but attracted another, indicating a need for more research.[260] Captive trials of Deer Away® Big Game Repellent (Intagra, Inc. Lakeville, Minnesota), a putrescent whole egg repellent, initially altered caribou feeding behavior, but feeding times and amount eaten returned to pretreatment levels.[280]

Manufacturers of a proprietary "chemical fence" (repellent chemicals encapsulated in slow release organic foam and applied to roadside posts or trees) reported some repellency and a reduction in frequency of roe deer-vehicle collisions in one treated section.[9,282] However, a more detailed assessment found DVCs rose in untreated sections.[58,283] A roadside wildlife warning system utilizing scent repellents has been developed (International Road Dynamics, (IRD) Inc., Saskatoon, Saskatchewan, Canada, http://www.irdinc.com/), but results from a study were not conclusive and the system is no longer in service (Rob Bushman, IRD Inc., personal communication).[267]

Case Studies and Contacts

For information about effectiveness of repellents on animal behavior, contact Lisa Shipley, Department of Natural Resource Sciences, Washington State University, (509) 543-8955 or Marion Carey, Project Monitor, Environmental Affairs Office, Washington Department of Transportation, (360) 705-7404.

Direct Benefits

In terms of reducing WVCs, evidence for effectiveness remains sparse and temporary at best.[22] Repellents are categorized as "experimental" (as defined by AASHTO Safety Strategy Groups) and "not generally used and rarely studied for safety impacts" in a critical evaluation of DVC crash countermeasures.[176]

Indirect Benefits

No indirect benefits were identified in the literature review.

Undesirable Effects

Kinley and Newhouse caution that unintended negative effects may arise from olfactory repellent application and recommend a cost-benefit analysis of associated safety, economic, and ecological factors.[275] Potential negative effects may include attracting predators to the roadside and causing a panic reaction (instead of avoidance) in ungulates resulting in erratic movements toward the roadway.

Costs

Costs should take into consideration maintenance requirements, time intervals for reapplications, the area to be treated, and ecological impacts.[22,176]

According to the literature, one liter of Plant Plus concentrate costs $30 (currency was not specified, but presumably Australian dollars).[284]

Guidelines

If olfactory repellents are used, it is important to ensure that the repellant works to deter animal movement and that animals do not become habituated to them.

DEER FLAGGING MODELS

Deer flagging models are based on the behavioral characteristic of white-tailed deer that raise their tails to expose the white underside when fleeing. Tail flagging, however, has not been shown to act as a warning signal to other members of the species.[285]

A single deer flagging model study was found.[286] The researchers used painted wooden silhouette models of deer with painted or actual deer tails in a control/treatment experiment and found the models to be ineffective for deterring deer from the roadway.[286] A number of confounding factors make it difficult to determine whether or not this mitigation alternative is viable.[176] Future studies that consider pertinent variables (e.g., fluctuations in deer movements) could validate or refute this study and address potential safety or DVC impacts of deer flagging models.[176]

Case Studies and Contacts

For review information about deer flagging models, contact Keith Knapp, Texas Transportation Institute, Work Zone and DMS Program, Room 410D, 3135 TAMU, College Station, TX 77843-3135, (979) 845-5686, k-knapp@tamu.edu.

For further information about deer tail flagging, contact Tim Caro, University of California-Davis, Wildlife, Fish, and Conservation Biology Department, 1395 Academic Surge Building, 95616, (530) 752-0596, tmcaro@ucdavis.edu.

Direct Benefits

Deer flagging models are categorized as "experimental" (as defined by AASHTO Safety Strategy Groups) and "not generally used and rarely studied for safety impacts" in a critical evaluation of DVC crash countermeasures.[176]

Indirect Benefits

No indirect benefits were identified in the literature review.

Undesirable Effects

No undesirable effects were identified in the literature review.

Costs

No costs were identified in the literature review.

Guidelines

No guidelines were identified in the literature review.

HAZING

Hazing or aversive conditioning is the practice of dispersing wildlife by frightening them, which has been done using such things as lights, lasers, water sprays, pyrotechnics, cannons, guns, helicopters and predatory-resembling chases. (See references 287, 288, 289, and 290.)

Romin and Bissonette found 3 of 43 natural resource agency respondents used hazing as a method to reduce deer road mortality, one of which reported success.[3] Hazing was not effective in moose-vehicle collision mitigation efforts in Alaska.[78] In British Columbia, Roosevelt elk (*Cervus canadensis roosevelti*) were relocated when hazing failed as a WVC mitigation measure.[72]

Green and blue lasers were found to be ineffective as frightening devices to disperse deer at night.[290] During treatment and control (observation with no laser) behavioral experiments, deer saw and followed the laser light and appeared to be more curious than frightened.[290] Red lasers were not tested because deer cannot see in the red portion of the spectrum.[290] Lasers have been proven to be effective on birds but not on deer, probably a result of species-specific threat perception (i.e., animals may not associate the disturbance with danger).[287,290] Lights and water sprays have only limited effectiveness.[287]

Hazing with sounds (e.g., pyrotechnics, cannons, guns, and helicopters) may offer a temporary solution for dispersing animals, but noise is a consideration in areas of human populations.[287,288] In a study of Key deer capture techniques, hazing with helicopters or shooting out of vehicles in residential areas was not attempted.[288]

Aversive conditioning treatments resembling predatory chases by humans and dogs were effective in increasing flight responses in 24 moderately habituated radio-collared elk; habituated animals have been associated with WVCs in Banff National Park.[289] Natural wolf activity, however, appeared to reduce the efficacy of the aversive conditioning techniques (i.e., elk remained closer to town sites).[289] Aversive conditioning has shown some success in keeping grizzly bears off roadsides.[291]

No scientific studies have been done to test the effectiveness of hazing on reducing WVCs, and hazing is not covered in other pertinent reviews on WVC mitigation measures.[61,176,231] DeNicola and others address hazing in managing deer in suburban environments but not within the context of WVC reduction.[287] Hazing can be difficult to implement in established conflict situations, because animal behavioral habits are difficult to change and habituation is possible.[287]

Case Studies and Contacts

For information about aversive conditioning in Banff National Park, contact Elsabe Louise Kloppers, University of Alberta, Canada, elsabekloppers@yahoo.ca.

Direct Benefits

Direct benefits are unknown. No scientific studies have been done to test the effectiveness of hazing on reducing WVCs.[61]

Indirect Benefits

No indirect benefits were identified in the literature review.

Undesirable Effects

No undesirable effects were identified in the literature review.

Costs

Aversive conditioning using humans was 15 percent less expensive than conditioning with dogs (Can$4,300).[289]

Guidelines

No guidelines were identified in the literature review.

DEICING ALTERNATIVES

The principal deicers used by highway agencies are chloride-based salts such as sodium chloride (NaCl), calcium chloride ($CaCl_2$), and magnesium chloride ($MgCl_2$), and acetate-based deicers such as potassium acetate, sodium acetate, and calcium magnesium acetate (Xianming Shi and Laura Fay, Western Transportation Institute, Montana State University, personal communication).

The use of chloride salts in winter maintenance can attract wildlife to the right of way and may increase WVCs, especially in areas without natural salt licks.(See references 61, 74, 176, and 292.) A study of 11 radio-collared moose in New Hampshire determined that all of their home ranges converged on the area containing roadside salt (NaCl) licks formed by runoff of road salt.[293] Implications associated with these roadside salt licks include increased moose-vehicle collisions and increased brain worm infections in moose and white-tailed deer.[293] Reducing the amount of salt or using alternative deicers (without salt), especially in areas of high WVCs, may reduce the attractiveness of the right of way.[294]

Lithium chloride, a gastrointestinal toxicant, was found to effectively discourage captive caribou from eating treated food and may prove useful in reducing WVCs by discouraging ungulates from licking road salt.[280] CaMg-acetate has been recommended as an alternative to deice roads in Finland instead of NaCl.[74] Attempts at discouraging animals from road salt using the deicer calcium chloride were unsuccessful in Jasper National Park, Canada.[295]

A study of the pattern of moose-vehicle collisions in relation to the presence of roadside saltwater pools showed that 43 percent of moose-vehicle collisions occurred within 100 m (328 ft) of a saltwater pool, higher than what would randomly be expected.[296] About the same number of collisions happened more than 300 m (984 ft) from a roadside saltwater pool.[176] Knapp questions the assumption of the study (i.e., all locations have an equal chance for a collision).[176]

Road salt and deicing alternatives are addressed in literature reviews; however, whether the reduction or replacement of the road salt would reduce WVCs involving ungulates remains unknown.[61,176,292]

Case Studies and Contacts

For further information on efforts using deicing alternatives, contact Jim Bertwistle, Warden, Jasper National Park, Alberta, Canada, (403) 852-6155.

Direct Benefits

Whether the reduction or elimination of the road salt would reduce WVCs remains unknown.[176] Deicing salt alternatives are categorized as "experimental" (as defined by AASHTO Safety Strategy Groups) and "used but not studied for safety impacts" in a critical evaluation of DVC crash countermeasures.[176]

Indirect Benefits

The intake of road salt has been found to be toxic to several bird species, porcupines, rabbits, deer, and moose that ingest it.[292,297] Reduction or elimination of road salt may reduce or eliminate this toxicity.

Brain worm in moose and white-tailed deer is associated with road salt; elimination of road salt may reduce this occurrence.[293]

Undesirable Effects

While the reduction or elimination of road salt may benefit certain species, alternatives to chloride salts may also be toxic to wildlife (Xianming Shi, Western Transportation Institute, Montana State University, personal communication), but this has not yet been specifically studied.

Costs

No costs were identified in the literature review.

Guidelines

No guidelines were identified in the literature review.

INTERCEPT FEEDING

Intercept feeding provides strategically placed supplemental food sources in an attempt to divert animals away from roadways.[176]

A two-year control/treatment experiment tested the effectiveness of intercept feeding as a means to reduce DVCs by diverting mule deer from roadsides in Utah.[298] The researchers concluded that intercept feeding may have reduced DVCs by as much as 50 percent.[298] However, no information was provided on the number of DVCs before intercept feeding stations were operational.[176]

After testing the effectiveness of scent marking, forest clearing, and supplemental feeding, researchers in Norway determined such mitigations might help reduce (but not eliminate) moose-train collisions if applied over long distances.[227] Attempts at discouraging animals from road salt using intercept mineral baiting were unsuccessful in Jasper National Park, Canada.[295]

Intercept feeding may work in some cases, such as for short-term reductions in areas of high deer concentrations or in combination with other mitigation measures. (See references 61, 176, 216, and 298.) Intercept feeding is labor intensive and may create a dependency on supplemental food and actually increase population size.[216,298] Intercept feeding is addressed in several pertinent literature reviews. (See references 61, 176, 216, and 231.)

Case Studies and Contacts

For further information on intercept feeding efforts, contact Jim Bertwistle, Warden, Jasper National Park, Alberta, Canada, (403) 852-6155.

Direct Benefits

Intercept feeding is categorized as "experimental" (as defined by AASHTO Safety Strategy Groups) and "not generally used and rarely studied for safety impacts" in a critical evaluation of DVC crash countermeasures.[176] Additional study that can refute or validate the effectiveness of intercept feeding in reducing DVCs would be appropriate.[176]

Indirect Benefits

No indirect benefits were identified in the literature review.

Undesirable Effects

Intercept feeding may create a dependency on supplemental food or increase population size.[298]

Costs

Intercept feeding is labor intensive.[216,298]

Guidelines

No guidelines were identified in the literature review.

INFLUENCE SPECIES COMPOSITION OR MINIMIZE NUTRITIONAL VALUE OF VEGETATION IN RIGHT OF WAY

Roadside vegetation can attract wildlife to roads and increase their vulnerability to WVCs.[299,300] The practice of planting trees near roadways for landscaping reasons can attract ungulates to the right of way and increase the risk of WVCs.[9] Several sources recommend managing vegetation in the right of way so that it does not serve as an attractant to wildlife (i.e., by planting unpalatable species, reducing forage quality, or applying noxious chemicals), while others focus on improving roadside habitat for wildlife. (See references 9, 74, 301, 302, 303, 304, 305, and 306.) Techniques employing forage repellents, unpalatable species, and roadside brush removal have been used with limited effectiveness or are not cost efficient when broadly applied.[304]

An experimental study of vegetation removal along a railway line (20–30 m (66–98 ft) on each side) in Norway caused a 56 percent (+/- 16 percent) reduction in moose-train collisions.[228] The researchers concluded that there would be an economic benefit to perform vegetation removal treatments in areas with more than 0.3 collisions per km (0.48 per mi) but that local evaluations are necessary to confirm that vegetation cover is the main contributor to collisions in specific sections.[228] It is possible, however, that the experimental design may have overstated the collision reduction potential of vegetation removal.[176,228]

A detailed literature review on roadside vegetation management, plant response to tissue removal, and ungulate foraging behavior yielded recommendations for more carefully designed cutting regimes as a countermeasure for reducing moose-vehicle collisions.[304] Willows cut in mid-July were found to be high in digestible energy and protein compared to plants cut at other times of the year and uncut controls, suggesting that summer brush cutting regimes may inadvertently be attracting moose with nutritious regrowth.[304,307] Cutting in early June results in browse with significantly less nutritional value for the first two years after cutting compared to plants cut later in the growing season and uncut controls.[304,307] Rea recommends cutting roadside brush in early spring soon after leaves develop to keep nutritional value and palatability to a minimum but recognizes operational challenges and limitations (i.e., ground too wet for tractor use, different ungulate species-specific responses to same management regime, etc.) and cautions that this countermeasure may not be suitable for all management areas.[304]

No studies were found that specifically analyze the WVC safety impacts of roadside management policies or plantings; however, a 1999 report by the Arizona Department of Transportation (ADOT) describes a future five-year monitoring plan to address the effectiveness of a number of mitigation measures (including those related to vegetation/habitat changes) on reducing WVCs.[176,308] The need to properly study the safety impact of vegetation management along roadways remains.[176]

Note: see also the section titled "Increase Visibility of Animals to Drivers: Vegetation Removal" in chapter 5.

Case Studies and Contacts

For information about roadside vegetation management, contact Roy Rea, Natural Resources and Environmental Studies, University of Northern British Columbia, Canada, reav@unbc.ca.

Direct Benefits

Roadside vegetation management is categorized as "tried" (as defined by AASHTO Safety Strategy Groups) and "used but rarely studied for safety impacts" in a critical evaluation of DVC crash countermeasures.[176]

Indirect Benefits

No indirect benefits were identified in the literature review.

Undesirable Effects

Minimizing the nutritional vegetation may restrict the use of native vegetation along the roadside. In addition, reducing habitat quality may increase the road effect zone.[83]

Costs

No costs were identified in the literature review.

Guidelines

Some guidance for implementing this mitigation measure is presented by Rea.[304]

REMOVE CARCASSES ALONG TRANSPORTATION CORRIDOR

Highway safety is an impetus for timely removal of road-killed animals, and carcass composting may yield economic, ecological, and aesthetic benefits.[176,309] The carcasses of road-killed animals that are not removed may serve as food sources for other wildlife, attracting them to roads and increasing their vulnerability to WVCs.[176] Evaluation of the impact of roadside carcass removal on reducing WVCs has not been studied and has rarely been considered.[176] While carcasses may be an attraction for scavengers, ungulates are not likely to be attracted or deterred by the presence of carcasses in the right of way. Therefore, carcass removal may not have a substantial effect on the number of DVCs and the total number of WVCs. Nonetheless,

omnivores and carnivores, including some rare, threatened, or endangered species, may experience less road mortality as a result of the removal of food sources along the roadway.

Case Studies and Contacts

For information about carcass removal efforts in New York State, contact Elisabeth Kolb, Maintenance Environmental Coordinator, New York State Department of Transportation, (845) 575-6158.

Direct Benefits

Carcass removal, as an element in "roadway maintenance, design and planning policies," is categorized as "tried" (as defined by AASHTO Safety Strategy Groups) and "used but rarely studied for safety impacts" in a critical evaluation of DVC crash countermeasures.[176]

Indirect Benefits

Carcass removal may reduce the frequency of secondary roadkill of scavengers that feed on carcasses.

Undesirable Effects

No undesirable effects were identified in the literature review.

Costs

In Canada, the clean-up and carcass removal and disposal costs for animal carcasses were estimated at Can$100 (deer), Can$350 (elk) and Can$350 (moose).[72] In Pennsylvania, the average cost for deer carcass removal and disposal in a certified facility was $30.50 per deer for contractors and $52.46 per deer for the Pennsylvania Department of Transportation in 2003–2004 (Jon Fleming, Pennsylvania Department of Transportation, personal communication).

Guidelines

Carcass removal allows for easy data collection of roadkill, which helps with planning and monitoring mitigations for WVCs. A composting plant would mitigate the waste management issue.

INCREASE MEDIAN WIDTH

Crossing several lanes of traffic moving in opposite directions is a difficult task for an animal to perform. Wider medians can provide a "refuge" for the animals, giving them a break in their roadway crossing. Medians allow animals to deal with only one direction of traffic at a time, enabling them to stop partway across the roadway and identify and wait for an adequate gap in traffic before crossing the second half of the roadway. A literature review by Clevenger and Kociolek found that it was unclear whether or not a vegetated median increased the ability of wildlife to cross the road safely.[310]

Case Studies and Contacts

No case studies were identified in this literature review.

Direct Benefits

No direct benefits were identified in the literature review.

Indirect Benefits

A wider median may provide a more aesthetically pleasing view to the driver. It may also allow for high beams to be kept on for longer periods at night to aid visibility.

Undesirable Effects

No undesirable effects were identified in the literature review.

Costs

No costs were identified in the literature review.

Guidelines

No guidelines were identified in the literature review.

CHAPTER 7. MITIGATION METHODS THAT SEEK TO REDUCE WILDLIFE POPULATION SIZE

A comprehensive review by Knapp, Putman and others suggests that a reduction of the population size across a relatively wide area can be effective in reducing DVCs. (See references 52, 53, 54, 58, 61, 62, and 311.) Nonetheless, actual data on the effectiveness of population reduction programs on WVCs are few. For example, a field test showed that a deer population reduction program in Minnesota reduced winter deer densities by 46 percent and DVCs by 30 percent.[52]

Deer population sizes, especially those of white-tailed deer, have grown substantially over the last century in the United States.[55] This population growth is especially apparent since the 1960s.[55,57] This increase in population size was triggered by better protection, a matrix of habitat providing cover (forests) and food (agriculture, silviculture), the loss or decline of their natural predators, and more recently, reduced hunting pressure by humans through an increase in refugia (private land, (sub) urban areas), and a decrease in hunters. (See references 55, 57, 312, 313, 314, and 315.) Currently, white-tailed deer numbers are believed to be higher than they have ever been in the past several hundred years, causing or contributing to a series of problems, including DVCs. (See references 55, 57, 314, and 316.) This situation has triggered efforts to eliminate, reduce, or control the size of the deer population, especially white-tailed deer.

The fertility of white-tailed deer depends on their population density; their reproduction is higher at relatively low densities than at higher densities. The fertility of white-tailed deer is weakly density dependent for adult does.[317] However, the fertility of first-year and yearling females is strongly density dependent, with very low fertility when population densities exceed 30 deer/km^2.[317] These observations suggest that as population density is reduced, increased effort is needed to keep the deer density at the lower level. This phenomenon needs to be addressed in potential population size reduction programs.

The relationship between deer population density and the number of DVCs seems intuitive but is often complex and variable.[59,60] Nonetheless, a comprehensive review by Knapp, Putman and others suggests that a reduction of the population size across a relatively wide area can be effective in reducing DVCs. (See references 52, 53, 54, 58, 61, 62, and 311.)

This chapter discusses the following measures to reduce wildlife population size along roads

- Wildlife culling.
- Wildlife relocation.
- Anti-fertility treatment.
- Habitat alteration away from the road.

WILDLIFE CULLING

Wildlife culling involves a substantial reduction of the population size through eliminating a large number of individual animals over a short period of time. This measure is typically applied to or proposed for deer. The culling is sometimes done by recreational hunters through increased quota; sometimes it is done by professionals, especially if there are refugia for the deer (private land, (sub)urban areas). (See references 52, 312, 318, and 319.)

A field test showed that a deer population reduction program in Minnesota reduced winter deer densities by 46 percent and DVCs by 30 percent.[52] Sharpshooting by professionals over bait was deemed to be the most effective and adaptable culling method in an urban setting, as opposed to controlled hunts in large parks and refuges or opportunistic sharpshooting by professionals.[52]

The killing of does (females) is more effective for reducing the population size than the killing of bucks (males), not only because the reproductive potential of the herd is more effectively reduced, but also because does tend to stay in their existing home range while bucks have a greater tendency to disperse.[55] The does are less likely to migrate and establish new populations elsewhere.

A modeling project by Porter and others showed that if female dispersal (i.e., animals that leave the area) was 8 percent, culling would have to reduce annual survival to 58 percent to maintain a population just under ecological carrying capacity (the maximum sustainable population size).[320] A further reduction of the annual survival to 42 percent would keep the population at 0.5 of the carrying capacity.[320]

Culling efforts are more likely to result in a substantial reduction in deer population size if the herd size is relatively small to begin with and if it is a closed population that does not allow influx of animals from nearby places. The effort has to be repeated periodically as the deer population will grow back to the same levels if the habitat conditions remain similar (i.e., it is not a one-time-only measure). In addition, the effort involved for population size reduction programs increases disproportionately with higher population size reduction goals, and substantial reductions (for example ≥50 percent) may be hard to obtain, perhaps capping the potential reduction in DVCs at 50 percent. Finally, wildlife culling can meet with strong public opposition.

Case Studies and Contacts

For information about a field test of four population management methods to reduce a deer population in Bloomington, MN, contact Michelle Doerr, 2887 Ulm Avenue, Stewart, MN 55385, ewiggers@islc.net.

For more information about a field test of the effects of baiting and supplemental antlerless seasons on deer harvest, contact Timothy Van Deelen, Department of Wildlife Ecology, University of Wisconsin, Madison, WI 53706-1598, trvandeelen@wisc.edu.

Direct Benefits

The relationship between deer population size and DVCs can be highly variable (see earlier discussion). Nonetheless, based on Doerr, Knapp and others, a certain percentage in population size reduction may result in a similar percentage in DVC reduction.[52,53] However, reductions in population size of 50 percent or more may be hard to obtain, perhaps capping the potential reduction in DVCs at 50 percent or less.[52]

Indirect Benefits

Indirect benefits of reducing wildlife population size include reduced negative impacts from "overpopulation" on agricultural crops, silviculture, and natural vegetation.[55]

Undesirable Effects

Wildlife culling may not be favored or accepted by the public, especially in areas that have a high degree of ecological integrity ("hands-off" approach).[57,321,322] A public relations campaign should be considered along with a culling effort.

Culling may not be possible or effective on private lands, in remote locations, or in urban and suburban areas.[55,312] If refugia are present, more intensive effort will have to be undertaken at locations that are accessible to hunters or wildlife managers.[312]

The effort will have to be repeated periodically as the deer population will grow back to the same levels if the habitat conditions remain similar; it is not a one-time-only measure.

Recreational hunters tend to focus on mature bucks rather than young animals or does, which is the least effective way to reduce the population size.[55] A change in regulations may be required to allow for greater quota, specifically for younger animals and does.[312,323]

The number of hunters is declining, perhaps demanding a shift from recreational hunting to professional culling.[313,318]

Baiting in order to facilitate wildlife culling increases efficacy but is illegal in some areas, and it can lead to undesirable side effects such as increased risk of the spread of diseases, reduction in the consumption of natural foods and consequent changes in the ecosystem, population increase and consequent starvation, crowding, fighting and injuries of deer, deer domestication and habituation to unnatural foods and humans, decrease in hunter satisfaction, and increase in concerns of the nonhunting public.[323,324]

Costs

The costs for a controlled hunt were estimated at $117 per deer killed. The cost of using professional sharpshooters was $108–121–194 per deer for conservation officers, park rangers, and police officers, respectively.[52] Others estimated these costs at $91–310 per deer.[287]

Guidelines

No guidelines were identified in the literature review.

WILDLIFE RELOCATION

Wildlife relocation involves the capture, transport, and release of animals (mostly moving deer to another location). It is typically considered if population reduction is required but culling is not an option.

At the Sea Pines residential area on Hilton Head Island, SC, a deer relocation experiment was conducted.[325] The relocated deer experienced relatively high mortality from capture-related causes, and 50 percent of the relocated deer dispersed from their release site.[325]

Case Studies and Contacts

For more information on a field test of the live-capture and small-scale relocation of urban deer on Hilton Head Island, SC, contact Jennifer Cromwell, United States Department of Agriculture, Wildlife Services, Moseley, VA, 23120, (804) 734-7739, jennifer.s.cromwell@aphis.usda.gov.

Direct Benefits

The relationship between deer population size and DVCs can be highly variable (see earlier discussion). Nonetheless, based on Doerr, Knapp and others, a certain percentage reduction in population size may result in a similar percentage reduction in DVCs.[52,53] However, reductions in population size of 50 percent or more may be hard to obtain, perhaps capping a potential reduction in DVCs at 50 percent or less.[52] The effectiveness can be seriously diminished if it is an open population that allows the individuals from neighboring populations to fill the gaps or that allows the relocated individuals to return.[325]

Indirect Benefits

Benefits include reduced negative impacts from "overpopulation" on agricultural crops, silviculture, and natural vegetation.[55]

Undesirable Effects

With an open population or relocation over relatively short distances, individuals from neighboring populations may fill the gaps or a substantial portion of the relocated individuals may return to the original location, seriously limiting the effectiveness of this measure.[325] In one study, 50 percent of the relocated deer did not remain in their release area.[325]

The effort will have to be repeated periodically as the deer population will grow back to the same levels (growth, immigration, including of individuals that were relocated) if the habitat conditions remain similar; it is not a one-time-only measure.

Relocated individuals tend to experience a lower survival rate and increased human-induced mortality, including from the capturing effort.[325,326] Relocation of deer can result in the spread of infectious diseases.[327] Wildlife relocation is, in general, not recommended.[328]

Relocated individuals may compete with individuals that are already present at the release site, or they may contribute to the growth and overpopulation at the release site and the negative effects associated with overpopulation.[55]

The effort may not be favored or accepted by the public, especially in areas that have a high degree of ecological integrity ("hands-off" approach).[57]

Costs

The costs for relocation were estimated at $387 per relocated deer.[326] Others estimated these costs at $431 or $400–2,931 per deer.[287]

Guidelines

No guidelines were identified in the literature review.

ANTI-FERTILITY TREATMENT

Anti-fertility treatment can reduce reproduction of deer. (See references 329, 330, 331, 332, and 333.). This measure is typically considered or applied where killing (through hunting) is illegal (private lands, legislation) or impractical ((sub) urban areas, public pressure), where recolonization possibilities from elsewhere are limited (closed population), and where a relatively small deer population exists (e.g., 2000 or fewer breeding females). (See references 330, 334, 335, 336, and 337.) Some drugs have shown to be effective for up to 1 or 2 years, but repeated application is often needed. The reversibility of anti-fertility treatment can be considered an advantage (if reproduction is necessary later) as well as a disadvantage (continuing treatment required).[330,338]

Modeling efforts have shown that sterilization in combination with hunting can control the population size of deer.[334,335] For the deer on Cumberland Island National Seashore, GA, (herd size 1,500 animals), the model predicted that the herd size could be controlled at 750 animals if 200 sterilizations are done per year for the first 3 years, followed by 42 sterilizations per year for the following years).[334] Should the existing levels of hunting and predation continue, these numbers can be reduced to 81 (initial 3 years), but they would be higher for the following years (58 per year). Modeling by Seagle and Close showed that with contraception rates of less than 50 percent of female deer, the population growth curve was less steep, but herd size was not reduced.[335] A minimal contraception rate of 50 percent was required to reduce the herd size. With contraception rates greater than 50 percent, substantial changes in population size were only observed after 5–10 years. Variability of the results was high, suggesting that it is difficult to detect population changes in the field.[335] Another modeling effort showed that a deer population could be reduced by 30–60 percent in 4–10 years if 25–50 percent of the fertile females were sterilized annually.[339] Models developed by Porter and others showed that with 8 percent female dispersal, contraception would need to be effective in 32 percent of the females if the population were at about carrying capacity, and 68 percent if the population were at one-half of carrying capacity.[320]

Results of a field test on a suburban white-tailed deer population in Irondequoit, NY, using immunocontraception suggest that the measure may be most practical when a population density

between 30 and 70 percent of ecological carrying capacity is acceptable. However, it is only considered useful in relatively small and closed populations (≤ 200 females).[336] Walter and others captured and treated suburban female white-tailed deer in Connecticut with a contraceptive.[340] Baiting and capturing of the deer was more effective in spring than in fall. The study indicated that treatment of about 70 percent of the population was possible.[340] A capture and sterilization program for a white-tailed deer population in Cayuga Heights, NY showed that capture efforts had to be relatively high because the traps were not sex or age specific.[341] Furthermore, the efficacy of the sterilization program was dramatically reduced because it was not a closed population.[341]

Case Studies and Contacts

For information on a field test using immunocontraception in a suburban white-tailed deer in Irondequoit, NY, contact Brent Rudolph, Department of Fisheries and Wildlife, Michigan State University, East Lansing, MI 48824, (517) 432-4943, rudolp13@msu.edu.

For information on a field test using a contraceptive in a suburban white-tailed deer in Connecticut, contact David Walter, Oklahoma Cooperative Fish and Wildlife Research Unit, Oklahoma State University, 404 Life Sciences West, Stillwater, OK, 74078, wdwalte@okstate.edu.

For information on a field test using sterilization in a white-tailed deer population in Cayuga Heights, NY, contact Johnny Merrill, Cornell University, Department of Natural Resources, Fernow Hall, Ithaca, NY 14853, jam82@cornell.edu.

Direct Benefits

The relationship between deer population size and DVCs can be highly variable (see earlier discussion). Nonetheless, based on Doerr, Knapp and others, a certain percentage in reduction of population size may result in a similar percentage reduction in DVCs.[52,53] However, reductions in population size of 50 percent or more may be hard to obtain, perhaps capping the potential reduction in DVCs at 50 percent or less.[336] The effectiveness is seriously diminished if it is an open population that allows the individuals from neighboring populations to fill the gaps.[341]

Indirect Benefits

Benefits include reduced negative impacts from "overpopulation" on agricultural crops, silviculture, and natural vegetation.[55]

Undesirable Effects

Fertility control and immunocontraceptives by some drugs disrupt normal reproductive behavior and can cause physical problems with the reproductive system, abscesses and inflammations, weight gain, changes in general behavior, and changes in the sex ratio in the herd.[342,343] However, health problems and effects on social behavior may not always occur, or they may be minimal.[338]

The efforts will have to be repeated constantly in a population, and depending on the drug used, the same animals may have to be treated multiple times during their lives.(See references 330, 334, 338, and 344.)

The effort is less effective, or not effective, when recolonization from elsewhere can occur (open population).[335]

The method may only be feasible for relatively small populations (200 or fewer females).[336]

Costs

Walter and others calculated that $33,833 ($1,128 per treated deer) was required to treat 30 deer for 2 years (labor was 64 percent of the total budget).[340]

Guidelines

No guidelines were identified in the literature review.

HABITAT ALTERATION AWAY FROM THE ROAD

Deer population density depends on the quality of their habitat. An abundance of food and cover, in combination with an absence of predators and hunting, allows for relatively high population densities. (See references 55, 57, 312, 313, 314, and 315.) In general, good feeding habitat for deer may include young forests (e.g., in harvested areas that have been replanted or that have naturally regenerated), agricultural lands (hay or alfalfa meadows, especially if they are fertilized and irrigated, and crop lands), lawns and gardens (including golf courses), and riparian habitat.

Good cover is provided by forests or shrubland. When there is a matrix of good cover with good feeding habitat, deer population densities are typically relatively high. The size of the herd can be reduced through culling, relocation, or anti-fertility treatment, but if the habitat remains similar, deer densities will quickly return to their original levels, partly as the result of density-dependent fertility. Therefore habitat alterations that will limit the population density in certain areas can be considered. These measures may include reducing the amount of edge habitat by having larger patches of cover and feeding habitat or reducing the quality and quantity of the available food.[345]

Reducing the quality of the available food may be achieved by certain mowing or cutting practices, allowing for natural succession to more mature forests (where applicable) with different grass-herb and shrub vegetation on the forest floor, and reducing or stopping irrigation and the use of fertilizers.[346] Reducing the quantity of the available food can be achieved by allowing the natural succession to more mature forests (where applicable) with less grass-herb and shrub vegetation on the forest floor, or making prime feeding habitat unavailable to the deer, e.g., through the use of wildlife fencing.[346,347]

Reducing the quality of the available food may only limit populations in relatively poor years, and stimulating attractive browse to lure animals away from croplands may only work on a small scale and affect primarily females and has to take into account the relative attractiveness of the foods available in the area [345,348,349]

Some of the measures discussed above may take a long time to take effect, while other measures may require a change in land use practices. However, these types of measures would reduce the frequency and level of population culling, relocation, and anti-fertility treatment needed to reduce deer population density to an "accepted" level.

Case Studies and Contacts

For information regarding movements of female white-tailed deer in relation to timber harvests in the central Appalachians, contact Tyler Campbell, Warnell School of Forest Resources, University of Georgia, Athens, GA 30602, (706) 542-4280,tcampbell@smokey.forestry.uga.edu.

For information on the effects of food or cover removal on spacing patterns and habitat use in roe deer (*Capreolus capreolus*), contact Sandro Lovari, Section of Behavioral Ecology, Ethnology and Wildlife Management, Department of Environmental Sciences, University of Siena, Via Mattioli 4, 53100, Siena, Italy, lovari@unisi.it.

For information on changes in roe deer population density in response to forest habitat succession, contact Robin Gill, Forest Commission Res. Div., Alice Holt Lodge, Farnham, Surrey GU10 4LH, United Kingdom, robin.gill@forestry.gsi.gov.uk.

Direct Benefits

The relationship between deer population size and DVCs can be highly variable (see earlier discussion). Nonetheless, based on Doerr, and Knapp and others, a certain percentage in population size reduction may result in a similar percentage in DVC reduction.[52,53] However, reductions in population size of 50 percent or more may be hard to obtain, perhaps capping the potential reduction in DVCs at 50 percent or less.[336] The effectiveness of habitat alteration is less dependent on having a relatively small and closed population compared to population culling, relocation, and/or anti-fertility treatment.

Indirect Benefits

This WVC mitigation approach minimizes damage to agricultural crops and gardens and lawns.

Undesirable Effects

If the habitat is negatively affected on a large scale within a short time period, population control may be required to avoid potential starvation or dispersal in response to the reduction in habitat quality and availability.

Costs

Costs are expected to be highly variable depending on site-specific circumstances. No costs were identified in the literature review.

Guidelines

No guidelines were identified in the literature review.

CHAPTER 8. MITIGATION METHODS THAT SEEK TO PHYSICALLY SEPARATE ANIMALS FROM THE ROADWAY

This broad category of WVC mitigation strategies includes those that attempt to physically separate animals from the roadway. The specific mitigation measures reported on in this chapter, by broad category based on their intent, consist of the following:

- Wildlife fencing.
- Boulders in the right of way.
- Long tunnels and bridges over landscape.
- Wildlife underpasses and overpasses.

WILDLIFE FENCING

Fencing is one of the most commonly applied measures to separate wildlife from motorists.[3] Wildlife fences in North America typically consist of 2.0–2.4-m (6.5–8-ft)-high wire mesh fence material (figure 42). Several types of fence material are used, but page wire or cyclone fence material is most common. The Utah Department of Transportation has painted wire mesh dark brown, which effectively camouflages the wire mesh. Wooden or metal fence posts are typically used, and the latter are particularly important when fencing over rock substrates.

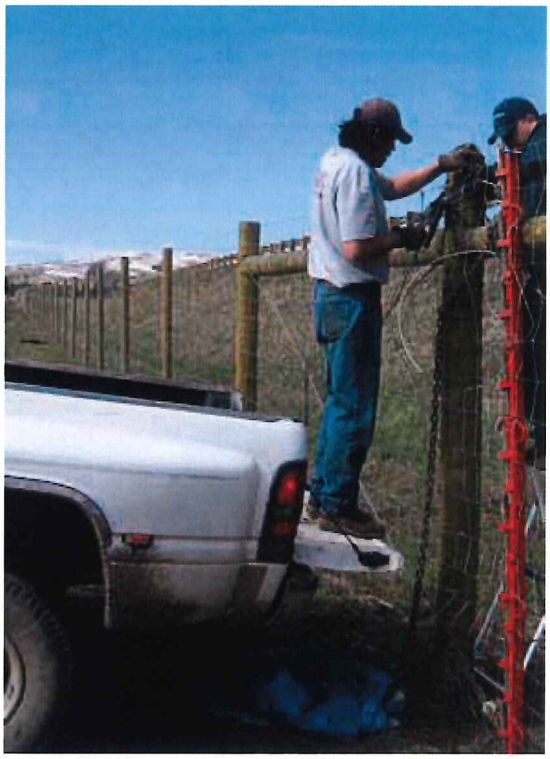


Figure 42. Photo. Wildlife fence along Interstate 90 near Bozeman, MT (copyright: Marcel Huijser, WTI).

Woods reported 94–97 percent reduction in ungulate-vehicle collisions along a fenced section of the Trans-Canada Highway.[350] Along the same road, Clevenger and others showed that fences were effective in reducing vehicle collisions with ungulates by 80 percent.[351] Clevenger and others also identified that WVCs were closer to fence ends than expected by chance; however, access points (gaps in the fence) were not hotspots for WVCs along the Trans-Canada Highway in Banff National Park, Alberta.[351] Dodd and others found that wildlife fencing in combination with underpasses reduced elk-vehicle collisions by 86.8 percent.[352] Reed and others reported an average reduction of 78.5 percent for deer vehicle accidents in Colorado, and Ward reported a reduction of greater than 90 percent for mule deer in Wyoming.[353,354] In Sweden, fencing reduced moose-vehicle collisions by 80 percent.[76] Boarman and Sazaki found that new or properly maintained fences significantly reduced mortality for several wildlife species, including the desert tortoise.[355] They found 93 percent fewer tortoise carcasses and 88 percent fewer vertebrate carcasses along a fenced section compared to an unfenced section of highway. In British Columbia, exclusion fencing (2.4 m (8 ft) high on both sides) was 97–99 percent effective at reducing accidents with large wildlife.[356] In Pennsylvania, Feldhamer and others determined that 2.7-m (8.9-ft)-high fence was more effective than the 2.2-m (7.2-ft)-high fence but that deer permeated both types of fences, and overall DVCs were not reduced.[294] They suggested that fencing may be effective if properly maintained to fix holes that people cut into it and to repair gaps that develop under the fence. They also suggest that the size of the openings in the woven wire mesh be decreased.

The effectiveness of electric fencing (ElectroBraid™) in keeping deer off runways at airports was studied by Seamans and VerCauteren, and their results could be applicable to preventing deer from accessing short segments of highway.[357] The authors found that fencing as low as 1.3 m (4.3 ft) was sufficient to exclude deer unless deer were pressured across it. Fences were highly effective (90 percent) when turned on and maintained.

In a theoretical study investigating how full fencing (no wildlife crossings) with the intent of keeping wildlife off of roadways and reducing wildlife mortality might affect the long-term viability of animal populations, Jaeger and Fahrig modeled population responses to a range of scenarios.[358] Their models showed that when no fencing was in place, traffic mortality had a stronger effect on population viability than the effect of animals avoiding the road. The authors concluded that fencing could improve viability in populations with high road mortality. They discouraged the use of fencing (without crossing structures) when the population size was stable.

Case Studies and Contacts

For more information about wildlife fencing in combination with wildlife overpasses and wildlife underpasses on the Trans-Canada Highway in Banff National Park, Canada, contact Anthony Clevenger, Western Transportation Institute, Montana State University, P.O. Box 174250, Bozeman, MT 59717-4250, (403) 609-2127, Tony.Clevenger@pc.gc.ca.

For more information about wildlife fencing and underpasses along State Route 260 in Arizona, contact Norris Dodd, Wildlife Research Biologist, Arizona Game and Fish Department, Research Branch, P.O. Box 2326, Pinetop, AZ 85935, (928) 368-5675, doddnbenda@cybertails.com.

For information about wildlife fencing along U.S. Highway 93, Flathead Indian Reservation, Montana, contact Pat Basting, Montana Department of Transportation, (406) 523-5872, pbasting@mt.gov.

For an evaluation of ElectroBraid™ fencing, contact Thomas Seamans; Wildlife Service, USDA, National Wildlife Resource Center, Ohio Field Station, Sandusky, OH 44870, thomas.w.seamans@usda.gov.

Direct Benefits

Depending on the species concerned, the type of fencing, and whether safe crossing opportunities are provided, wildlife fencing may reduce the number of WVCs 80–99 percent. It is important to note, however, that these reductions were obtained where wildlife fencing was used in combination with wildlife overpasses and/or wildlife underpasses. If safe crossing opportunities are not provided for, or if they are too few, too small or too far apart, animals are more likely to break through the wildlife fence, reducing the effectiveness of the wildlife fencing.

Indirect Benefits

Wildlife fences help keep pedestrians away from the travel lanes with fast-moving traffic.

Undesirable Effects

Wildlife fences, when installed correctly, form a nearly impermeable barrier to large mammals. While this can nearly eliminate collisions with large mammals or at least reduce the number of collisions substantially, wildlife fences result in several unintended side effects, for example:

- Animal movements across the road are blocked or nearly completely blocked, which increases the barrier effect of the road, disrupting daily, seasonal, and dispersal movements and potentially reducing the population survival probability of the species concerned. The species affected may include species that are not a safety threat or that may not have a population in the immediate vicinity of the transportation corridor. Therefore, absolute barriers, such as wildlife fencing, should always be accompanied with safe crossing opportunities.

- Animals are more likely to break through the wildlife fencing if safe crossing opportunities are not provided or if they are too few, too small, or too far apart. Even if safe crossing opportunities have been provided for, animals may still end up in between the fences, caught in the transportation corridor, and these animals may pose a safety risk and expose the species concerned to road mortality after all. Animals may end up in between the fences around fence ends, digging under the fence (coyotes slipped beneath the fence along the Trans-Canada Highway in Banff National Park), through gaps in the fence, or they may be able to climb the fence. Therefore, absolute barriers, such as wildlife fencing, should always be accompanied with escape opportunities for animals that end up in between the fences.

- Animals can and do cross the road where fences end. In some cases it can result in a concentration of AVCs at fence ends (Norris Dodd, Arizona Game and Fish Department, personal communication).[351] Therefore, consideration should be given to measures that mitigate a potential concentration of WVCs at fence ends.

- Wildlife fencing can have a negative impact on landscape aesthetics; many people perceive tall wildlife fences as ugly.

- Wildlife fencing may pose a direct or indirect mortality risk for certain species. Large mammals may get tangled up in the fence, or fences may injure them, potentially resulting in a slow death. In addition, wildlife fences may also be exploited by predators when pursuing prey. After the addition of two lanes on the Trans-Canada Highway and installation of fencing that cut off escape terrain for bighorn sheep, coyotes learned to stampede sheep into the fence. More than 30 sheep were killed this way until a mitigation measure was put in place (discussed later). In addition, wolves, bears, and other predators have also occasionally been seen running prey species into the wildlife fences.[359] Finally, birds may collide with fences and die.[360,361]

- Access roads to the main road require a disruption of the wildlife fencing, resulting in an opening that has to be mitigated in order to avoid animals getting caught inside the fences along the transportation corridor.

- Access for people (hiking, biking, fishing) may be blocked by wildlife fencing.

Wildlife underpasses and overpasses are tunnels and vegetated bridges designed for wildlife to allow them to cross the road. In addition, wildlife jump-outs are usually integrated with wildlife fencing. These features allow animals that do manage to cross the fence to escape from the fenced road and right of way. Other potential solutions for the unintended side effects described above are described in the next section "Addressing Undesirable Effects of Wildlife Fencing."

Costs

Wildlife fencing (2.4 m (8 ft) high) in Banff National Park, Alberta cost Can$30 per meter (Can$9 per ft) (one side of highway) during the phase 3A Trans-Canada Highway expansion in 1997 (Terry McGuire, Parks Canada, personal communication). For the entire 18-km section of highway, fencing both sides cost roughly Can$1,000,000. ElectroBraid™ fencing used in the study by Seamans and VerCauteren consisted of five-rope strands at 25 cm (9.7 inches) and cost $9 per meter ($2.7 per ft).[357] 1.2-m (4-ft)-high 5-Braid™ ElectroBraid™ Deer Exclusion Fence is advertised at $4,300 per km ($7,000 per mi), while 1.5-m (5-ft)-high, 5-Braid™ ElectroBraid™ Moose Exclusion Fence is advertised at $4,750 per km ($7,500 per mi).[362]

Sielecki compared the benefits to costs of fencing over different time spans (20–30 years) and given different levels of potential damage prevented. He determined that benefits of the wildlife fencing outweighed potential costs in 12 of 16 cases.[356] Fencing in his study ranged from Can$40,000–80,000 per km.

The cost of wildlife fencing along U.S. Highway 93 on the Flathead Reservation in Montana varied depending on the road section concerned: $26, $38, or $41 per m ($7.9, $11.6, or $12.5 per ft) (Pat Basting, Montana Department of Transportation, personal communication). A finer mesh fence was dug into the soil and attached to the wildlife fence for some fence sections at a cost of $12 per m ($6.7 per ft) (Pat Basting, Montana Department of Transportation, personal communication).

Fencing could be impractical in dense vegetation areas, where there is little or no public roadside right of way.

Guidelines

For large mammals and particularly ungulate species, the standard height of wildlife fencing is currently 2.4 m (8 ft). When targeting specific fauna of smaller size, lower fence heights and more customized designs are generally used.[355,363,364] To keep some climbing species (cougars, bears) from scaling, wildlife fences can be made higher, the mesh size can be made smaller, and outriggers or overhangs can be incorporated into the design.[365,366] Some testing of these fences has taken place in captive settings, but they have not been objectively tested in the field. Fencing should also be tied to the ground or buried into the ground, depending on the target species and soil characteristics. If properly installed, fence material (wire and posts) should last 20 years or more without integral replacement (Terry McGuire, Parks Canada, personal communication).[367] However, regular inspection for gaps and other problems is required.[368]

Regular fence maintenance is critical in order to keep the fence functioning properly. Earth slumping on hill slopes, inadequate installation techniques resulting in gaps between ground and fence bottom, and breaches of the fence by the public (e.g., hunters, snowmobile operators) allow animals to gain entry to the right of way. Fence maintenance is a major concern because priorities and budgets change over time. Fence maintenance is usually neglected shortly after construction; meanwhile fence damage and gaps are a recurrent problem.

ADDRESSING UNDESIRABLE EFFECTS OF WILDLIFE FENCING

Absolute barriers such as wildlife fences increase the barrier effects of a road, disrupting daily, seasonal, and dispersal movements and potentially reducing the population survival probability of the species concerned. The species affected may include species that are not a safety threat or that may not even have a population in the immediate vicinity of the transportation corridor. Therefore absolute barriers, such as wildlife fencing, should always be accompanied by safe crossing or escape opportunities for wildlife. The specific mitigation measures reported on in this section, by broad category based on their intent, consist of the following:

- Create gaps in fencing.
- Install wildlife underpasses and overpasses.
- Provide escape opportunities for wildlife stuck in the right of way using:
    - Jump-outs or escape ramps.
    - One-way gates.
- Mitigate WVCs at fence ends using:
    - Boulders between fence and roadway.
    - Animal detection systems.
- Improve landscape aesthetics of wildlife fencing.
- Reduce wildlife mortality risk of fencing.
- Mitigate gaps in fencing at access roads using:
    - Gates.
    - Cattle or wildlife guards.

Despite the fact that the primary intention of the various measures described in this section is to mitigate undesirable side effects of absolute barriers, some of the measures can also help further reduce WVCs while others may lead to an increase in WVCs. This is noted in the "direct benefits" and "undesirable effects" sections of the individual measures.

SAFE CROSSING OPPORTUNITIES: GAPS IN FENCE

Gaps in fences on opposite sides of the road allow animals to cross the road. In most cases such gaps are accompanied with wildlife warning signs, crosswalks for wildlife, wildlife warning signs in combination with mandatory or advisory speed limit reductions, or animal detection systems. Along SR 260 near Payson, AZ, a gap in an electric fence has been combined with an animal detection system (David Bryson, Electrobraid Fence Ltd., personal communication; Norris Dodd, Arizona Game and Fish Department, personal communication).

A system of wildlife fences and gaps was installed to reduce vehicle collisions with mule deer (*Odocoileus hemionus*) along a two-lane and divided four-lane highway in northeastern Utah.[41] The gap had warning signs for motorists, and a crosswalk was painted on the road surface as an additional sign for motorists. Road mortality was reduced by 42.3 percent (four-lane highway) and 36.8 percent (two-lane highway) compared to the expected road mortality. However, statistical significance of this reduction could not be demonstrated.

Similar to wildlife fences, median barriers can be an absolute or partial barrier to certain species.[310] In some cases gaps have been created in the median barrier to allow animals to cross the road. However, the effectiveness of these gaps has largely been untested.[310]

Case Studies and Contacts

For information on gaps in wildlife fencing with warning signs and crosswalk, contact John Bissonette, Utah Cooperative Fish Wildlife Research Unit, Utah State University, Logan, UT, 84322-5290, (435) 797-2511, john.bissonette@usu.edu.

An example of a gap in a wildlife fence accompanied by wildlife warning signs and an advisory speed limit reduction in The Netherlands is shown in figure 43.

An example of a gap in a wildlife fence combined with an animal detection system and accompanying wildlife warning signs and an advisory speed limit reduction in The Netherlands is shown in figure 44.



Figure 43. Photo. Gap in a wildlife fence accompanied by wildlife warning signs and advisory speed limit reduction, The Netherlands (copyright: Marcel Huijser).



Figure 44. Photo. Gap in a wildlife fence combined with an animal detection system, wildlife warning signs, and advisory speed limit reduction, The Netherlands (copyright: Marcel Huijser).

Direct Benefits

Wildlife fences may reduce road mortality by 80–99 percent but may increase the barrier effect of the road. Gaps in the wildlife fence allow animals to cross the road, but since they cross at grade, mortality occurs, reducing the effectiveness of the wildlife fence. Data are not available on the roadkill that occurs at a gap with or without warning signs, but a gap in a wildlife fence that is combined with wildlife warning signs and a crosswalk reduced the effectiveness of the wildlife fence from 80–99 percent to 42.3 percent (four-lane highway) and 36.8 percent (two-lane highway).[41] Animal detection systems have been used at gaps in wildlife fences, but there are no data on the effectiveness of this measure in combination with a gap in a fence. As a standalone mitigation measure, however, animal detection systems may reduce collisions with ungulates by 82 percent on average.[197]

Indirect Benefits

No indirect benefits were identified in the literature review.

Undesirable Effects

At gaps in fences, animals cross the road at grade, exposing the drivers and wildlife to potential collisions. This may reduce the effectiveness of the wildlife fence, but this depends on what type of warning signals are presented to drivers at the gap in the fence. No data have been located about the risk of gaps that have static warning signs, but the available data for animal detection systems suggest that a gap with an animal detection system may reduce the effectiveness of the wildlife fencing from 87 percent (on average) to 82 percent. In addition, once through a gap, animals may wander along the road or in the right of way, becoming trapped in between the wildlife fences, exposing the drivers and wildlife to other potential collisions. Measures that allow animals to escape from the road and right of way should be implemented (see further information later in this section).

Costs

The costs of crosswalks across a two-lane road and a four-lane road (excluding wildlife fencing and escape from right of way measures) were reported at $15,000 and $28,000, respectively.[41]

The estimated cost of animal detection systems at a gap in the fence is $50,000 (including installation and fence).[197]

Guidelines

See Lehnert and Bissonette for guidelines.[41]

SAFE CROSSING OPPORTUNITIES: WILDLIFE UNDERPASSES AND OVERPASSES

Wildlife underpasses and overpasses are used extensively by a wide array of species to get from one side of the road to the other side (figure 45 through figure 47). (See references 294, 368, 369, and 370.) The performance of these structures in reducing WVCs and creating crossing opportunities is linked to associated wildlife fencing that keeps animals off the road and funnels

them toward the wildlife overpasses and underpasses.[368] In some cases wildlife fencing is only installed over relatively short distances funneling wildlife towards a crossing structure.[371] The use of wildlife fencing was found to increase the use of underpasses by elk (*Cervus elaphus*) and increase the permeability of a road substantially.[352] In other cases wildlife underpasses and overpasses have no or very limited wildlife fencing, making them the primary measure to reduce WVCs on short road sections.

The location, type, and dimensions of wildlife crossing structures must be carefully planned with regard to the species and surrounding landscape. For example, grizzly bears, deer and elk tend to use wildlife overpasses to a greater extent than wildlife underpasses, while black bears and mountain lions use underpasses more frequently than overpasses.[368] In addition, different species use different habitats, influencing their movements and where they want to cross the road. Other factors that should be considered are the vegetation in the direct vicinity of the crossing structure (cover), co-use by humans, and the time it takes for animals to learn the location of the structures and to learn that they are safe to use.

In North America, wildlife overpasses are far less common than in Europe. Therefore there are few experiences with tunnels and wildlife overpasses, as only six of the latter are found in North America and only two in Banff have been studied with regard to their effectiveness in terms of reducing road mortality and allowing for safe crossing opportunities.

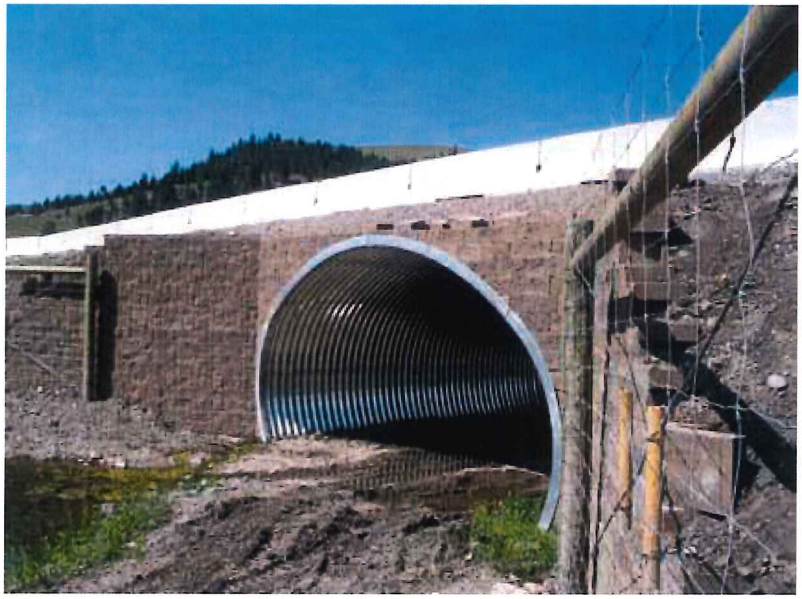


Figure 45. Photo. Wildlife underpass along U.S. Highway 93 on the Flathead Indian Reservation, MT (copyright: Marcel Huijser, WTI).

The use of wildlife underpasses and overpasses depends on many parameters, including their location in the landscape, their dimensions, the habitat surrounding the structures, human co-use,

and the time since installation (learning curve for the animals).[368] Furthermore, different species have different preferences.



Figure 46. Photo. Wildlife overpass in Banff National Park, Alberta, Canada (copyright: Marcel Huijser).



Figure 47. Photo. Underpass in southern Florida that allows for ecosystem processes (hydrology) as well as wildlife use, including the Florida panther (copyright: Marcel Huijser).

Case Studies and Contacts

For information on crossing structures in Banff National Park, contact Tony Clevenger, Western Transportation Institute, (403) 609-2127, tony.clevenger@pc.gc.ca.

For information on Florida crossing structures, contact Melissa Foster, University of Florida, Gainesville, FL.

For more information on wildlife underpasses and one wildlife overpass along U.S. Highway 93 on the Flathead Indian Reservation in Montana and on one wildlife overpass across Montana Highway 83 near Salmon Lake (in planning, under construction and completed), contact Pat Basting, Montana Department of Transportation, (406) 523-5872, pbasting@mt.gov.

For more information about wildlife fencing and underpasses along State Route 260 in Arizona, contact Norris Dodd, Wildlife Research Biologist, Arizona Game and Fish Department, Research Branch, P.O. Box 2326, Pinetop, AZ 85935, (928) 368-5675, doddnbenda@cybertails.com.

Direct Benefits

Wildlife overpasses and underpasses increase the effectiveness of wildlife fencing or other barriers alongside the road in reducing WVCs. If no safe crossing structures are provided, animals are more likely to break through the wildlife fencing (or other barrier) and thereby reduce the effectiveness of the wildlife fencing.

Indirect Benefits

Wildlife overpasses and underpasses provide crossing opportunities for wildlife, which are needed to mitigate habitat fragmentation effects of roads and maintain viable populations over the long term.

Undesirable Effects

If overpasses are not designed properly, wildlife that are reluctant to use the structure may try to breach the fence and cross the highway.

Costs

Costs vary widely depending on dimensions of underpass structures. Some estimated costs for different underpass structures are box culverts (3.0 m (9.8 ft) high by 2.5 m (8.2 ft) wide) = $Can2,800 per m ($854 per ft) length, elliptical culverts (4 m (13 ft) high by 7 m (23 ft) wide) = $Can5,400 per m ($Can1,646 per ft) length, open span bridge underpass (13 m (43 ft) wide by 5 m (16 ft) high) = $Can55,000 per m length (Terry McGuire, Parks Canada, unpublished data).

In The Netherlands, large underpasses (7–10 m (23–33 ft) wide) are estimated to cost €30,000–50,000 per m.[372]

Tunneling and overpass structures can cost approximately $Can33,650 per m ($Can10,259 per ft) for a 50-m (164-ft)-wide overpass to $Can119,300 for a 27-m (88-ft)-wide and 200-m

(656-ft)-long tunnel (Terry McGuire, Parks Canada, unpublished data). Actual overpasses were estimated at Can$1,750,000 (Anthony P. Clevenger, Western Transportation Institute, Montana State University, personal communication).

A proposed overpass across Montana Highway 83 near Salmon Lake (two-lane road) is estimated to cost $1,500,000–2,400,000.

The costs for seven wildlife overpasses in The Netherlands ranged between €1,400.000 and €5,600,000.[372]

Guidelines

Recommended minimum dimensions for underpasses and overpasses have been suggested for some ungulate species, but the needs of wide-ranging species are vague at best.[166] The most comprehensive guidelines for designing wildlife crossing structures, including most below-grade crossing structures, can be found in Iuell.[373] This European handbook draws from the wealth of European experience building a variety of wildlife crossings. Guidelines for different wildlife taxa in Europe and North America can be found in Iuell, Foster and Humphrey, Clevenger and Waltho, Clevenger and Waltho, and Kruidering and others. (See references 166, 372, 373, 374, and 375.) The last publication includes cost estimates for a range of types of crossing structures. Guidelines for wildlife crossings are being developed from NCHRP 25 to 27 and will available in 2008.

If large species are involved that are sensitive to human disturbance, or if multiple habitats have to be provided for on an overpass, wildlife overpass structures are generally recommended to be at least 50–70 m (164–230 ft) wide. Further rationale for this width is provided by Pfister and others, who showed that the increase in use of wildlife overpasses increases linearly until a width of about 50 m (164 ft) at which point the increase in wildlife use starts to taper off.[376]

ESCAPE OPPORTUNITIES FROM RIGHT OF WAY

Animals may end up in between fences or other barriers placed along the transportation corridor, posing a safety risk and exposing the species concerned to road mortality. Therefore, absolute barriers, such as wildlife fencing, should always be accompanied with escape opportunities for animals that have ended up in between the fences. (See references 82, 294, 370, and 377.)

ESCAPE OPPORTUNITIES FROM RIGHT OF WAY: JUMP-OUTS OR ESCAPE RAMPS

Jump-outs or "escape ramps" are sloping mounds of soil placed against a backing material approximately 1.5 m (5 ft) in height and constructed on the right-of-way side of the fence (figure 48). The highway fence (2.4 m (8 ft)) is lowered at the ramp site and forms an integral part of the jump-out that allows deer or other species to jump to the safe side of the fence. The vertical drop off on the back side of escape ramps is designed to preclude deer from gaining access to the right of way from the nonhighway side of the fence. Deer and elk are the most common users of jump-outs along the Trans-Canada Highway in Banff National Park, but moose and bighorn sheep have also used these structures (Bruce Leeson, personal communication).



Figure 48. Photo. Jump-out or escape ramp along U.S. Highway 93 on the Flathead Indian Reservation, MT (copyright: Marcel Huijser, WTI).

Bissonette and Hammer studied the effectiveness of earthen escape ramps (jump-outs) and one-way gates along a fenced section of U.S. 91 and U.S. 40 in northern Utah.[82] The 2.4-m (8-ft) fence was not 100 percent effective, due to human vandalism and gaps under the fence, so additional measures were necessary to help get deer off the highway. The authors noted peaks in DVCs in spring and fall, and noted that DVCs declined after installation of jump-outs. Jump-outs were eight to eleven times more effective than one-way gates. The authors calculated that if the ramps offset even 2 percent of deer mortality, they would be considered cost effective within 1 to 2 years. They recommended jump-outs instead of one-way gates and determined that (with fencing) these are effective mitigation measures at removing deer from highway rights of way and minimizing accidents with motorists. Clevenger and others documented use of jump-outs by deer, elk, and coyote on the Trans-Canada Highway.[378]

Case Studies and Contacts

For information on jump-outs along U.S. Highway 93, Flathead Indian Reservation, Montana, contact Pat Basting, Montana Department of Transportation, (406) 523-5872, pbasting@mt.gov.

For more information on field tests with escape ramps in Utah, contact John Bissonette and Mary Hammer, USGS Utah cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife, College of Natural Resources, Utah State University, Logan, UT 84322-5290, (435) 797-2511, john.bissonette@usu.edu; and hammer@wra-ca.com.

For information on field observations from jump-out use along the Trans-Canada Highway, Canada, contact Tony Clevenger, Western Transportation Institute, Montana State University, P.O. Box 174250, Bozeman, MT 59717-4250, (403) 609-2127, Tony.Clevenger@pc.gc.ca.

Direct Benefits

Using jump-outs or escape ramps along two fenced road sections reduced collisions by 28.6 percent on average.[82]

Indirect Benefits

No indirect benefits were identified in the literature review.

Undesirable Effects

If the jump-outs are not high enough, animals may jump up and end up in the right of way in between the fences. On the other hand, if jump-outs are too high, animals will not use them to escape from the transportation corridor. Furthermore, jump-outs need to be well away from the travel lanes and recovery zone to avoid cars running into them.

Costs

Reported costs for one jump-out include $11,000 and $6,250 (Pat Basting, Montana Department of Transportation, personal communication).[82]

Guidelines

The wall of a jump-out must be just high enough to discourage wildlife from trying to jump up into the right of way, but not so high that they discourage wildlife from jumping off. This is a delicate balance, and the optimal height of the jump-out is likely to be influenced by the species that is expected to breach the fence most often and the nature of the terrain surrounding the jump-outs (e.g., up slope or down slope). To prevent injury to the animals that jump out, the landing spot at the bottom of the jump-out should consist of loose soil or other soft material (Bruce Leeson, personal communication). Where bears are present, the walls must be smooth to prevent them from climbing into the right of way (Bruce Leeson, personal communication). Furthermore, it is thought to be best for jump-outs to be positioned in a set-back in the fence, in an area protected with tree cover, where animals may calm down and have time to decide whether to jump off the jump-out (Bruce Leeson, personal communication). A short fence on the jump-out itself, perpendicular to the road and the right-of-way fence, may also help guide animals to the jump-outs. For additional guidelines see Bissonette and Hammer.[82]

ESCAPE OPPORTUNITIES FROM RIGHT OF WAY: ONE-WAY GATES

One-way gates allow animals to enter from the road side and go through the fence, providing a possible opportunity for escape from the transportation corridor. Gates (figure 49 and figure 50) have been built for different species, including elk, deer, and the Eurasian badger.[82,370,372] Reed and others found one-way gates relatively effective for deer, whereas Lehnert found that only 17 percent of the deer that approached the gates ended up using them.[377,379] In general one-way

gates are no longer recommended as wildlife can learn how to use them to get into the right of way, sometimes aided by hikers, fisherman, equestrians, and bikers who propped and tied the gates open (Bruce Leeson, personal communication).[368] In Banff National Park, Canada, an elk herd not only learned how to go through the gate the "wrong way," but they also destroyed the gate within a week after they learned how to enter the gate from the wrong side (Bruce Leeson, personal communication). In the same area, coyotes learned to crawl through the tines to feed on mice that became more abundant in the right of way now that it was no longer grazed by ungulates (Bruce Leeson, personal communication). At another location, at least one elk has been observed taking a gate "out" as the gate was too small for its body size (Monique DiGiorgio, Southern Rockies Ecosystem Project, personal communication), and at least one moose has been observed getting stuck with its antlers and damaging its velvet (Rick Sinnott, Alaska Fish and Game, personal communication). Finally, jump-outs appear more effective than one-way gates in allowing ungulates to escape from the right of way.[82]

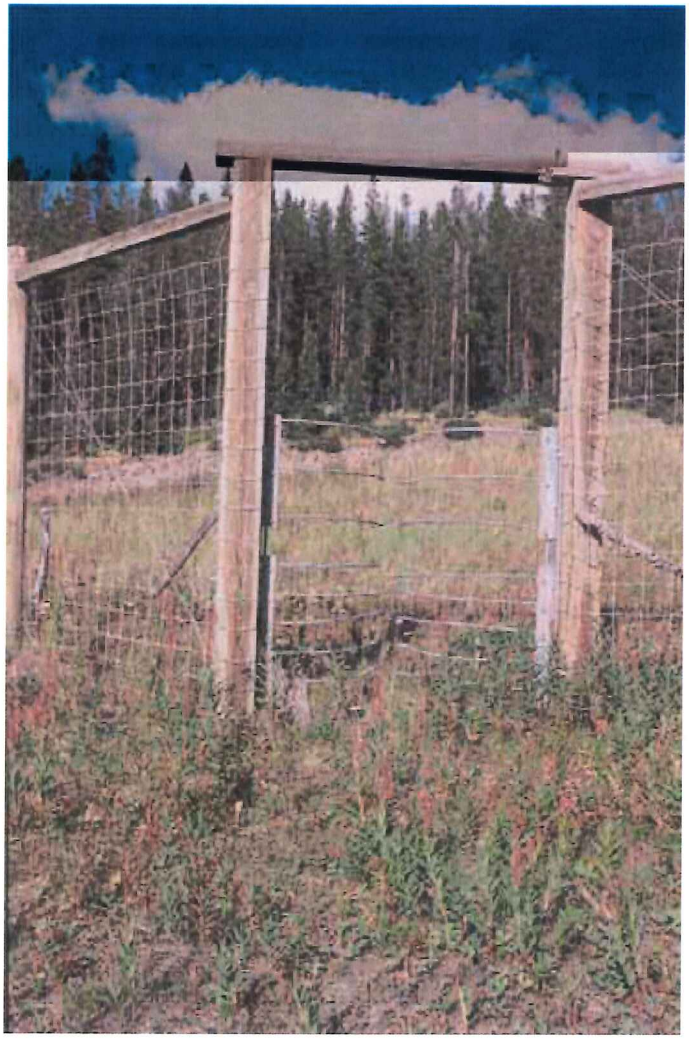


Figure 49. Photo. One-way elk gate in British Columbia, Canada (copyright: Marcel Huijser).



Figure 50. Photo. One-way Eurasian badger gate, The Netherlands (copyright: Marcel Huijser).

Case Studies and Contacts

For more information on one-way gates for deer in Utah, contact John A. Bissonette, Utah Cooperative Fish Wildlife Research Unit, Utah State University, Logan, UT, 84322-5290, (435) 797-2511, john.bissonette@usu.edu.[82]

Direct Benefits

No direct benefits were identified in the literature review.

Indirect Benefits

No indirect benefits were identified in the literature review.

Undesirable Effects

There are undocumented reports that animals tried to back up in elk gates, got stuck, wounded themselves, and died.

Costs

Estimated costs were reported at $8,000 per one-way gate.[82]

Guidelines

See Bissonette and Hammer for guidelines.[82]

MITIGATION FOR FENCE ENDS: BOULDERS BETWEEN FENCE AND ROADWAY

To discourage ungulate species from entering the fenced sections of the Trans-Canada Highway in Alberta, Canada, rock impediments or boulder fields were placed at the ends of the fence between the roadway and the fence, as shown in figure 51.[378] Boulders roughly the size of bowling balls were laid out uniformly to create a boulder field. The boulders are thought to discourage animals, especially ungulates, from walking on them.

The boulder field at Dead Man's Flats wildlife underpass along the Trans-Canada Highway east of Canmore, Alberta, is 100 m (328 ft) long with the width varying from about 8–20 m (26–66 ft), depending on how close the fence is positioned to the roadway, with the boulders extending right from the edge of pavement up to the fence (Bruce Leeson, personal communication) (figure 51). In addition, a 19-m (62-ft)-wide strip of boulders was placed in the median. The boulders are subangular, quarried rock, ranging in size from 20 to 60 cm (7.8–23.6 inches) (about 75 percent are larger than 30 cm (11.8 inches)). The boulder apron, at a depth of about 40–50 cm (15.7–19.7 inches), is installed on geofabric on subexcavated smoothed ground. The boulders project about 20–30 cm (7.8–11.8 inches) above the local ground surface (Bruce Leeson, personal comment).

Case Studies and Contacts

For information on the use of boulders between the fence and roadway at fence ends along the Trans-Canada Highway in Banff National Park, contact: Bruce Leeson, Bruce F. Leeson Environmental Consulting Co., 10011 5th St. S.E., Calgary, Alberta, Canada T2J 1L4, (403) 271-7235 (desk), (403) 869-8180 (cell), bfleeson@shaw.ca; and Tony Clevenger, Western Transportation Institute, Montana State University, P.O. Box 174250, Bozeman, MT 59717-4250, (403) 609-2127, Tony.Clevenger@pc.gc.ca.

Direct Benefits

Clevenger and others found that the combination of the boulder field and wildlife fencing were effective in reducing WVCs. Six DVCs occurred prior to fencing (and boulder field installation), while only two occurred after fencing.[378] The boulders were believed to be an effective deterrent in keeping ungulates from wandering in between the fences.[378]

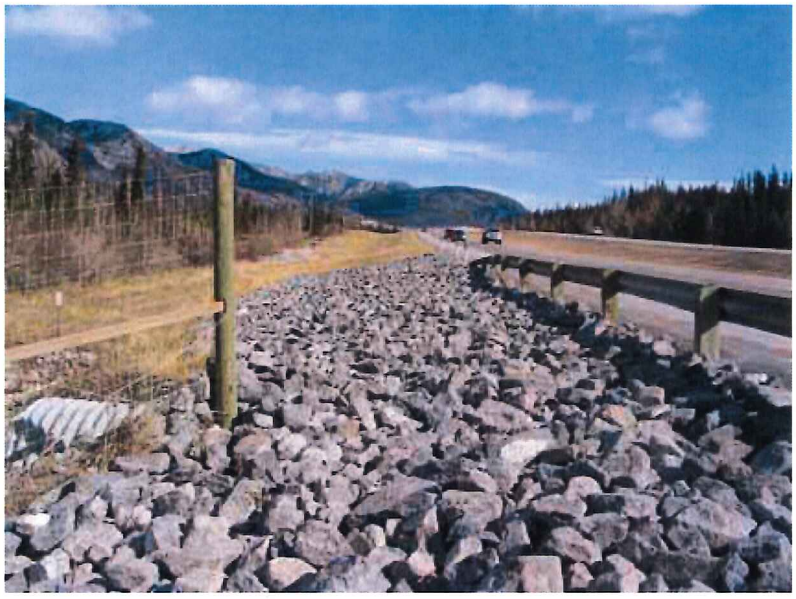


Figure 51. Photo. The boulder field at the fence end at Dead Man's Flats along the Trans-Canada Highway east of Canmore, Alberta, Canada (copyright: Bruce Leeson).

Indirect Benefits

No indirect benefits were identified in the literature review.

Undesirable Effects

In areas of regular snowfall, the boulder fields become covered with snow, which allows ungulates to travel across them. There may be some motorist safety issues for some states by having an obstruction (and hazard) within the clear zone. In Alberta these safety issues were addressed by placing a guard rail at the road edge.

Costs

The material and labor for the installation of boulders at the fence end at Dead Man's Flats wildlife underpass along the Trans-Canada Highway east of Canmore, Alberta, was estimated to cost Can$65,000 (installed in 2005, cost estimate for 2007) (Bruce Leeson, personal communication).

Guidelines

The boulder field begins at the fence end, sits on the margin of the paved edge of the highway, and is approximately 15 m (49 ft) wide. The length of the field starting at the fence ends is approximately 20–25 m (66–82 ft).

MITIGATION FOR FENCE ENDS: ANIMAL DETECTION SYSTEMS

Animals may cross the road where fences end, which can in some cases result in a concentration of AVCs. In Arizona, an experiment is currently being conducted with animal detection systems at fence ends to mitigate a concentration of deer and elk vehicle collisions (Norris Dodd, Arizona Game and Fish Department, personal communication).

Case Studies and Contacts

For information on animal detection systems at fence ends, contact Norris Dodd, Wildlife Research Biologist, Arizona Game and Fish Department, Research Branch, P.O. Box 2326, Pinetop, AZ 85935, (928) 368-5675, doddnbenda@cybertails.com.

Direct Benefits

The benefits of using animal vehicle detection systems at fence ends are unknown, but as a standalone mitigation measure, animal detection systems can reduce collisions with large ungulates by 82 percent.[197] The application of animal detection systems at fence ends can be expected to result in a similar reduction in WVCs, but data on effectiveness are relatively scarce and may vary.

Indirect Benefits

No indirect benefits were identified in the literature review.

Undesirable Effects

No undesirable effects were identified in the literature review.

Costs

No cost were identified in the literature review.

Guidelines

See Huijser and others for general design considerations.[197]

LANDSCAPE AESTHETICS OF WILDLIFE FENCING

Wildlife fencing can have a negative impact on landscape aesthetics; many people perceive tall wildlife fences as ugly. A potential solution is to replace wildlife fencing with large boulders (see earlier) to discourage ungulates from entering the right of way. However, there are no data on how effective large boulders are at reducing WVCs. Other approaches have been tried or are in the process of being tried to make the fence less visible by installing fences behind trees and painting the fence brown or green so that it blends in better with the background (Terry McGuire, Parks Canada, personal communication).

Case Studies and Contacts

For details on installation of fences behind trees along Trans-Canada Highway, contact Terry McGuire, Parks Canada, terry.mcguire@pc.gc.ca.

For information on future experiments with green instead of metal-colored fencing along the Trans-Canada Highway, contact Terry McGuire, Parks Canada, terry.mcguire@pc.gc.ca.

Direct Benefits

Colored fencing has no known additional impact on WVCs beyond the standard colored wildlife fencing.

Indirect Benefits

Less visible fences have reduced impact on landscape aesthetics.

Undesirable Effects

As fencing becomes less visible, the risk of wildlife colliding with it may increase (see "Reduce Mortality Risk of Wildlife Fencing" below).

Costs

Fencing costs remain similar to standard wildlife fencing (see earlier) (Terry McGuire, Parks Canada, personal communication).

Guidelines

Similar to standard wildlife fencing (see earlier).

REDUCE MORTALITY RISK OF WILDLIFE FENCING

Wildlife fencing may pose a direct or indirect mortality risk for certain species through entangling or wounding animals, or because predators run prey species into the wildlife fence. Parks Canada installed a green "curtain" on the wildlife fence along a section of the Trans-Canada Highway, which enabled the sheep to see the fence and veer away from it (Terry McGuire, Parks Canada, personal communication). Chestnut paling has been used in deer exclusion fences to make them more visible to birds, especially capercaille (*Tetrao urogallus*).[361]

Case Studies and Contacts

For details on the green curtain on the wildlife fence used to increase visibility for bighorn sheep along the Trans-Canada Highway in Banff National Park, contact Terry McGuire, Parks Canada, terry.mcguire@pc.gc.ca.

For information on chestnut paling used in a deer exclusion fence to increase visibility for birds, especially capercaille, contact: John Dobson, The Croft, Balmoral, Ballater, Scotland, AB35 5TX, forestry@balmoralestate.co.uk.

Direct Benefits

There is no additional benefit from this alteration that further reduces WVCs as compared to the basic WVC mitigation measure.

Indirect Benefits

Wildlife mortality as a result of the presence of the fence is decreased.

Undesirable Effects

Increased visibility of the fence may negatively impact landscape aesthetics.

Costs

No costs were identified in the literature review.

Guidelines

No guidelines were identified in the literature review.

GAPS CAUSED BY ACCESS ROADS

Access roads to the main road require a disruption of the wildlife fencing, resulting in an opening that has to be mitigated in order to avoid animals getting caught inside the fences along the transportation corridor. The following sections describe potential solutions to this problem.

GAPS CAUSED BY ACCESS ROADS: GATES

Gates can be opened when leaving or accessing the main road. This approach is an inconvenience to drivers, as they have to stop and get in and out of their vehicle. Gates are normally only installed at access roads that have very low traffic volume.

Case Studies and Contacts

For information on gates along U.S. Highway 93, Flathead Indian Reservation, MT, contact: Pat Basting, Montana Department of Transportation, (406) 523-5872, pbasting@mt.gov.

Direct Benefits

The use of gates results in no further reduction in collisions compared to an undisrupted wildlife fence (presuming the gates are closed by users).

Indirect Benefits

No indirect benefits were identified in the literature review.

Undesirable Effects

Gates are an inconvenience to drivers, and they may potentially increase WVCs if they are left open.

Costs

Costs for single- and double-panel gates along U.S. Highway 93 on the Flathead Indian Reservation, MT, were $300–360 and $350–550, respectively (Pat Basting, Montana Department of Transportation, personal communication).

Guidelines

No guidelines were identified in the literature review.

GAPS CAUSED BY ACCESS ROADS: CATTLE OR WILDLIFE GUARDS

Cattle or wildlife guards are designed to discourage wildlife, especially ungulates, from walking through a gap in the fence (figure 52). However, standard cattle guards may be easily passable by Florida Key deer and mule deer and dangerous to pedestrians and cyclists, and special designs may be needed (for example, those developed for the Florida Key deer).[380,381] In some cases, such as along a side road of the Trans-Canada Highway in Banff National Park, Canada, a wildlife guard has also been put under electric current to discourage bears from walking across it. An electrified mat across an access road has also been used to discourage ungulates from using a gap in a fence for an access road to approach a larger road with higher traffic volume and vehicle speeds (David Bryson, Electrobraid Fence Ltd, personal communication).



Figure 52. Photo. Wildlife guard along U.S. Highway 93 on the Flathead Indian Reservation, MT (copyright: Marcel Huijser, WTI).

Case Studies and Contacts

For details on an electrified wildlife guard in Banff National Park, Canada, contact Terry McGuire, Parks Canada, terry.mcguire@pc.gc.ca.

For information on wildlife guards along U.S. Highway 93 on the Flathead Indian Reservation, MT, contact Pat Basting, Montana Department of Transportation, (406) 523-5872, pbasting@mt.gov.

Direct Benefits

Cattle or wildlife guards offer no additional benefits in reducing WVCs compared to undisrupted wildlife fencing. Depending on the type of cattle or wildlife guard, the guard may be ineffective at discouraging certain species, or it may be only partly effective (e.g., 75–99 percent for Florida Key deer), depending on the type of wildlife guard.[381] Intrusions result in wildlife ending up on the road or in between the fences along the right of way, posing a threat to traffic safety and putting the animal's life in danger.

Indirect Benefits

Wildlife guards are easy on drivers as they do not require them to stop or get out of their vehicle. In addition, in contrast to a gate, a wildlife guard cannot accidentally be left open.

Undesirable Effects

Depending on the design, cattle or wildlife guards may be dangerous to pedestrians and cyclists and unpleasant to drivers.

As mentioned above, depending on the design and target species, some cattle or wildlife guards may be fully or partially passable to certain wildlife species.

Costs

The reported cost of a specially designed wildlife guard was $30,000 (Pat Basting, Montana Department of Transportation, personal communication).

Guidelines

See Peterson and others for guidelines.[381]

ACCESS FOR PEOPLE SUCH AS HIKERS, SKIERS, CYCLERS, AND FISHERS

Wildlife fencing presents people with a barrier. In some cases, access has been provided that allows people to cross the wildlife fence, for example to hike, cycle, or fish on the other side of the fence. Angled openings (figure 53) and swing gates, with or without steps to accommodate for deep snow (figure 54), have been implemented to allow access for people. In The Netherlands, gates for people have been installed that have angled doors that allow gravity to automatically close the gate (Marcel P. Huijser, Western Transportation Institute, Montana State University, personal communication).



Figure 53. Photo. Angled opening in fence allowing access for people along U.S. Highway 93, MT (copyright: Marcel Huijser, WTI).



Figure 54. Photo. Swing gate in fence (spring loaded) allowing access for people, along the Trans-Canada Highway in Banff National Park, Alberta, Canada (copyright: Adam Ford, TCH research project/WTI-MSU).

Case Studies and Contacts

For details on an opening in a fence along U.S. Highway 93 (south), contact Pat Basting, Montana Department of Transportation, (406) 523-5872, pbasting@mt.gov.

Direct Benefits

No direct benefits were identified in the literature review.

Indirect Benefits

No indirect benefits were identified in the literature review.

Undesirable Effects

Some access designs (e.g., the opening in a fence along U.S. Highway 93 (south) in Montana), have not been evaluated yet with regard to wildlife potentially using the structure to get into the right of way.

Not all access designs are accessible to handicapped individuals.

Costs

No costs were identified in the literature review.

Guidelines

No guidelines were identified in the literature review.

BOULDERS IN THE RIGHT OF WAY

Large boulders have been placed in the right of way, outside of the clear zone, as an alternative to wildlife fencing. Large boulders are thought to make it hard for animals, especially ungulates, to walk across an area. Boulders have been used for this purpose along State Route 260 in Arizona (Terry Brennan, U.S. Forest Service, personal communication; Norris Dodd, Arizona Game and Fish Department, personal communication) (figure 55 and figure 56). The boulder barrier was not extended through areas with steep slopes, since it was thought that wildlife would not move through these steep areas. However, animals have traveled through these areas. The barrier is thought to be effective with exception of the gaps in the steep areas. (Norris Dodd, Arizona Game and Fish Department, personal communication).



Figure 55. Photo. Large boulders pPlaced in the right of way as a barrier to elk and deer along State Route 260 in Arizona (copyright: Marcel Huijser).



Figure 56. Photo. Large boulders placed in the right of way as a barrier to elk and deer with a view of State Route 260 (under construction) in Arizona (copyright: Marcel Huijser).

Case Studies and Contacts

For information about the use of boulders as an alternative to wildlife fencing along State Route 260 in Arizona, contact Terry Brennan, Tonto National Forest, (602) 225-5375, tbrennan@fs.fed.us; and Norris Dodd, Arizona Game and Fish Department, Pinetop, AZ 85935, (928) 367-5657, doddnbenda@cybertrails.com.

Direct Benefits

The large boulders are believed to be an effective alternative to wildlife fencing if all the gaps are eliminated.

Indirect Benefits

In contrast to wildlife fences, large boulders are natural and, depending on the landscape, can address the landscape aesthetics concern associated with wildlife fences.

Undesirable Effects

If boulders are indeed an absolute barrier to ungulates and/or other species groups, safe passage may have to be provided for wildlife at selected locations. See the previous section on wildlife fencing on addressing undesirable effects of wildlife fencing.

Costs

Costs for the Arizona case study were less than $197 per m (less than $60 per linear ft) (Norris Dodd, Arizona Game and Fish Department, personal communication).

Guidelines

No guidelines were identified in the literature review.

LONG TUNNELS AND LONG BRIDGES OVER LANDSCAPE

In this section, long tunnels (or landscape bridges) are defined as tunnels that are at least several hundreds of meters long, sometimes many kilometers. They may include "cut and cover" strategies, where a "roof" is constructed over the road rather than a tunnel, leaving the landscape above intact. Long bridges (or elevated road sections) are defined as bridges that are at least several hundreds of meters long, sometimes many kilometers. Long tunnels and bridges are primarily constructed because of the nature of the terrain (e.g., through a mountain, across a floodplain), but in some cases they are constructed to avoid areas that are ecologically very sensitive and where no alternatives are available. If the nature of the terrain permits, animals can move freely over long tunnels or under long bridges, and because the animals are physically separated from traffic, WVCs are eliminated. While long tunnels and long bridges may be among the most effective mitigation measures to reduce roadkill, they are rarely specifically designed to reduce WVCs.

Long tunnels and long bridges should not be confused with wildlife overpasses or wildlife underpasses. Wildlife overpasses and underpasses are typically combined with wildlife fencing, and it is the wildlife fencing that keeps the animals from entering the roadway, whereas the primary function of wildlife overpasses and wildlife underpasses is to mitigate the barrier effect of the wildlife fencing and to provide safe crossing opportunities. Long tunnels and long bridges are not necessarily combined with wildlife fencing. They allow for free animal movements over or under the road, as well as other ecosystem processes, including those related to soil and hydrology (figure 57).



Figure 57. Photo. Long bridge on Arizona State Route 260 constructed in such a way as to minimize the impact to soil and vegetation (copyright: Marcel Huijser).

Case Studies and Contact

At one section of the U.S. 61 reconstruction project in Minnesota, Silver Creek Cliff, a tunnel was constructed. To meet the design standards for the reconstruction, the cliff top needed to be removed (estimated to be a million cubic yards of cut). Environmental and aesthetic concerns led to what was actually a less expensive solution. The Minnesota Department of Transportation was able to use the existing highway as a bypass during tunnel construction, which they would not have been able to do if a typical cut would have been used. This approach resulted in cost savings of earthwork (to remove the cliff top which was estimated to be one million cubic yards (765,000 cubic meters)) and no need for a construction of a bypass (estimated at $2 million due to the terrain restrictions). Additionally, this alternative was a much more environmentally friendly and aesthetically pleasing. The tunnel was constructed using the new Australian Tunneling Method (Scott Bradley, Minnesota Department of Transportation, personal communication). For further information, contact Scott Bradley, FASLA, Chief Landscape Architecture, MNDOT, (651) 284 3758, scott.bradley@dot.state.mn.us.

When State Route 40 in Florida was constructed, a long bridge over dry land was built in anticipation of a planned canal (figure 58). The canal was never built, but the bridge allows wildlife to pass unharmed underneath.



Figure 58. Photo. Long bridges do not have to be excessively large to provide ample space for wildlife crossings. While not exceedingly long, this bridge provides plentiful space for both the stream and wildlife to cross.

There are numerous other examples of long bridges and tunnels. A cut and cover option was used for a long tunnel in the United Kingdom (A12 Hackney to M11 link). A long bridge was constructed on roadway A9, over an important wetland surrounding the Mino River near Galicia, Spain. Interstate 70 in Glenwood Canyon, CO, has several sections that are elevated viaducts.

Direct Benefits

No data are available, but since there is a physical separation of the vehicles and animals, WVCs should be reduced by 100 percent or close to 100 percent.

Indirect Benefits

Long tunnels and long bridges allow for connectivity at the landscape level for a wide array of species. In multifunctional and agricultural landscapes, they also allow for humans, forest products, crops and livestock to freely move from one side of the road to the other.

Undesirable Effects

No undesirable effects were identified in the literature review.

Costs

A 200-m (660-ft)-long tunnel was constructed for Can$24,000,000. A 200-m (660-ft)-long elevated roadway (long bridge) cost Can$12,500,000 (Anthony P. Clevenger, Western Transportation Institute, Montana State University, personal communication).

Guidelines

No guidelines were identified in the literature review.

WILDLIFE UNDERPASSES AND OVERPASSES

Wildlife underpasses and overpasses are not always installed in combination with wildlife fencing (see earlier section on wildlife fencing in this chapter).[382] In some cases, the landscape in the surroundings of the crossing structures may guide the animals to the crossing structures, reducing the need for wildlife fencing. In other cases, wildlife fencing may not be on option, for example because of landscape aesthetics. For a discussion on wildlife underpasses and overpasses see the earlier section on addressing the undesirable effects of wildlife fencing in this chapter.

CHAPTER 9. PLANNING AND DESIGN CONSIDERATIONS

Many of the WVC mitigation measures discussed in this paper focus on spot or corridor solutions where WVCs are already a problem on existing roadways. However, integration of transportation planning and wildlife management on a regional level can impact WVCs. Typically these planning efforts are focused on mitigating environmental impacts. The context-sensitive design and context-sensitive solution (CSD/CSS) process may be a way to incorporate consideration of WVCs in planning and design. This section discusses selected planning efforts that can have an impact on reducing WVCs, including the following:

- Identifying and prioritizing WVC problem areas.
- Improved data collection and monitoring.
- Adjusting the road alignment by:
    - Considering the no-build option.
    - Considering alternative alignments.
    - Road removal.
- Consideration of design features of roadways.

IDENTIFYING AND PRIORITIZING WVC PROBLEM AREAS

WVC "hot spots" can be identified with crash and carcass data. To develop an understanding of the root causes of WVCs, one must also consider a context broader than simply the site of an animal carcass. This approach is multidisciplinary in nature and involves landscape ecology (a discipline that stresses understanding of the interactions of physical and biological phenomena at multiple spatial and temporal scales) and conservation biology (a discipline that integrates biological, social and physical sciences to develop a sound basis for the conservation, management, and restoration of biological resources). These scientific fields of study can lend understanding to the effects of spatial patterns, ecological processes, animal behavior, and related factors. Design of transportation systems and ecological networks (habitat linkage zones or greenways) should be based on such concepts. In turn, this scientific knowledge can be used in coordinated planning at multiple scales (e.g., site, local and regional planning) to address WVCs in broader contexts, thus avoiding such conflicts whenever possible.

In order to focus limited resources, some states have identified and prioritized habitat linkage zones that act as corridors for animals to move between major areas of habitat (e.g., development of Wildlife Habitat Linkage Plans). Again, the primary motivation is to improve habitat connectivity for wildlife and not necessarily to reduce WVCs. However, with proper planning these habitat corridors can focus animal movement to specific locations along the highway, which in turn allows for more focused mitigation of WVCs at those crossing locations.

There are a number of methods for prioritizing habitat linkage zones. One method is to look at existing WVC data to identify hot spots. Although this is a primary input for many prioritization methods, by itself it is not very forward looking, because changes in land use patterns can cause changes in animal movements. Also, there are many other sources of information that can be

used to identify potential future WVC problem areas, such as known locations of threatened and endangered species and known migration corridors.

Ruediger has been involved in a number of regional and statewide wildlife habitat linkage plans.[383] In formulating such plans, he suggests using a variety of data including aerial photos, vegetation maps, topography maps, wildlife habitat and range maps, and roadkill information. Another important source of information is local knowledge, which can be accessed by holding a workshop with appropriate stakeholders. The aforementioned data should be collected and presented on maps for this workshop. Also, a method for selecting prioritized linkage zones should be determined prior to the meeting. It is important to record information about the linkage zones identified (e.g., location, species of concern, local agencies and individuals with special knowledge of the linkage zone, major purpose of the linkage zone, and a prioritization ranking for the linkage zone).

According to Levy, a prioritized linkage zone map was created for Arizona.[384] The map was created during Arizona's Missing Linkages Workshop in April 2004. The workshop included representatives from ADOT, FHWA, U.S. Fish and Wildlife Service, Arizona Game and Fish Department, U.S. Department of the Interior's Bureau of Land Management, Tonto National Forest, and Northern Arizona University. This initial map was refined during six ecoregional workshops in November 2004. Geographic Information Systems (GIS) databases were helpful in obtaining some of the data that were used in prioritizing the linkage zones.

The University of Alaska Anchorage produced a "toolbox" for the Alaska Department of Transportation and Public Facilities to assess how Alaskan roads affect habitat quality and connectivity.[385] The project specifically addressed the use of GIS to assist transportation planners with project development. Based on workshops, GIS data sets, and relevant literature, the effort identified high-priority areas for habitat linkage based on four criteria:

- Places where good data exist on habitat features and that represent the diversity of ecosystems.
- Riparian corridors.
- Places where funding can be leveraged.
- Places that can provide a source of baseline data.

The Florida Department of Transportation has created a program to identify and prioritize habitat linkage zones that intersect with highways.[386] The purpose of this program is to consider underpasses or culverts on a statewide level in order to restore habitat connectivity and ecological processes. This method uses a rule-based GIS model to assimilate multiple factors such as roadkill hot spots, riparian areas, greenways, protected conservation lands, and known wildlife movement routes.

The Idaho Transportation Department identified wildlife connectivity areas using an approach that integrated GIS spatial data, GIS linkage model analysis, and expert workshops to identify areas of interest for mitigation consideration in the southeast corner of the state.[387] A number of

models predict optimal crossing locations for specific species such as Key deer in Big Pine Key, FL, and grizzly bear in the area around Evaro Hill, MT.[388,389]

Once habitat linkage zones are identified and prioritized, efforts need to be made to preserve them. A crossing structure can be constructed in a high WVC zone only to have development adjacent to the highway block animal movement so the animals cross at another location along the highway.

This type of effort is inherently multi-agency in nature and should involve local land grants, cities, counties, special interest groups, land owners, resource agencies, rail lines, and State DOTs. A team is attempting to follow this process for Interstate 90 on Bozeman Pass in Montana. The team includes Gallatin Valley Land Trust, Forest Service, Montana Department of Transportation, Montana Rail Link, American Wildlands, and others. This location is clearly a habitat corridor as two areas of the Gallatin National Forest are separated by a corridor that includes private land under heavy development, an interstate, and a rail line. Any effort to preserve the corridor by a single agency would be ineffective, because increased interstate traffic and increased development each threaten to block animal movement. However, by prioritizing specific crossing locations, land trusts can focus efforts to preserve adjacent lands, and the Montana Department of Transportation can optimize its investment in mitigation measures on the interstate.

The effort must go beyond prioritizing greenways to incorporation of linkage zones into transportation and conservation planning elements (of comprehensive plans) that are developed at both local and state levels of government. At a minimum, the statewide transportation improvement program should be reviewed annually for reconstruction projects that cross these habitat linkage zones. Incorporating WVC mitigations into a reconstruction project (especially at the initial project planning stage) will be much less expensive than installing them as separate projects.

Case Studies and Contacts

For information on efforts in Arizona, contact Steve Thomas, Environmental Program Manager, FHWA Arizona Division, steve.thomas@fhwa.dot.gov.

For information on Florida's prioritization efforts, contact Dan Smith, Western Transportation Institute, (406) 994-6114, dan.smith@coe.montana.edu.

For general methodologies for prioritizing habitat linkage zones, contact Bill Ruediger, Wildlife Consulting Resources, (contracted by USDA Forest Service, Wildlife, Fish and Watershed Unit, Washington Office) bruediger@fs.fed.us.

For information on the Bozeman Pass collaboration in Montana, contact Deborah Wambach, Montana Department of Transportation, (406) 444-0461, dwambach@mt.gov; or Josh Burnim, American Wildlands, (406) 586-8175, jburnim@wildlands.org.

For general information on the planning process, consult chapter 6 in National Research Council, chapter 3 in NCHRP Synthesis 305 by Evink, chapters 6 and 7 in Moore and Thorsnes, and the

following Web sites: FHWA, www.fhwa.dot.gov/planning/, and American Planning Association, www.planning.org.[86,302,390]

DATA COLLECTION AND MONITORING

Like prioritizing habitat linkage zones (discussed in the previous section), data collection and monitoring will not have direct benefits in reductions of WVCs, but without good data on the magnitude, location, and type of WVCs, all other mitigations discussed in this report cannot be installed at the locations where they will have the most impact. WVC data are crucial in justifying and prioritizing locations for mitigation. Additionally, in order to utilize the most effective mitigations for WVCs, the effectiveness of currently installed measures must be evaluated.

As discussed in the chapter on Causes and Factors, there are three primary sources of WVC data: insurance data (which are not spatially located), crash reports, and animal carcass counts. The NCHRP Project 20-05–Topic 37-12 provides a current state of the practice on WVC data collection. The report for this project is currently in draft form.[31] A survey conducted as part of this report asked states if they collected WVC data (crashes or carcasses). Of the 30 State transportation departments that responded to the survey, 19 collected crash data on WVCs, 13 collected carcass data, and 8 collected neither. It should be noted that although the states reported that they did not collect WVC data, a review of crash reports shows that every state except one has "animal" as a check box on the crash form. Of the 30 responding state departments of natural resources, 9 said they collected crash data, 15 said they collected carcass data, and 12 said they collected neither. There is also a dramatic drop in data collection on local and collector roads compared to interstates and arterials. Many states discussed problems with the data, including inconsistencies, location accuracy, and underreporting.

There are currently efforts underway to improve WVC data. For collecting carcass data, the Maryland Department of Transportation has a program Large Animal Accident Removal Reporting System (LARRS) that is implemented from the top down so that there is a consistent standard within the department. This program is integrated with an existing form for maintenance tasks that maintenance workers are required to fill out regardless of carcass data collection. Since maintenance workers are required to fill out the form anyway, they are more likely to accurately complete the required form (as opposed to adding another form exclusively for carcass data). To assist with data collection of carcasses, GPS-enabled handheld computers (personal digital assistants) have been developed, mostly as prototypes. One such system is the Roadkill Observation Collection System (ROCS) currently under development by the Western Transportation Institute. Another potential source of data is the use of volunteers.

Case Studies and Contacts

For information on the Maryland LARRS carcass data collection method, contact William Branch, Maryland Department of Transportation, (410) 545-8626, WBranch@sha.state.md.us.

For more information on handheld GPS units for automatically collecting data (ROCS), contact Amanda Hardy, Western Transportation Institute, (406) 994-2322, ahardy@coe.montana.edu.

ALTERNATIVE ALIGNMENT, ROAD REMOVAL, OR NO NEW ROAD

Integration of transportation and conservation planning at multiple scales is essential to addressing WVCs. With this integration, the transportation network can be developed with consideration of ecologically sensitive areas, and some efforts can be made to minimize environmental impacts in locating new roads and possibly closing existing roads. Typically these efforts are aimed at conservation but can have an impact on reducing WVCs.

There are several models that are used to assess the ecological impact of new roadway alignment options on wildlife. Maurer developed one such model for the Pennsylvania Department of Transportation.[391] A community-based, landscape-level terrestrial decision support system was developed with the objective to maintain the ecological integrity of Pennsylvania ecosystems. This model is founded on seven basic characteristics: comparison, reasonableness, practicality, sensitivity, data, process, and decision making. Variables for Assessing Reasonable Mitigation in New Transportation (VARMINT) include habitat importance, stewardship, patch size and shape, connectivity, proximal land use, relative significance, natural processes, diversity, anthropic use, and intangibles. Each site is assigned scores for each of these criteria. Comparison of scores determines relative ranking.

CSD/CSS processes are used to incorporate community values, aesthetics, and environmental and other priorities into the design process. Using the CSD/CSS process could result in alignments that minimize the impact of WVCs. For more information on the overall CSD/CSS process, refer to the following reports:

- NCHRP 480, *A Guide to Best Practices for Achieving Context Sensitive Solutions.*[392]
- *AASHTO Guide for Achieving Flexibility in Highway Design.*[393]
- NCHRP Report 69, *Performance Measures for Context Sensitive Solutions: A Guidebook for State DOTs.*[394] Note that this report details how to develop a CSD/CSS program and track performance with surveys. Although there is some discussion on developing performance criteria (at the project and programmatic level), specific measures are not discussed as the title may imply.

In 2003, the California Department of Transportation closed a functional but little-used highway interchange (e.g., on ramps, off ramps and underpass) on State Route 91 called the Coal Canyon Interchange. The mainline is eight lanes with 200,000 vehicles per day, but the interchange was used by fewer than 150 motorists per day. The main motivation for the closure was connecting habitat between Chino Hills and Cleveland National Forest. However, WVCs were another consideration due to mountain lion roadkills.[395] The underpass (in combination with fencing) now serves as a critical connection in a wildlife migration route.[395]

Closing the Coal Canyon Interchange was seen by one city as a loss of tax revenue since it limited development on one side of the highway. There will likely be heavy opposition to such closures by some landowners based on concerns regarding reduced property values and ability to develop property. Obviously, significant resources went into the original construction and maintenance of the roadway and removing a roadway essentially wastes that initial investment in

infrastructure. A better option is to more strategically plan the transportation network (e.g., do not build the road in the first place). However, in some cases it may be feasible to remove a roadway given the right mix of limited development, public grass roots support, and preservation of surrounding habitat.

The Coal Canyon project cost $440,000 to remove the roadway underpass, remove the on/off ramps, provide a median turnaround for emergency vehicles, and provide fencing to guide animals to the underpass. Note that $40,000,000 was used to purchase the surrounding land to protect the habitat.

Most other examples of removing roadways in the United States involve gravel roads on public lands (e.g., forest service roads). As Switalski and others point out, the impact to wildlife has not been monitored or researched.[396] Switalski and others suggest costs for road removal are as follows:

- Gating the roadway ends and leaving the road intact: $1,000–2,800.
- Blocking the roadway ends with permanent traffic barriers such as boulders and berms: $800–1,000.
- Ripping roadbed: $400–1,200 per km ($650–1,950 per mi).
- Stream crossing restoration: $500–150,000 per crossing.
- Full recontour of slopes: $3,000–200,000 per km ($4,850–322,000 per mi).[396]

Figure 59 shows a road removal in process in Belgium. In this case there was an alternate route, and this roadway was considered unneeded. It was replaced by a nonmotorized multiuse pathway.



Figure 59. Photo. Road removal in progress in Belgium (note that a path for pedestrians and bicyclists remains in place.) (copyright: Bethanie Walder).

Case Studies and Contacts

For further information on the Coal Canyon Interchange removal, contact California Department of Transportation, District 12, (949) 724-2000.

Although primarily focused on roads on public lands, a good source of information on road removal is the Wildlands Center for Preventing Roads, http://www.wildlandscpr.org/ (accessed January 25, 2007).

CONSIDERATION OF DESIGN FEATURES

Consideration of some basic WVC mitigation principles in designing various elements of a highway could minimize the potential for WVCs. Some of these items have been discussed in the previous chapters but could be implemented as part of the initial design and thus are mentioned here. The following items should be considered when designing roadways that have a high likelihood for WVCs (see chapter 2), such as two-lane, rural/suburban, low-/medium-volume highways that pass through wildlife habitat:

- Steep side slopes can hide approaching animals from the driver's view. The AASHTO Green Book recommends slopes of one foot vertical to four feet horizontal or flatter.[1] It further recommends that slope transitions should be gently rounded. This slope is clearly visible (whether cut or fill) by the driver. Designers should use steeper fill slopes with caution, as drivers may not be able to see deer approaching the roadway until the animal

leaps over the guardrail. If a steeper side slope is used, consider a landing on the top for animals to be visible to drivers (and visa versa) before jumping over the guardrail.

- At locations where the roadway crosses drainages, known migration corridors, or known animal habitat, the designer should take extra caution to make animals visible to drivers. At these locations avoid curves, steep side slopes, and narrow clear zones.

- At locations where culverts or bridges are installed, consider making the culverts and bridges wide enough to include opportunities for animals to cross under the road. This consideration relates especially to terrestrial animals that may require a bank on either side of a stream or river to cross under the road.

- When designing drainage, consider the impact on wildlife movement and attraction. Avoid creating pooled water in the right of way which can create attractive vegetation. Some wildlife will avoid crossing rip-rap. If rip-rap funnels animals to an undesirable crossing location, consider filling gaps in the rip-rap with sand and gravel (which may make it more conducive for animals to cross) or extend the rip-rap to a more suitable crossing location.

- When considering seeding mixes for the roadside, consider unpalatable species. Also consider plants that do not grow so tall as to visually obscure animals approaching the roadway.

- Concrete median barriers can cause problems for wildlife. When crossing the roadway, wildlife may pause at the barrier or turn around, increasing their time in the roadway. A summary of the literature by Clevenger and Kociolek found that "the general hypothesis is that concrete Jersey barriers may increase the risk of direct vehicle mortality [of wildlife]."[310] Mitigations include gaps in the barrier at strategic hot spot locations, cutouts at the bottom for small animals, or using cable barrier designs instead.

- Aside from the basic principles listed here, the designer should estimate the potential magnitude of the WVC problem when designing a road. If there are areas along the route that have a high potential for WVCs, the designer should consider including some of the mitigations mentioned in this report (e.g., wildlife fencing).

CHAPTER 10. EVALUATION OF MITIGATION METHODS BY TECHNICAL WORKING GROUP

The WTI-Berger Team convened a Technical Working Group Meeting on January 25, 2007, at FHWA Headquarters. The Technical Working Group consisted of a panel of seven national experts in the area of WVCs. The experts were identified and selected by the FHWA Project Committee during the June 30, 2006, kickoff meeting. An effort was made to include representation from academia, State transportation departments, Federal agencies, and nongovernment organizations. The Technical Working Group members are listed in table 9.

Table 9. Technical working group members.

Name	Organization
Bill Branch	Maryland DOT
Michael Pawlovich*	Iowa DOT
Scott Jackson	U.S. Fish and Wildlife Service
Susan Hagood	The Humane Society of the United States
Brent Haglund	Sand County Foundation
Sandy Jacobson	Forest Service
Keith Knapp	Texas Transportation Institute

*Participated by phone

The Technical Working Group reviewed a draft version of this report and helped identify other sources of information that would be beneficial. Another purpose of this meeting was to have a group of national experts evaluate the effectiveness of the mitigations based on their knowledge. Initially, the Project Committee (FHWA) and the WTI-Berger Team wanted to use the NCHRP 500 categories for safety mitigations. The categories defined in the NCHRP 500 report are:

> Tried (T)—Those strategies that have been implemented in a number of locations and may even be accepted as standards or standard approaches but for which valid evaluations have not been found. These strategies, while in frequent or even general use, should be applied with caution, carefully considering the attributes cited in the guide and relating them to the specific conditions for which they are being considered. Implementation can proceed with some degree of assurance that there is not likely to be a negative impact on safety and very likely to be a positive one. As the experiences of implementation of these strategies continues under the AASHTO Strategic Highway Safety Plan initiative, appropriate evaluations will be conducted, so that effective information can be accumulated to provide better estimating power for the user, and the strategy can be upgraded to a "proven" one.[397]
>
> Experimental (E)—Those strategies that have been suggested and that at least one agency has considered sufficiently promising to try on a small scale in at least one location. These strategies should be considered only after the others have proven not to be appropriate or feasible. Even where considered, their implementation should initially occur using a very controlled and limited pilot study that includes

> a properly designed evaluation component. Only after careful testing and evaluations show the strategy to be effective should broader implementation be considered. As the experiences of such pilot tests are accumulated from various state and local agencies, the aggregate experience can be used to further detail the attributes of this type of strategy so that it can be upgraded to a "proven" one.[397]
>
> Proven (P)—Those strategies that have been used in one or more locations and for which properly designed evaluations have been conducted that show it to be effective. These strategies may be employed with a good degree of confidence, but with the understanding that any application can lead to results that vary significantly from those found in previous evaluations. The attributes of the strategies that are provided will help the user judge which strategy is the most appropriate for the particular situation.[397]

A properly designed evaluation for the "proven" category has a fairly strict definition in the safety field, including a Bayesian analysis of crash data. (Note: Bayesian analysis evaluates the consistency or inconsistency of new evidence with a given hypothesis.) Bayesian analysis does require the a priori assignment of probabilities to hypotheses, which, depending on the question, may be subjective. As an example, a mitigation that has been proven to keep animals off the road would not be proven if no studies on WVCs with a Bayesian analysis were completed, even though logically these would be known to be effective. The Technical Working Group concluded that under this definition, none of the mitigations would be defined as proven, and almost all of the mitigation measures would be classified in the "tried" category. The Working Group members felt that the strict safety definitions would not do justice to their experience with certain mitigation measures and effectiveness data gathered on them. The meaning of "properly designed evaluation" was left up to the individual members of the Technical Working Group and did not require a Bayesian analysis of crash data. To avoid confusion with the safety definitions, the names of the above three definitions were changed. Also, two categories were added. The new definitions adopted by the Technical Working Group for this evaluation were:

- Successful (similar to "proven" safety definition): Mitigation measures that have been used in one or more locations and for which properly designed evaluations have been conducted that show them to be effective.

- Demonstrated (similar to "tried" safety definition): Mitigation measures that have been implemented in multiple locations and that may even be accepted as standards or standard approaches but for which valid evaluations have not been found.

- Attempted (similar to "experimental" safety definition): Mitigation measures that have been suggested and that at least one agency has considered sufficiently promising to try on a small scale in at least one location. However, data on effectiveness have not been documented or have not yet been published.

- Unknown: Mitigation measures that have not been tried or that have been tried, but not for WVC reduction, were not implemented correctly, or are only recently being tried.

- Failed: Mitigation measures that have been used in one or more locations and for which properly designed evaluations have been conducted and show them NOT to be effective.

The procedure for voting was as follows. The mitigation was described by the WTI-Berger Team. The panel members were asked to base their vote on the effectiveness in reducing DVCs. The vote was not based on mitigation for other effects related to roads and traffic (e.g., barrier effect) or for species other than deer (white-tailed and mule deer combined). Deer are involved with the majority of all reported WVCs (chapter 2). If panel members had been asked to consider multiple species representing very different species groups, the procedure would have had to have been repeated for each species or species group. Limited data are available to evaluate the effectiveness of many of the mitigation measures for species other than deer.

After hearing a description of each individual mitigation measure, the Technical Working Group voted. If the vote was unanimous, the next mitigation was considered. If there was contention, the panel discussed the rationale for their votes, and the members were allowed to change their votes based on new information provided by the other panel members. However, a unanimous vote or consensus was not required.

The results of this process are shown in table 10. The mitigation "reduce speed by posting advisory speed signs" was not included since the Group felt this was very similar to warning signs. The mitigation "carcass removal" was also not included since the Group felt that this mitigated for scavengers only and not for deer. The mitigation "increase visibility of animals to drivers: reduce height of snow banks" was not included because this section was added to the report after the ranking meeting. Most of the mitigations that provide crossing opportunities are not included, since their purpose is to mitigate the barrier effect of fencing and are not mitigations for WVCs by themselves.

Table 10. Technical working group rankings.

Measure	Votes Received				
	Suc-cessful	Demon-strated	Attemp-ted	Un-known	Failed
Mitigations that attempt to influence driver behavior					
Public information and education		7			
Standard wildlife warning signs		2			5
Large, nonstandard wildlife warning signs	1	5			1
Seasonal wildlife warning signs		7			
Roadside animal detection systems (RADS)		2	5		
In-vehicle (veh.) warnings: RADS to on-board				7	
In-veh. warning: on-board animal detectors			7		
Increase visibility: roadway lighting		7			
Increase visibility: vegetation removal		7			
Increase visibility: wider road striping				7	
Reflective collars (buffalo)				7	
Reduce traffic volume on road network				7	
Seasonal closure				7	
Reduce speed by reducing posted speed limit		6	1		
Reduce speed by traffic calming	1	5	1		
Wildlife crossing guards	4*	3			
Mitigations that attempt to influence animal behavior or population size					
Deer reflectors and mirrors		6			1
Audio signals in row or deer whistles		1			6
Olfactory repellants		3	4		
Deer flagging models			6	1**	
Hazing		3	4		
Investigate deicing alternatives			7		
Intercept feeding			7		
Influence species/nutritional value in ROW		7			
Expanded median				7	
Mitigations that seek to reduce wildlife population size					
Wildlife culling		7			
Wildlife relocation		6			1
Anti-fertility treatment		7			
Habitat alteration			4	3	
Mitigations that attempt to physically separate animals from the roadway					
Wildlife fencing	4	3			
Boulders fence			7		
Long tunnels and long bridges	7*				
Underpasses and overpasses		7			
Underpasses/overpasses and fencing	7				

*Although this mitigation has not been proven through evaluation procedures, it is intuitive that it definitely works.
**Although this technique has been tried, it was not implemented appropriately.
Note: ROW = right of way.

Although the above table gives good insight into what works and what does not, most of the mitigations fall into the uncertain categories (demonstrated, attempted, or unknown). Also, it does not take into account costs of implementation, feasibility of implementation, and overall effectiveness. As a follow-up, the Technical Working Group was asked (by email) to categorize the same mitigation measures as the following:

- Recommended for implementation.
- Recommended for further research.
- Not recommended for implementation or further research.

The results of this categorization are presented in table 11. Note that, relative to this second categorization effort, there are some mitigations where one or more members of the group did not vote.

Table 11. Technical working group recommendations.

Measure	Votes Received		
	Recommended	Further Research	Not Recommended
Mitigations that attempt to influence driver behavior			
Public information and education		7	
Standard wildlife warning signs		2	
Large, nonstandard wildlife warning signs	1	5	
Seasonal wildlife warning signs		7	
Roadside animal detection systems (RADS)		2	5
In-vehicle (veh.) warnings: RADS to on-board			
In-veh. warning: on-board animal detectors			7
Increase visibility: roadway lighting		7	
Increase visibility: vegetation removal		7	
Increase visibility: wider road striping			
Reflective collars (buffalo)			
Reduce traffic volume on road network			
Seasonal closure			
Reduce speed by reducing posted speed limit		6	1
Reduce speed by traffic calming	1	5	1
Wildlife crossing guards	4	3	
Mitigations that attempt to influence animal behavior or population size			
Deer reflectors and mirrors		1	5
Audio signals in row or deer whistles		1	6
Olfactory repellants		3	4
Deer flagging models		1	6
Hazing		2	5
Investigate deicing alternatives	1	4	2
Intercept feeding		2	5
Influence species/nutritional value in ROW		5	1
Expanded median		4	2
Mitigations that seek to reduce wildlife population size			
Wildlife culling	2	4	1
Wildlife relocation		1	6
Anti-fertility treatment		3	4
Habitat alteration	1	3	3
Mitigations that attempt to physically separate animals from the roadway			
Wildlife fencing	6	1	
Boulders fence	2	5	
Long tunnels and long bridges	2	4	1
Underpasses and overpasses	2	4	1
Underpasses/overpasses and fencing	4	1	

Note: ROW = right of way.

Referring to table 11, the panel voted on whether each mitigation measure should or should not be implemented or whether further research should be undertaken. A majority of votes (four or

more) was required to make a positive recommendation for implementation of the mitigation measure. Also, a majority of votes (four or more) for "not recommended" resulted in the rejection of the mitigation measure. Finally, if a majority did not cast votes to recommend implementation, but at least four votes were divided between "recommended" and "further research," the panel's recommendation was that further research should be undertaken for that particular mitigation measure.

When interpreting the results, it is important to keep in mind that these opinions only relate to deer and to mitigating DVCs. The opinions do not necessarily relate to other species or mitigating other effects associated with roads and traffic such as habitat loss, reduced habitat quality, and barrier effect (except for direct road mortality). The subsequent outcome of this process is as follows:

- Where feasible and appropriate, the following mitigations should be implemented:
    - Public information and education.
    - Wildlife fencing.
    - Underpasses and overpasses with fencing.
- Research or construction resources should **not** be used for the following mitigations:
    - Standard wildlife warning signs.
    - Deer reflectors and mirrors.
    - Audio signals in the right of way or deer whistles on vehicles.
    - Olfactory repellents.
    - Deer flagging models.
    - Hazing.
    - Intercept feeding.
    - Wildlife relocation in order to reduce population size.
    - Anti-fertility treatment in order to reduce population size.
    - Seasonal road closures.
    - Reflective collars placed on wildlife.

- Mitigations that may be promising, but require further investigation include the following:
    - Reduce traffic volume on road network.
    - Reduce speed by reducing the posted speed limit.
    - Reduce speed by traffic calming or reducing the design speed.
    - Wildlife crossing guards.
    - Large, nonstandard wildlife warning signs.
    - Seasonal wildlife warning signs.
    - Animal detection systems.
    - In-vehicle warnings: roadside animal detection system communicating with on-board computers.
    - In-vehicle warnings: on-board animal detectors.
    - Increase visibility through roadway lighting.
    - Increase visibility through vegetation removal.
    - Investigate deicing alternatives.
    - Influence plant species in the roadside to limit nutritional value.
    - Reduce population size through wildlife culling.
    - Reduce population size through habitat alteration.
    - Boulders forming a barrier.
    - Long tunnels and long bridges.
    - Overpasses and underpasses by themselves.
    - Wider more reflective striping along white line.
    - Expanded median.

CHAPTER 11. GAPS IN CURRENT KNOWLEDGE

This chapter summarizes the challenges that currently prevent a systematic, nationwide approach to WVC reduction.

DATA ISSUES

Generally, the greatest challenge to reducing WVCs is the absence of reliable information and documentation on mitigation measures such as effectiveness, historic use, challenges, etc. This lack of data is characterized by the fact that the Technical Working Group (chapter 10), categorized 20 of the 34 mitigations as "recommended for further research." There are numerous syntheses (including this one) that summarize potential solutions to WVCs. However, the effectiveness of a number of mitigation measures is still uncertain due to lack of evaluation, inaccurate data collection, and inconsistent measures of effectiveness.

One of the challenges relating to monitoring the effectiveness of WVC mitigations is the lack of reliable standardized and spatially precise data on the location of WVCs and animal carcasses. The national databases, summarized in chapter 2, all have some shortcomings in these regards. Most importantly, location data are not included in the national databases (i.e., GES, FARS, and State Farm Insurance Claims). Most of these datasets suffer from underreporting. Inconsistently collected data make it difficult to accurately characterize WVC issues and properly address them (e.g., identifying the best location to deploy a mitigation measure to address a particular situation). Problems also arise when attempts are made to use such data to evaluate the effectiveness of various mitigation measures after they have been installed. Furthermore, data that have been collected are not always readily available or even analyzed. All of these issues pose major challenges for the current study of WVCs.

ANALYSIS ISSUES

Effectiveness of mitigation measures can be evaluated relative to many different criteria. Each criterion has its own associated characteristics and methods of measurement, which can make evaluation of mitigation measures based on multiple criteria a difficult task. For example, effectiveness can relate to collision reduction (the criteria used in this study) but also to habitat connectivity. These are very different parameters, namely, safety and nature conservation, that are measured in very different ways. Development of sound methodologies to both singly and collectively consider these various criteria in evaluating mitigation measures would be useful.

Relative specifically to safety issues, some crash models exclude WVCs altogether. If AVCs are included in crash models, they tend to focus on road, traffic, and right of way characteristics only, and ecological parameters that extend away from the road are rarely included. Only a limited number of studies have looked at both groups of parameters at the same time.

Relative to specific WVC problem locations, the tendency is to identify such locations using past roadkill data. Given the investment and life span of some of the mitigation measures, it is advisable, however, to project 50–80 years into the future. The potential presence, population viability, and needs of selected wildlife species will likely change in this time period.

NEEDED TOOLS

With respect to specific mitigation technology used, basic research needs to be conducted to understand how existing mitigation measures can be made more effective. There should be a continuous drive to make these measures cheaper, smaller, more robust, and as mobile as possible to address costs, landscape aesthetics, safety concerns, operation and maintenance efforts, and a highly dynamic environment.

Modeling should be further developed and applied to assist in the optimization of the location, type, and dimensions of mitigation measures. Basic data collection is required to obtain inputs for these models. Existing long-term monitoring studies may need to be supplemented with studies that address specific questions that may not have been addressed yet. Once the recommendations based on these models have been implemented, the mitigation measures should be monitored for their effect on population viability parameters to verify that the models simulate the real world environment to an acceptable degree.

Addressing the broader picture, tools and procedures should be developed to measure the effects of roads and traffic on ecosystem processes, how these effects can be minimized, and how the disrupted processes can be restored.

SUMMARY

To summarize, future research should focus on the following:

- Developing and implementing guidelines and standards for collecting and reporting WVCs.
- Developing and implementing guidelines for the evaluation of mitigation measures.
- Evaluating the effectiveness of mitigation measures that have been recommended for further research.
- Conducting research and development to improve existing mitigation measures.
- Developing and applying population viability models that assist with the location, type, and dimensions of mitigation measures.

CHAPTER 12. COST-BENEFIT ANALYSES OF DEER COLLISION REDUCTION MEASURES

This chapter summarizes the costs of the mitigation measures reviewed in this report and their effectiveness in reducing WVCs, specifically DVCs. The information in this chapter should be considered inclusively with the reviews on over 34 mitigation measures from information available in the literature (chapters 5–8) and the rankings of these measures by the Technical Working Group (chapter 10).

The costs are presented (where possible) as cost per kilometer of road length per year. These costs were calculated from the various estimates found in the literature for the cost of each mitigation measure, as reported in the earlier chapters of this report. The potential benefits as a result of reducing DVCs will vary greatly depending on the measure, animal population density, type of roadway, and effectiveness of the measure. For this analysis, researchers used a hypothetical 1 km (0.62 mi) road section of a four-lane road (two lanes in each direction) that had five DVCs per year (see table 12). The benefits of mitigation were simply calculated as the avoided costs associated with the collisions prevented as a result of the mitigation measure. For this analysis, the cost associated with one DVC was estimated at $8,388 (see chapter 3). The avoided cost with the mitigation in place was then calculated by multiplying the cost of the collisions (five collisions times $8,388 per collision equals $41,940) times the effectiveness of the mitigation (expressed in terms of percent reduction in DVC). Effectiveness was estimated from information presented in the literature. Finally, the annual balance (dollar amount saved per kilometer per year) was calculated as benefit minus cost. It is important to note that the costs for these mitigation measures are primarily the responsibility of transportation agencies, while the benefits are mostly for insurance companies. Thus a positive balance between benefits and costs for a given mitigation measure generally indicates that the mitigation measure concerned could be a wise investment for society as a whole, but the costs and benefits are paid for and received by different groups in society.

It should be noted that the costs and benefits in table 12 are based on the literature reviewed. The costs do not necessarily include all costs, such as maintenance, financing, and impact of construction on traffic. Benefits, as discussed in chapter 11, are measured inconsistently in the literature. Costs and benefits can vary widely for different sites and situations (e.g., geographic locations, effectiveness, frequency of WVCs, surrounding terrain). For these reasons, the dollar values presented in this chapter should be viewed as indicative rather than precise estimates.

For some mitigation measures, the costs could not be translated to costs per kilometer per year, and no cost-benefit calculations were conducted. However, this does not necessarily mean that these mitigation measures are not effective in reducing DVCs or that they are not a wise investment. Instead it may only indicate that further research or analysis would be necessary to quantify their costs and benefits.

The calculations presented here do not include inflation indexes, and discounting was not applied. Table 12 provides the best guess about costs, effectiveness, and benefits based on the information currently available. Nonetheless, the calculations only provide an initial insight into the balance between the costs and benefits of different mitigation measures and how the balance

compares between measures. Note that measures for which no cost estimates and no effectiveness estimates were available were excluded from table 12.

The remainder of this chapter discusses the values in table 12 for each mitigation measure for which sufficient data were available to conduct analysis.

Table 12. Summary cost-benefit of mitigation measures for five DVCs per km per yr.

Mitigation measure	Cost ($/km/yr)	% DVC Reduction	Benefit ($/km/yr)	Balance ($/km/yr)
Standard warning signs	$18	0%	$0	-$18
Enhanced wildlife warning signs	$249	?	?	?
Seasonal wildlife warning signs	$27	26%	$10,904	$10,878
Animal detection systems (ADS)	$31,300	82%	$34,391	$3,091
ADS linked to on-board computer	?*	82%	$34,391	?
On-board animal detectors	$2,225*	?	?	?
Vegetation removal	$500	38%	$15,937	$15,437
Deer reflectors and mirrors	$495	0%	$0	-$495
Deer whistles	$23.5*	0%	$0	?
Carcass removal	$250*	?	?	?
Population culling	$2,508	50%	$20,970	$18,462
Relocation	$10,260	50%	$20,970	$10,710
Anti-fertility treatment	$61,702	50%	$20,970	-$40,732
Fence (including dig barrier)	$3,760	87%	$36,488	$32,728
Boulders in right of way	$2,461	?	?	?
Long bridges	$781,250	100%	$41,940	-$739,310
Long tunnels or long bridges	$1,500,000	100%	$41,940	-$1,458,060
Fence with gap and warning signs	$3,772	0%	$0	-$3,772
Fence with gap and crosswalk	$5,585	40%	$16,776	$11,191
Fence with gap and ADS	$9,930	82%	$34,391	$24,461
Fence with underpasses	$5,860	87%	$36,488	$30,628
Fence with overpasses	$26,485	87%	$36,488	$10,003
Fence with under- and overpasses	$7,510	87%	$36,488	$28,978

Assumes 1 km with 5 DVCs per year.
* Costs not in dollars/km/year, but in a different unit; see text.
? = Unknown or uncertain.

The costs and the potential reductions in WVCs resulting from a reduction in traffic volume, reduction of traffic speed, and the efforts of wildlife crossing assistants are unknown. Therefore these mitigation measures were not included in the analyses.

Standard wildlife warning signs are relatively inexpensive: $62 for a 76 by 76 cm (30 by 30 inches) sign.[195] The costs per kilometer per year (two signs per km, one sign for each travel direction, assumed life span of 7 years, no maintenance) are $18, but since standard wildlife warning signs are considered ineffective in reducing WVCs (i.e., $0 benefit), the final cost for this mitigation measure remains at

$18 per km ($30 per mi) per year.[195] The effectiveness of enhanced wildlife warning signs is largely unknown, causing them to be excluded from the analyses. Seasonal wildlife warning signs (two signs per km, one sign for each travel direction, and an assumed life span of 10 years, no maintenance) may result in a 26 percent reduction of DVCs, and could end up saving $10,878 per km ($17,517 per mi) per year. However, keep in mind that these types of signs are only applicable in situations where deer (or other large animals) display road crossing behavior that is concentrated in space and time. Animal detection systems (life span 10 years, costs include maintenance) cost more, but because of their effectiveness in reducing WVCs by 82 percent, they still result in a positive balance of $3,091 per km ($4977 per mi) per year.

Too little is known about the costs or effectiveness of animal detection systems linked to an on-board computer or on-board animal detectors for these measures to be included in the analyses. Furthermore, the costs and benefits for these mitigation measures depend on the number of vehicles equipped with this technology rather than a standard cost per kilometer of road length per year.

There are insufficient data available to evaluate the cost-benefit relationship for roadway lighting measures and public information and education programs. Vegetation removal, however, demonstrates more potential and may result in a positive balance of $15,437 per km ($24,858 per mi) per year.

Assuming that deer reflectors and mirrors (life span 12.5 years, costs include maintenance) are indeed not effective in reducing DVCs, they have a negative balance of $495 per km ($797 per mi) per year. The costs for deer whistles are per vehicle rather than per kilometer per year; therefore, this mitigation measure was not included in the analyses. However, this measure is not considered effective. There are insufficient data available to analyze the cost-benefit relationship of audio and visual warning signals in the right of way, olfactory repellents, deer flagging, hazing, reducing or replacing road salt, intercept feeding, influencing the species composition and the nutritional quality of right-of-way vegetation, and carcass removal. Some carcass removal data were available, and costs were expressed in costs per kilometer per year based on the removal of five deer carcasses.

Population culling is cheaper than wildlife relocation or anti-fertility treatment. The costs for these mitigation measures are typically expressed in costs per animal. These costs were translated to dollars per kilometer per year based on the following assumptions and estimates. The width of the zone that the culling, relocation, or anti-fertility treatment would be conducted in was based on the home range of white-tailed deer in a suburban environment (43 to 144 ha (106 to 356 acres)).[326,398,399] Assuming a home range of 75 ha (185 acres), a deer living within 977 m (3237 ft) (the diameter of the home range), could cross the road. For a 1-km (0.6-mi)-long road section, this zone is 97.7 ha (241 acres) for one road side and 195.4 ha (482 acres) for both road sides. Population densities of (suburban) white-tailed deer that are considered a "problem" have been estimated at 50–91 individuals per km^2.[57,400] Assuming a population density of 70 individuals per km^2, there are 136.8 deer in 195.4 ha. The cost for culling, relocation, and anti-fertility treatment was set at $110, $450, and $1,128 (females only), respectively. Assuming that a population can only be reduced by 50 percent before the culling, relocation or anti-fertility treatment effort becomes much more labor intensive, and the one-time culling and relocation of 68.4 deer costs $7,524 and $30,780 (reduction of 68.4 deer), respectively. Suburban white-tailed

deer populations can double their population size every 2–5 years, depending on the circumstances.[287] Assuming a closed population (no immigration from adjacent areas), and a doubling of population size every 3 years, the culling and relocation effort would have to be repeated every 3 years, resulting in an annual cost per km of $2,508 and $10,260 ($4,038 and $16,512 per mi) for culling and relocation, respectively. For the anti-fertility treatment it was assumed that 80 percent of the females (80 percent of 68.4 female deer is 54.7 female deer, assuming an equal sex ratio), would have to be treated annually to stabilize or reduce the population density.[287,336] This results in an annual cost for anti-fertility treatment of $61,702 per km ($99,300 per mi). The above calculations result in a positive balance for culling and relocation and in a negative balance for anti-fertility treatment. Bear in mind that if the population is open to immigration from adjacent areas, the effectiveness for the culling, relocation, and anti-fertility treatment efforts will be much reduced or potentially eliminated.

Wildlife fences (life span 25 years, not including maintenance) reduce collisions with ungulates by 87 percent on average and have a positive balance of $32,728 per km ($52,702 per mile) per year. While insufficient data were available in the literature to evaluate cost-benefit for boulders in right of way (as an alternative to wildlife fences), assuming a life span of 80 years, the costs were estimated at $2,461 per km ($3,963 per mile) (boulders on both sides of the road) per year. The costs for long bridges and long tunnels were set at $781,250 and $1,500,000 per km ($1,258,051 and $2,415,459 per mile) per year respectively (80-year life span). Both long bridges and tunnels have a strongly negative balance.

To accommodate animal movements from one side of a road to the other, wildlife fences are often combined with measures that allow animals to cross the road at grade or to cross under or over the road through crossing structures. This section focuses on crossing opportunities for large animals only (deer size and up). The cost-benefit analysis assumed one crossing opportunity per 2 km (1.2 mi) (0.5 crossing opportunity per km) (e.g., along Trans-Canada Highway in Banff National Park, Canada), even though higher concentrations of crossing structures for large mammals may be required.[352] In addition, gaps were set at a width of 100 m (328 ft), and the number of escape ramps between gaps was set at 2 per roadside (1 every 300 m (984 ft) between gaps). In addition, the animals could "escape" through the gaps. The number of escape ramps between crossing structures was set at 4 per roadside (two immediately next to a crossing structure (50 on either side from center), and two in between at 300-m (984-ft)-intervals between the crossing structures). The escape ramps on either side of a crossing structure are required because of the contiguous wildlife fencing and the assumption that animals will want to cross the road most often at the location of the crossing structures, as that should be one of the most important criteria for the placement of these crossing structures. The length of the fence was not reduced because of gaps or crossing structures because of possible additional fencing at gaps and overpasses and the contiguous nature of fencing for underpasses. In addition, for at-grade crossings, it was assumed that all deer movements that would have taken place in the unmitigated road section (and that resulted in 5 DVCs per km per year), would be funneled through these gaps, and that the number of DVCs is not reduced as the result of a potential reduction in the number of deer crossings because of the presence of the wildlife fence.

The life span of the material associated with crosswalks was set at 10 years, while the life span for wildlife crossing structures was set at 80 years. The cost for the mitigation measure that includes a combination of wildlife fencing and under- and overpasses was based on 0.5 crossing

structures per km, all of them underpasses except for one overpass every 25 km (15.5 mi). The cost for an underpass was set at $200,000, while the cost for an overpass was set at $3,500,000. The cost for an escape ramp was set at $8,500 (life span 80 years). Following this analysis, wildlife fences with gaps that are mitigated by warning signals have a negative balance, while wildlife fences in combination with a crosswalk, an animal detection system, wildlife underpasses, wildlife overpasses, or a combination of wildlife under- and overpasses all have a positive balance.

Many of the mitigation measures showed a positive balance. Some of the mitigation measures (long tunnels, long bridges, and anti-fertility treatment) showed a strongly negative balance. Because of their strongly negative balance, these mitigation measures are not recommended, at least not from a strictly monetary perspective. The other mitigation measures had a positive or slightly negative balance. However, it is also important to evaluate mitigation measures on the balance of the problem that may not have been solved; none of the mitigation measures are 100 percent effective in reducing collisions, and if a substantial number of collisions and associated costs remain, a mitigation measure may not be attractive, despite a potential positive balance.

Figure 60 shows the individual mitigation measures (excluding long tunnels, long bridges, and anti-fertility treatment) in relation to their balance and effectiveness. The figure has several groupings. Based on the rough estimates in this chapter, wildlife fencing, with or without wildlife underpasses or a combination of wildlife underpasses and overpasses, and animal detection systems with wildlife fencing have high effectiveness and a high return on investment. (identified by solid oval, measures 8, 11, 12, and 14 in figure 60). Animal detection systems without wildlife fences or wildlife fences with a high density of wildlife overpasses (identified by dashed oval, measures 3 and 13 in figure 60) also have high effectiveness, but their positive financial balance is less strong.

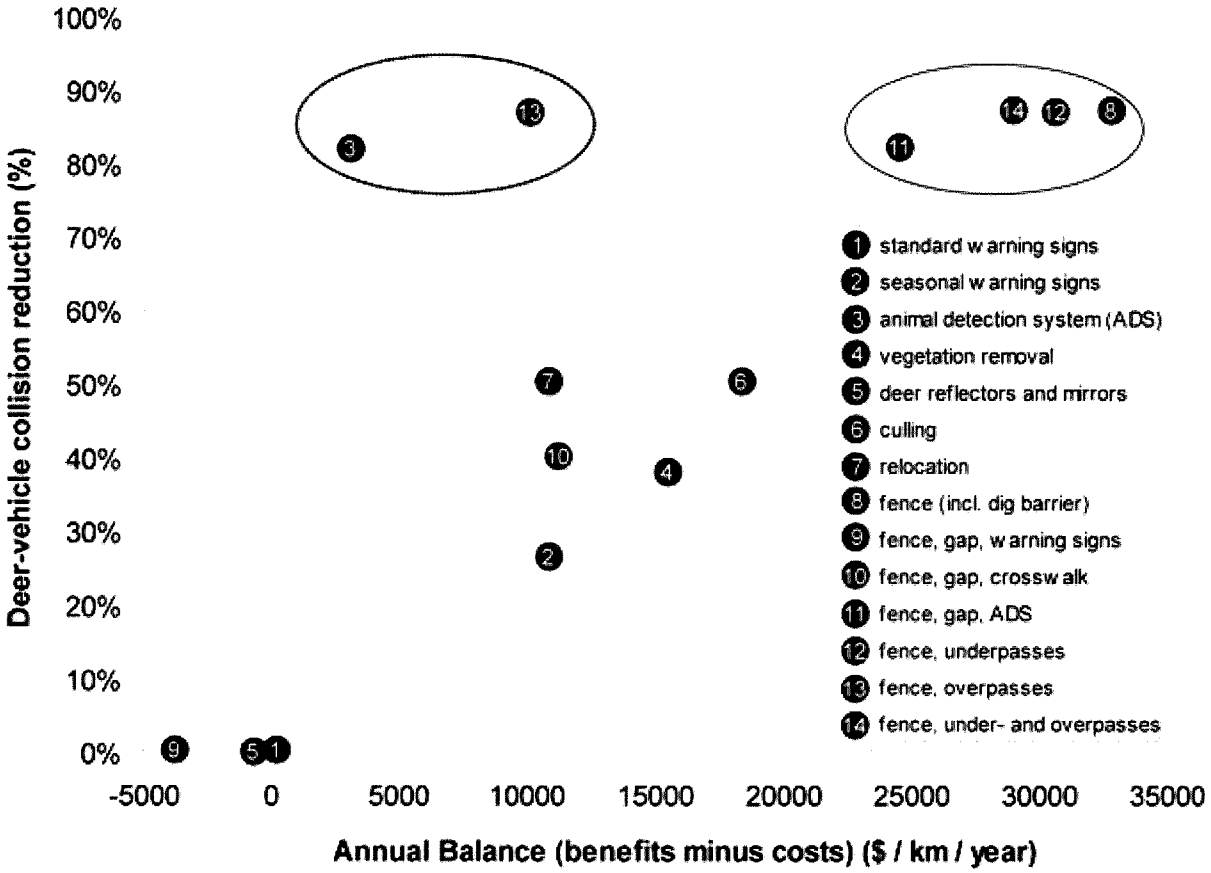


Figure 60. Graph. Annual balance and collision reduction for the different mitigation measures (further explanation in text).

CHAPTER 13. CONCLUSION

This report has summarized the considerable body of existing knowledge on the impacts and mitigations of WVCs. Based on several data sources, it was estimated that one to two million WVCs occur annually (focusing on large animals) and that they continue to be a significant challenge, costing society billions of dollars. WVCs also result in human injuries and fatalities, although this is relatively rare compared to other types of accidents. WVCs are also a serious safety risk for animals, not only for the individuals involved, but in some cases for populations or the entire species. This report identified 21 federally threatened and endangered species for which road mortality was identified as one of the major threats to their long-term survival.

This report reviewed over 34 mitigation measures aimed at reducing WVCs. Wildlife fencing, with or without wildlife crossing structures, animal detection systems, and long tunnels or bridges were found to provide the greatest reduction of WVCs. Site-specific conditions will dictate the appropriate mitigation measure(s), as there is no single, low-cost solution for WVCs that can or should be applied everywhere. A successful mitigation strategy requires a detailed analysis of the problem and the local situation and often involves a combination of different types of mitigation measures. Moreover, improved objective evaluation of the mitigation measures will help States and others make better informed decisions.

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Estimate of the Area Affected Ecologically by the Road System in the United States

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Abstract: *In view of an extensive road system, abundant and rapidly growing vehicular traffic, and a scattered literature indicating that some ecological effects of roads extend outward for >100 m, it seems likely that the cumulative ecological effect of the road system in the United States is considerable. Two recent studies in The Netherlands and Massachusetts (U.S.A.) evaluated several ecological effects of roads, including traffic noise effects, and provide quantitative evidence for a definable "road-effect zone." Based on the approximate width of this asymmetric convoluted zone, I estimate that about one-fifth of the U.S. land area is directly affected ecologically by the system of public roads. I identify a series of assumptions and variables suggesting that over time this preliminary estimate is more likely to rise than drop. Several transportation planning and policy recommendations, ranging from perforating the road barrier for wildlife crossings to closing certain roads, offer promise for reducing this enormous ecological effect.*

Estimación del Area Ecológicamente Afectada por el Sistema Carretero de los Estados Unidos

Resumen: *En vista de un sistema carretero extensivo, un abundante y creciente tráfico vehicular y una literatura dispersa indicando que algunos efectos ecológicos de las carreteras se extienden más allá de 100 m, parece probable que los efectos ecológicos acumulativos del sistema carretero en los Estados Unidos es considerable. Dos estudios recientes en los Países Bajos y Massachusetts (USA) evaluaron diversos efectos ecológicos de las carreteras, incluyendo efectos del ruido del tráfico y proporcionan evidencia cuantitativa para una definible "zona de efecto carretero". En base a la amplitud aproximada de esta zona compleja y asimétrica, estimé que alrededor de una quinta parte del área terrestre de los Estados Unidos es directamente afectada ecológicamente por el sistema de carreteras públicas. Identifiqué series de conjeturas y variables que surgieren que a lo largo del tiempo esta estimación preliminar es mas probable que incremente a que disminuya. Diversos planes de transportación y recomendaciones políticas, que van desde perforar la barrera carretera para propiciar el cruce de vida silvestre hasta el cierre de ciertas carreteras ofrecen la promesa de reducir este efecto carretero.*

Introduction

The 6.2 million-km system of public roads in the United States, used by 200 million vehicles, permeates and links essentially every local area (National Research Council 1997). These roads and roadsides cover about 1% of the land, equivalent in area to Austria or South Carolina. A suite of ecological effects of roads involving species, soil, and water has been identified, with effects varying in distance outward from meters to kilometers (Ellenberg et al. 1991; Forman 1995). The outer limits of these significant ecological effects along a road thus describe a "road-effect zone" (Fig. 1; Forman et al. 1997; Forman & Deblinger 1998, 1999).

A limited amount of evidence for the width of the road-effect zone is available from Europe and North America. Therefore, my objective was to estimate the total area or proportion of the United States ecologically affected by the road system.

A road system of course has both positive and negative ecological effects, and understanding these helps to identify solutions for transportation policy and planning. Transporting people and goods efficiently between points is a familiar advantage of roads to society. Less recognized is the resulting ecological protection of the

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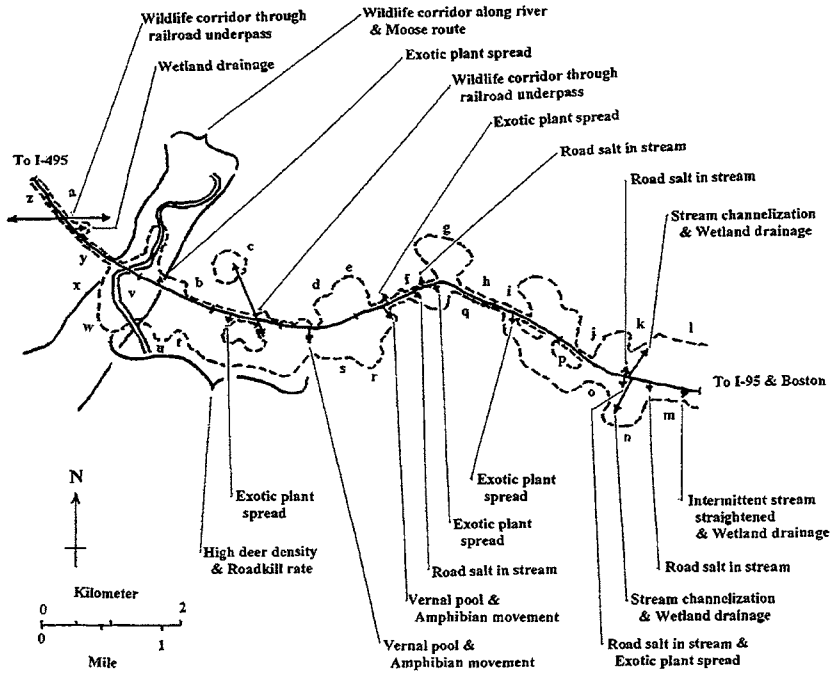

Figure 1. Road-effect zone along 10 km of a Massachusetts highway. Locations of key road effects are indicated by arrows. Dashed lines border areas where forest and grassland bird communities are estimated to be affected by traffic noise (effect-distance for most sensitive species is 680 m in forest and 810 m in grassland; M. Reijnen et al. 1995; R. Reijnen et al. 1995, 1996). Factors near the road that affect the width of a traffic-noise effect are indicated by letters: (a) built area, (b) built area, (c) downwind of (agricultural) grassland, (d) low area, (e) forest, (f) road embankment, (g) forest, (h) road embankment, (i) built area, (j) road embankment and built area, (k) hill, (l) forest, (m) built area, (n) forest, (o) low embankment by road, (p) built area, (q) road embankment, (r) forest, (s) small hill, (t) forest, (u) grassland, (v) river, (w) open wetland area, (x) golf course, (y) hill, and (z) built area. This section of Route 2, a four-lane divided highway west of Boston that supports 50,000 vehicles/day, begins 2 km west of Interstate Highway 95 and extends 10 km through Lincoln and Concord. Modified from a study of 25 km along Route 2 (Forman & Deblinger 1998, 1999).

surrounding matrix against disturbance by convoluted routes, "random searches," or off-road vehicles. Another example of an ecological benefit is the maintenance of native grassland plants and of nesting sites on roadsides in landscapes of intensive agriculture. In Australia a giant green nature reserve borders the road network in many agricultural landscapes (Forman & Alexander 1998). Nevertheless, most of the ecological effects of road systems are negative, and their cumulative effect covers an extensive area. Mitigation and transportation planning solutions for most of the ecological effects exist in scattered locations (Forman & Hersperger 1996; Canters 1997; Forman et al. 1997; Forman & Alexander 1998), but the widespread use of such solutions awaits recognition by the scientific community, highly visible pilot projects, and greater public understanding.

The road-effect zone is also promising as a basis for transportation planning. Landscape ecologists and scholars of related fields increasingly recognize ecological flows across the landscape as critical for long-term nature protection (Forman 1995, 1999; Harris et al. 1996). For example, groundwater, surface water, foragers, dispersers, migrants, pollinators, fire, heat energy, and sediments move across the heterogeneous landscape of patches, corridors, and matrix. These flows and movements create and maintain patterns from spatial to biological diversity. In contrast to this landscape-wide perspective, transportation engineers focus closely on the road or highway itself and the critical narrow band alongside. Road design and construction involve local factors, such as roadbed particle sizes, erosion, sediment flows, soil drainage, erosion, slopes, ditches, plantings, bridges, and guardrails, and are accomplished according to precise codes and practices. The spatial disconnect between these ecological and engineering perspectives is striking. The road-effect zone appears promising as a middle ground, the spatial perspective that provides both the ecological and engineering objectives of society.

The ecological factors determining the road-effect zone are related to species, soil, and water. Effects extend outward and can be linked directly to a specific road. I excluded from my analysis the indirect ecological effects of transportation, such as air pollutants in vehicle emissions that accumulate in the atmosphere and cause ecological effects often far from the source road (National Research Council 1997).

The total area of the road-effect zone for a nation was first estimated for The Netherlands by R. Reijnen et al. (1995) and was based on avian community composition in forest and agricultural grassland at varying distance from main roads. Evidence indicates that traffic noise is the major cause of the degradation of avian communities near busy roads (M. Reijnen et al. 1995; R. Reijnen et al. 1995, 1996). The average density of Dutch main roads (highways) is 0.3 km/km^2, compared with an average of 0.13 km/km^2 for main (state-maintained) roads in the United States and 1.2 km/km^2 for all U.S. public roads. Traffic volume on Dutch main roads apparently ranges from 10,000 to >100,000 vehicles per day, presumably a higher average than in the United States. In addition to more main roads and traffic, The Netherlands has proportionally more built area, more open land, and less forest than the United States. This means that on average traffic noise should affect a greater portion of The Netherlands. Secondary roads and roads in urban areas apparently were not included in the Dutch studies.

R. Reijnen et al. (1995) estimate that 10% of the land area of The Netherlands is significantly disturbed ecologically by traffic noise. This estimate is based on the average effect-distances—distance that a significant effect extends from a road—for all bird species combined. In contrast, based on the most sensitive bird species, which are of primary conservation importance, the authors estimate that >17% of the land is disturbed. Avian diversity is reduced and total bird density is one-third lower in the areas affected by roads and vehicles. These estimates are based on 1986 data, and, due to traffic increases, the figures are projected to be 15–20% higher in 1999. Therefore road-effect zones apparently cover at least 12–20% of The Netherlands.

A recent study measured and estimated nine ecological variables along a 25-km, divided four-lane highway in Massachusetts and incorporated the Dutch results in the analysis (Forman & Deblinger 1998, 1999). All effects believed to extend >100 m from the road were included in the study: wetland drainage, stream channelization, road salt in surface water bodies, planted roadside exotics invading forest, moose (*Alces alces*), deer (*Odocoileus virginiana*), forest birds, grassland birds, and vernal pool amphibians. The road-effect zone was then mapped (Fig. 1), which highlighted its (1) asymmetry (2) convoluted borders, and (3) occasional "fingers" protruding from a border. Some effects such as traffic noise appeared along much of the road length, whereas a few effects including stream channelization occurred only at points along the road. Asymmetry of the zone results from directional wind- and water-flow processes and from differences in topography, land use, and habitat suitability on opposite sides of the road. Thus the Massachusetts and Dutch studies provide the basis for a preliminary estimate of the total area ecologically affected by a road system.

Estimate for the United States

Assumptions

To make an estimate of the total ecological effect of the U.S. system of public roads, I made the following assumptions:

(1) Total area of United States is 9,372,610 km^2.

(2) Total road length includes 3,836,381 km of secondary roads in rural areas (county, town, township, federal [U.S. Forest Service, U.S. National Park Service, and reservations that are not part of the state or local highway systems], and other local public roads), 1,237,198 km of primary roads (under state control) in rural areas, 927,122 km of secondary roads in urban areas, and 178,394 km of primary roads in urban areas (Fig. 2a).

(3) All road length in rural areas and 25% of road length in urban areas are roughly estimated to be near natural ecosystems (for both primary and secondary roads). Natural ecosystems include agricultural land (which, for example, contains grassland birds of conservation interest) but exclude built areas (thus ignoring ecological effects there). Near natural ecosystems means adjoining or close enough to produce road effects.

(4) Traffic volume (24-hour total, Monday through Friday, half the vehicles going each direction, roughly estimated averages) for primary roads in rural areas (highways in towns, villages, and more remote areas) is 10,000 vehicles/day and in urban areas is 50,000 vehicles/day.

(5) Road-effect zones for primary roads (in both rural and urban areas) are calculated as two times the effect distances for the most sensitive bird species highlighted in the Dutch studies (R. Reijnen et al. 1995, 1996). The effect distance is 305 m for 10,000 vehicles/day in woodland, 365 m for 10,000 vehicles/day in grassland, and 810 m for 50,000 vehicles/day in natural ecosystems in urban areas (average of results for forest birds and grassland birds; Forman & Deblinger 1999).

(6) Road-effect zone for secondary roads is 200 m wide, a rough estimate for a highly variable zone. Lower traffic volume may be associated with localized short-distance effects, such as most roadkills or road dust and road salt effects on vegetation, whereas higher traffic volume produces long-distance effects, including blocking wildlife corridors and subdividing populations into smaller, less stable subpopulations.

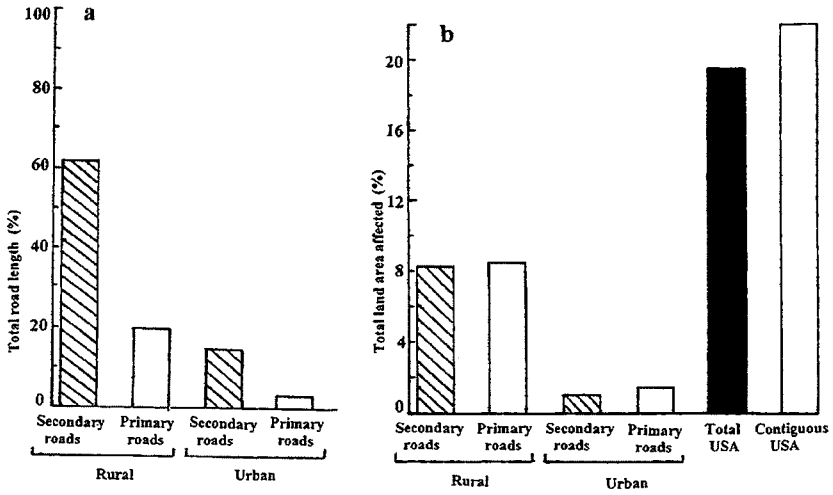

Figure 2. The (a) road length and (b) area affected ecologically by roads in the United States. Total road length in the United States is 6.2 million km (Federal Highway Administration terminology and data for 1985). Area ecologically affected is calculated based on estimates of road-effect zones in Massachusetts and The Netherlands and on other data.

Estimated Area

Calculations based on the preceding assumptions indicate that 19% of the total area of the United States is directly affected ecologically by roads and associated vehicular traffic (Fig. 2b). A breakdown of this total by road type and location shows that roads in rural areas have by far the greatest total ecological effect (16.7% vs. 2.5% in urban areas). Primary and secondary roads have the same total ecological effect (Fig. 2b), even though primary roads are only one-quarter of the total road-network length (Fig. 2a). Excluding Alaska (which has few roads in a large area) and Hawaii means that 22% of the contiguous United States is estimated to be ecologically altered by the road network (Fig. 2b).

Variables that Lower or Raise the Estimate

It is useful to identify key variables that would lower or raise these overall estimates. The following would be expected to lower the estimated area affected ecologically: (1) Eliminate overlapping road-effect areas in the vicinity of road intersections in rural areas and in high-road-density urban areas. (2) Ignore the most sensitive species and calculate the effect-distance of primary roads based on the density of all species combined (R. Reijnen et al. 1995, 1996; Forman & Deblinger 1999). (3) Calculate the effect-distance based only on variables whose effects generally extend meters to tens of meters outward, such as roadbed erosion and heavy-metal effects on populations (Forman & Alexander 1998). (4) Assume that primary roads in rural areas have an average traffic volume of <10,000 vehicles/day. For example, if traffic volume is 5000 vehicles/day, the effect-distance decreases somewhat; if traffic volume is <3000 vehicles/day, the effect-distance for avian communities may be less than that for several other road effects (van der Zande et al. 1980; M. Reijnen et al. 1995; R. Reijnen et al. 1996). (5) Reduce the road-effect zone width on secondary roads. If it were halved to 100 m, for example, the total affected area in the contiguous United States would be 18% instead of 22%. (6) Omit roads in agricultural and other human-modified open landscapes even though sensitive grassland birds are present.

In contrast, the following key variables would be expected to raise estimates of the total U.S. area ecologically affected: (1) Include the effects of cutting or blocking of major long-distance wildlife corridors. (2) Include the effects of subdividing previous large populations into smaller populations occupying isolated patches distant from the road in which the populations remain as less stable and more vulnerable to local extinction. (3) Add the effects of human access to remote areas (due to the presence of roads) where overhunting or varied human disturbances occur, sometimes affecting large areas. (4) Include areas by secondary roads subjected to certain long-distance effects, such as some stream and river channelization, sedimentation downstream of bridges, altered water tables, wetland drainage, and spread of planted roadside exotic species into nearby natural ecosystems. (5) Assume that traffic volume on secondary roads in rural or urban areas exceeds an average of 10,000 vehicles/day, so the road-effect zone based on the most sensitive bird species would be greater than the 200 m used in calculations. (6) Increase the road-effect zone for primary roads in rural grasslands by using the most sensitive species actually recorded in the Dutch studies (it was presumed to be an outlier and hence omitted from calculations), which would triple the width of the road-effect zone. (7) Use 1999 in lieu of 1985 transportation data (total road length has changed little; National Research Council 1997). With rapid urbanization, however, urban road length has significantly increased and rural road length decreased. Also, traffic volume has increased as people spend more time driving. Therefore in 1999 more road length has higher traffic volume than in 1985 and, consequently, greater

ecological effect-distances would be used in the calculations. (8) Add the ecologically affected area by nonpublic roads, including logging areas on private timberland, farm and ranch roads, and driveways. (9) Include the effects of off-road vehicles.

Comparing the lists of factors that may decrease or increase the estimated ecological effect of roads suggests that one-fifth of the United States land area is a conservative estimate of ecological effects. It is more likely that future estimates based on additional data will rise rather than fall. Also, if the effects of vehicular air pollutants such as CO_2, O_3, and NO_x (National Research Council 1997) were added, the cumulative effect of the road system would be still greater.

Conclusion and Policy Implications

A significant portion of the ecological literature is doubtless based on studies within road-effect zones. In thinking about this literature and in designing research studies of the future, greater attention to the ecological effects of roads is warranted. Roads, and especially traffic, are increasing in the United States and worldwide. Clearly, the estimate of total area affected ecologically is a preliminary estimate. Better data sets and fuller analyses should lead to better estimates in the future.

My calculations suggest some policy approaches that could have a significant effect on reducing the huge area affected directly by roads and vehicles. The following five actions could make a difference. (1) Perforate the road as a barrier to animal movement by using tunnels, underpasses, overpasses, and other mitigation technology, thus reducing the effects of blocking wildlife corridors and of subdividing populations into smaller, less stable subpopulations. (2) Close, and where ecologically important, remove logging and other roads in remote areas to reduce the disturbance effects of human access. (3) Increase the use of soil berms, plantings, depressed roads, and other construction techniques to reduce the distance and area ecologically affected by traffic noise. (4) Concentrate traffic on primary roads, especially in rural landscapes, and minimize the conversion of secondary roads from light- to medium-traffic usage. (5) Reduce traffic noise by changing tire design, vehicle aerodynamics, road surface, proportion of truck traffic, and total amount of vehicle miles (kilometers) traveled. Such policy changes would reverberate through society, yet I suspect that the demand for appropriate solutions to the ecological road-system effects that permeate the land is closer than we think.

Acknowledgments

I am pleased to acknowledge colleagues on a National Research Council committee on the future of U.S. transportation in a sustainable environment, as well as R. Reijnen's studies, which initially stimulated my interest in this subject. I warmly thank S. R. Godwin and R. D. Deblinger for key insights.

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ROAD ECOLOGY: SCIENCE AND SOLUTIONS

By Richard T.T. Forman, Daniel Sperling, John A. Bissonette, Anthony P. Clevenger, Carol D. Cutshall, Virginia H. Dale, Lenore Fahrig, Robert France, Charles R. Goldman, Kevin Heanue, Julia A. Jones, Frederick J. Swanson, Thomas Turrentine, and Thomas C. Winter
Island Press
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U.S. List Price $55.00
ISBN 1-55963-933-4 (paper)
U.S. List Price $27.50

A central goal of transportation is the delivery of safe and efficient services with minimal environmental impact. In practice, though, human mobility has flourished while nature has suffered. Awareness of the environmental impact of roads is increasing, yet information remains scarce for those interested in minimizing the ecological effects of roads and vehicles.

Road Ecology addresses that shortcoming by bringing together previously fragmented knowledge into a broad and inclusive framework for understanding and developing solutions. This book explores the history of the five-million-mile road network in North America (the United States and Canada), provides a substantial overview of the many ways that roads impact the environment, and looks at the current techniques being applied to mitigate these impacts on wildlife, land, water, and plant ecosystems. The text delves into four main areas: roads, vehicles and ecology; vegetation and wildlife; water, chemicals, and atmosphere; and road systems and land. The book was coauthored by 14 specialists in fields ranging from landscape ecology, civil engineering, and environmental science, to biology, wildlife research ecology, watershed management, limnology, and transportation.

For more than a century, the transportation community has been learning how to guard road systems from nature's assaults, through better planning, design, materials, and construction. But we are just beginning to recognize the many ways that roads assault nature, and, consequently, our need to understand these phenomena to mitigate negative outcomes. Recognizing this need, the book delivers a clear call for a new field of study, identified by the authors as "road ecology."

Existing requirements to assess environmental impacts of new road projects has helped to develop a new group of environmental experts, and a body of literature that, no doubt, has improved the design of many poorly conceived schemes. But this book makes it clear that *ad hoc* environmental analysis has left many gaps in our understanding of effective mitigation for individual road projects and is unlikely to ever effectively reduce the impact of a growing system of roads.

The core objective of this book is to reduce the gaps cited above by integrating dispersed theories, models, and concepts important to road ecology into a coherent body of principles applicable to transportation planning, practice, and policy. In the process, the authors identify a range of examples, applications, and case studies for the reader to consider. Its primarily North American focus is complemented by worldwide examples. Impact on the atmosphere is briefly included, but the authors focus on land, water, plants, and animals. Concepts and models in the new field of road ecology are integrated to establish a coherent basis for developing transportation policy, planning, and projects. Topics examined include:

- Foundations of road ecology;
- Roads, vehicles, and transportation planning;
- Vegetation and roadsides;
- Wildlife populations and mitigation;
- Water, sediment, and chemical flows;
- Aquatic ecosystems;
- Wind, noise, and atmospheric effects; and
- Road networks and landscape fragmentation.

By looking at problems associated with vegetation, wildlife, aquatic ecosystems, wind and atmospheric effects, and flows of water, sediment, and chemicals, the authors have described the issues and provided a target for researchers in many fields to focus their efforts. Until now, the fields of opportunity in road ecology have been ripe but the workers few.

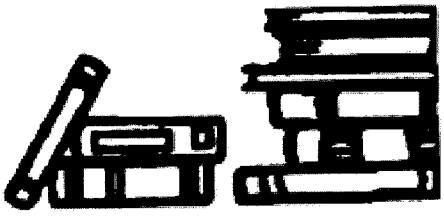
With more than 100 illustrations and examples from around the world, *Road Ecology* is an indispensable and pioneering work for anyone involved with transportation, including practitioners and planners in state and province transportation departments, federal agencies, and nongovernmental organizations. This is an impressive and much-needed synthesis that "maps a road" forward for scientific discovery, and better transportation planning and action. It is a "must read" for transportation specialists and ecologists alike. The book also opens up an important new research frontier, and will provide the incentive and direction that will lead to a new generation of leaders and specialists dedicated to finding answers to these pressing problems.

RESTORATION OF PUGET SOUND RIVERS

By David R. Montgomery, Susan Bolton, Derek B. Booth, and Leslie Wall
University of Washington
Seattle, WA, and London, UK (2003)
512 pages
ISBN 0-295-98295-0
U.S. List Price $30.00 (paper)

The recent listing of Pacific salmon under the Endangered Species Act has led to substantial interest in the scientific basis for river restoration in the Pacific Northwest. Millions of dollars in state and federal funding has been earmarked for habitat restoration efforts to stem the decline of salmon populations in the region. This book addresses the need for a solid understanding of fluvial processes and aquatic ecology in order to predict both river and salmonid response to restoration projects.

In the Pacific Northwest, as in most regions of the United States, we are still learning about the processes that create habitat and river structure, how those processes influence aquatic ecosystems, and how to gauge the response of river systems to both land-use changes and restoration efforts. River systems are still responding to historic changes, and degraded habitat may not be successfully restored if natural conditions





Roads and Their Major Ecological Effects

Richard T. T. Forman; Lauren E. Alexander

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ROADS AND THEIR MAJOR ECOLOGICAL EFFECTS

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KEY WORDS: animal movement, material flows, population effects, roadside vegetation, transportation ecology

ABSTRACT

A huge road network with vehicles ramifies across the land, representing a surprising frontier of ecology. Species-rich roadsides are conduits for few species. Roadkills are a premier mortality source, yet except for local spots, rates rarely limit population size. Road avoidance, especially due to traffic noise, has a greater ecological impact. The still-more-important barrier effect subdivides populations, with demographic and probably genetic consequences. Road networks crossing landscapes cause local hydrologic and erosion effects, whereas stream networks and distant valleys receive major peak-flow and sediment impacts. Chemical effects mainly occur near roads. Road networks interrupt horizontal ecological flows, alter landscape spatial pattern, and therefore inhibit important interior species. Thus, road density and network structure are informative landscape ecology assays. Australia has huge road-reserve networks of native vegetation, whereas the Dutch have tunnels and overpasses perforating road barriers to enhance ecological flows. Based on road-effect zones, an estimated 15–20% of the United States is ecologically impacted by roads.

INTRODUCTION

Roads appear as major conspicuous objects in aerial views and photographs, and their ecological effects spread through the landscape. Few environmental scientists, from population ecologists to stream or landscape ecologists, recognize the sleeping giant, road ecology. This major frontier and its applications to planning, conservation, management, design, and policy are great challenges for science and society.

0066-4162/98/1120-0207$08.00

This review often refers to The Netherlands and Australia as world leaders with different approaches in road ecology and to the United States for especially useful data. In The Netherlands, the density of main roads alone is 1.5 km/km^2, with traffic density of generally between 10,000 and 50,000 vehicles per commuter day (101). Australia has nearly 900,000 km of roads for 18 million people (66). In the United States, 6.2 million km of public roads are used by 200 million vehicles (85). Ten percent of the road length is in national forests, and one percent is interstate highways. The road density is 1.2 km/km^2, and Americans drive their cars for about 1 h/day. Road density is increasing slowly, while vehicle kilometers (miles) traveled (VMT) is growing rapidly.

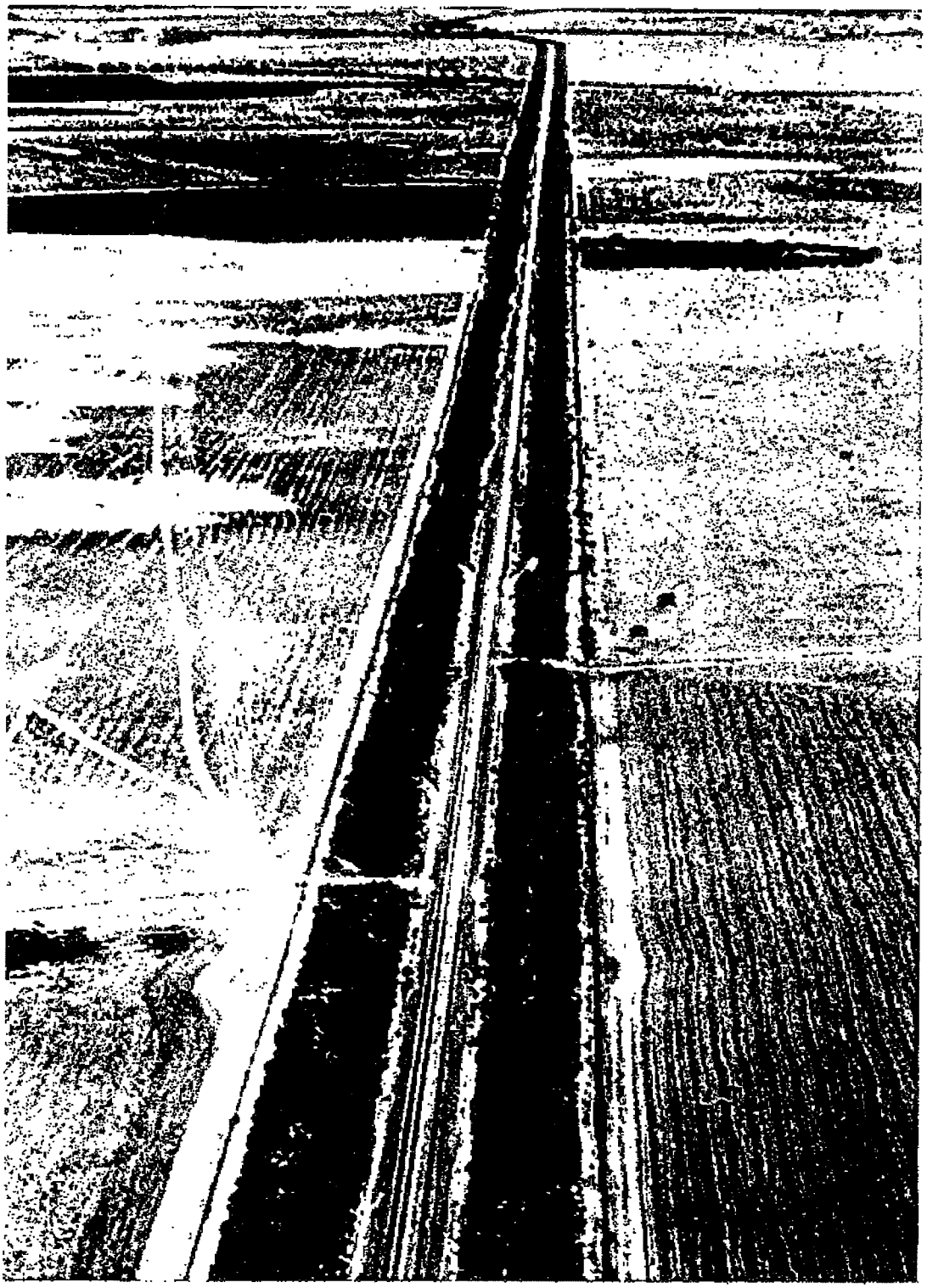
The term road corridor refers to the road surface plus its maintained roadsides and any parallel vegetated strips, such as a median strip between lanes in a highway (Figure 1; see color version at end of volume). "Roadside natural strips" of mostly native vegetation receiving little maintenance and located adjacent to roadsides are common in Australia (where road corridors are called road reserves) (12, 39, 111). Road corridors cover approximately 1% of the United States, equal to the area of Austria or South Carolina (85). However, the area directly affected ecologically is much greater (42, 43).

Theory for road corridors highlights their functional roles as conduits, barriers (or filters), habitats, sources, and sinks (12, 39). Key variables affecting processes are corridor width, connectivity, and usage intensity. Network theory, in turn, focuses on connectivity, circuitry, and node functions (39, 71).

This review largely excludes road-construction-related activities, as well as affiliated road features such as rest stops, maintenance facilities, and entrance/exit areas. We also exclude the dispersed ecological effects of air pollution emissions, such as greenhouse gases, nitrogen oxides (NOX), and ozone, which are reviewed elsewhere (85, 135). Bennett's article (12) plus a series of books (1, 21, 33, 111) provide overviews of parts of road ecology.

Gaping holes in our knowledge of road ecology represent research opportunities with a short lag between theory and application. Current ecological knowledge clusters around five major topics: (*a*) roadsides and adjacent strips; (*b*) road and vehicle effects on populations; (*c*) water, sediment, chemicals, and streams; (*d*) the road network; and (*e*) transportation policy and planning.

Figure 1 Road corridor showing road surface, maintained open roadsides, and roadside natural strips. Strips of relatively natural vegetation are especially characteristic of road corridors (known as road reserves) in Australia. Wheatbelt of Western Australia. Photo courtesy of BMJ Hussey. See color version at end of volume.



ROADSIDE VEGETATION AND ANIMALS

Plants and Vegetation

"Roadside" or "verge" refers to the more-or-less intensively managed strip, usually dominated by herbaceous vegetation, adjacent to a road surface (Figure 1). Plants on this strip tend to grow rapidly with ample light and with moisture from road drainage. Indeed, management often includes regular mowing, which slows woody-plant invasion (1, 86). Ecological management may also maintain roadside native-plant communities in areas of intensive agriculture, reduce the invasion of exotic (non-native) species, attract or repel animals, enhance road drainage, and reduce soil erosion.

Roadsides contain few regionally rare species but have relatively high plant species richness (12, 139). Disturbance-tolerant species predominate, especially with intensive management, adjacent to highways, and exotic species typically are common (19, 121). Roadside mowing tends to both reduce plant species richness and favor exotic plants (27, 92, 107). Furthermore, cutting and removing hay twice a year may result in higher plant species richness than does mowing less frequently (29, 86). Native wildflower species are increasingly planted in dispersed locations along highways (1).

Numerous seeds are carried and deposited along roads by vehicles (70, 112). Plants may also spread along roads due to vehicle-caused air turbulence (107, 133) or favorable roadside conditions (1, 92, 107, 121, 133). For example, the short-distance spread of an exotic wetland species, purple loosestrife (*Lythrum salicaria*), along a New York highway was facilitated by roadside ditches, as well as culverts connecting opposite sides of the highway and the median strip of vegetation (133). Yet few documented cases are known of species that have successfully spread more than 1 km because of roads.

Mineral nutrient fertilization from roadside management, nearby agriculture, and atmospheric NOX also alter roadside vegetation. In Britain, for example, vegetation was changed for 100–200 m from a highway by nitrogen from traffic exhaust (7). Nutrient enrichment from nearby agriculture enhances the growth of aggressive weeds and can be a major stress on a roadside native-plant community (19, 92). Indeed, to conserve roadside native-plant communities in Dutch farmland, fertilization and importing topsoil are ending, and in some places nutrient accumulations and weed seed banks are reduced by soil removal (86; H van Bohemen, personal communication).

Woody species are planted in some roadsides to reduce erosion, control snow accumulation, support wildlife, reduce headlight glare, or enhance aesthetics (1, 105). Planted exotic species, however, may spread into nearby natural ecosystems (3, 12). For example, in half the places where non-native woody species were planted in roadsides adjacent to woods in Massachusetts (USA), a species had spread into the woods (42).

Roadside management sometimes creates habitat diversity to maintain native ecosystems or species (1, 86, 131). Mowing different sections along a road, or parallel strips in wide roadsides, at different times or intervals may be quite effective (87). Ponds, wetlands, ditches, berms, varied roadside widths, different sun and shade combinations, different slope angles and exposures, and shrub patches rather than rows offer variety for roadside species richness.

In landscapes where almost all native vegetation has been removed for cultivation or pasture, roadside natural strips (Figure 1) are especially valuable as reservoirs of biological diversity (19, 66). Strips of native prairie along roads and railroads, plus so-called beauty strips of woodland that block views near intensive logging, may function similarly as examples. However, roadside natural strips of woody vegetation are widespread in many Australian agricultural landscapes and are present in South Africa (11, 12, 27, 39, 66, 111). Overall, these giant green networks provide impressive habitat connectivity and disperse "bits of nature" widely across a landscape. Yet they miss the greater ecological benefits typically provided by large patches of natural vegetation (39, 41).

In conclusion, roadside vegetation is rich in plant species, although apparently not an important conduit for plants. The scattered literature suggests a promising research frontier.

Animals and Movement Patterns

Mowing, burning, livestock grazing, fertilizing, and planting woody plants greatly impact native animals in roadsides. Cutting and removing roadside vegetation twice a year in The Netherlands, compared with less frequent mowing, results in more species of small mammals, reptiles, amphibians, and insects (29, 86). However, mowing once every 3–5 y rather than annually results in more bird nests. Many vertebrate species persist better with mowing after, rather than before or during, the breeding period (86, 87). The mowing regime is especially important for insects such as meadow butterflies and moths, where different species go through stages of their annual cycle at different times (83). Roadsides, especially where mowed cuttings are removed, are suitable for ~80% of the Dutch butterfly fauna (86).

Planting several native and exotic shrub species along Indiana (USA) highways resulted in higher species richness, population density, and nest density for birds, compared with nearby grassy roadsides (105). Rabbit (*Sylvilagus*) density increased slightly. However, roadkill rates did not differ next to shrubby versus grassy roadsides.

In general, road surfaces, roadsides, and adjacent areas are little used as conduits for animal movement along a road (39), although comparisons with null models are rare. For example, radiotracking studies of wildlife across the landscape detect few movements along or parallel to roads (35, 39, 93). Some exceptions are noteworthy. Foraging animals encountering a road sometimes

move short distances parallel to it (10, 106). At night, many large predator species move along roads that have little vehicular or people traffic (12, 39). Carrion feeders move along roads in search of roadkills, and vehicles sometimes transport amphibians and other animals (11, 12, 32). Small mammals have spread tens of kilometers along highway roadsides (47, 60). In addition, migrating birds might use roads as navigational cues.

Experimental, observational, and modeling approaches have been used to study beetle movement along roadsides in The Netherlands (125–127). On wide roadsides, fewer animals disappeared into adjacent habitats. Also, a dense grass strip by the road surface minimized beetle susceptibility to roadkill mortality (126, 127). Long dispersals of beetles were more frequent in wide (15–25 m) than in narrow (<12 m) roadsides. Nodes of open vegetation increased, and narrow bottlenecks decreased, the probability of long dispersals. The results suggest that with 20–30-m-wide roadsides containing a central suitable habitat, beetle species with poor dispersal ability and a good reproductive rate may move 1–2 km along roadsides in a decade (127).

Adjacent ecosystems also exert significant influences on animals in corridors (39). For example, roadside beetle diversity was higher near a similar patch of sandy habitat, and roadsides next to forest had the greatest number of forest beetle species (127). In an intensive-agriculture landscape (Iowa, USA), bird-nest predation in roadsides was highest opposite woods and lowest opposite pastures (K Freemark, unpublished data). Finally, some roadside animals also invade nearby natural vegetation (37, 47, 54, 60, 63, 127).

The median strip between lanes of a highway is little studied. A North Carolina (USA) study found no difference in small-mammal density between roadsides on the median and on the outer side of the highway (2). This result was the same whether comparing mowed roadside areas or unmowed roadside areas. Also, roadkill rates may be affected by the pattern of wooded and grassy areas along median strips (10).

In conclusion, some species move significant distances along roadsides and have major local impacts. Nevertheless, road corridors appear to be relatively unimportant as conduits for species movement, although movement rates should be better compared with those at a distance and in natural-vegetation corridors.

ROAD AND VEHICLE EFFECTS ON POPULATIONS

Roadkilled Animals

Sometime during the last three decades, roads with vehicles probably overtook hunting as the leading direct human cause of vertebrate mortality on land. In addition to the large numbers of vertebrates killed, insects are roadkilled in prodigious numbers, as windshield counts will attest.

Estimates of roadkills (faunal casualties) based on measurements in short sections of roads tell the annual story (12, 39, 123): 159,000 mammals and 653,000 birds in The Netherlands; seven million birds in Bulgaria; five million frogs and reptiles in Australia. An estimated one million vertebrates per day are killed on roads in the United States.

Long-term studies of roadkills near wetlands illustrate two important patterns. One study recorded >625 snakes and another >1700 frogs annually roadkilled per kilometer (8, 54). A growing literature suggests that roads by wetlands and ponds commonly have the highest roadkill rates, and that, even though amphibians may tend to avoid roads (34), the greatest transportation impact on amphibians is probably roadkills (8, 28, 34, 128).

Road width and vehicle traffic levels and speeds affect roadkill rates. Amphibians and reptiles tend to be particularly susceptible on two-lane roads with low to moderate traffic (28, 34, 57, 67). Large and mid-sized mammals are especially susceptible on two-lane, high-speed roads, and birds and small mammals on wider, high-speed highways (33, 90, 106).

Do roadkills significantly impact populations? Measurements of bird and mammal roadkills in England illustrate the main pattern (56, 57). The house sparrow (*Passer domesticus*) had by far the highest roadkill rate. Yet this species has a huge population, reproduces much faster than the roadkill rate, and can rapidly recolonize locations where a local population drops. The study concluded, based on the limited data sets available, that none of the >100 bird and mammal species recorded had a roadkill rate sufficient to affect population size at the national level.

Despite this overall pattern, roadkill rates are apparently significant for a few species listed as nationally endangered or threatened in various nations (~9–12 cases) (9, 39, 43; C Vos, personal communication). Two examples from southern Florida (USA) are illustrative. The Florida panther (*Felis concolor coryi*) had an annual roadkill mortality of approximately 10% of its population before 1991 (33, 54). Mitigation efforts reduced roadkill loss to 2%. The key deer (*Odocoileus virginianus clavium*) has an annual roadkill mortality of ~16% of its population. Local populations, of course, may suffer declines where the roadkill rate exceeds the rates of reproduction and immigration. At least a dozen local-population examples are known for vertebrates whose total populations are not endangered (33, 39, 43).

Vehicles often hit vertebrates attracted to spilled grain, roadside plants, insects, basking animals, small mammals, road salt, or dead animals (12, 32, 56, 87). Roadkills may be frequent where traffic lanes are separated by impermeable barriers or are between higher roadside banks (10, 106).

Landscape spatial patterns also help determine roadkill locations and rates. Animals linked to specific adjacent land uses include amphibians roadkilled

near wetlands and turtles near open-water areas (8). Foraging deer are often roadkilled between fields in forested landscapes, between wooded areas in open landscapes, or by conservation areas in suburbs (10, 42, 106). The vicinity of a large natural-vegetation patch and the area between two such patches are likely roadkill locations for foraging or dispersing animals. Even more likely locations are where major wildlife-movement routes are interrupted, such as roads crossing drainage valleys in open landscapes or crossing railway routes in suburbs (42, 106).

In short, road vehicles are prolific killers of terrestrial vertebrates. Nevertheless, except for a small number of rare species, roadkills have minimal effect on population size.

Vehicle Disturbance and Road Avoidance

The ecological effect of road avoidance caused by traffic disturbance is probably much greater than that of roadkills seen splattered along the road. Traffic noise seems most important, although visual disturbance, pollutants, and predators moving along a road are alternative hypotheses as the cause of avoidance.

Studies of the ecological effects of highways on avian communities in The Netherlands point to an important pattern. In both woodlands and grasslands adjacent to roads, 60% of the bird species present had a lower density near a highway (102, 103). In the affected zone, the total bird density was approximately one third lower, and species richness was reduced as species progressively disappeared with proximity to the road. Effect-distances (the distance from a road at which a population density decrease was detected) were greatest for birds in grasslands, intermediate for birds in deciduous woods, and least for birds in coniferous woods.

Effect-distances were also sensitive to traffic density. Thus, with an average traffic speed of 120 km/h, the effect-distances for the most sensitive species (rather than for all species combined) were 305 m in woodland by roads with a traffic density of 10,000 vehicles per day (veh/day) and 810 m in woodland by 50,000 veh/day; 365 m in grassland by 10,000 veh/day and 930 m in grassland by 50,000 veh/day (101–103). Most grassland species showed population decreases by roads with 5000 veh/day or less (102). The effect-distances for both woodland and grassland birds increased steadily with average vehicle speed up to 120 km/h and also with traffic density from 3000 to 140,000 veh/day (100, 102, 103). These road effects were more severe in years when overall bird population sizes were low (101).

Songbirds appear to be sensitive to remarkably low noise levels, similar to those in a library reading room (100, 102, 103). The noise level at which population densities of all woodland birds began to decline averaged 42 decibels (dB), compared with an average of 48 dB for grassland species. The most sensitive

woodland species (cuckoo) showed a decline in density at 35 dB, and the most sensitive grassland bird (black-tailed godwit, *Limosa limosa*) responded at 43 dB. Field studies and experiments will help clarify the significance of these important results for traffic noise and birds.

Many possible reasons exist for the effects of traffic noise. Likely hypotheses include hearing loss, increase in stress hormones, altered behaviors, interference with communication during breeding activities, differential sensitivity to different frequencies, and deleterious effects on food supply or other habitat attributes (6, 101, 103, 130). Indeed, vibrations associated with traffic may affect the emergence of earthworms from soil and the abundance of crows (*Corvus*) feeding on them (120). A different stress, roadside lighting, altered nocturnal frog behavior (18). Responses to roads with little traffic may resemble behavioral responses to acute disturbances (individual vehicles periodically passing), rather than the effects of chronic disturbance along busy roads.

Response to traffic noise is part of a broader pattern of road avoidance by animals. In the Dutch studies, visual disturbance and pollutants extended outward only a short distance compared with traffic noise (100, 103). However, visual disturbance and predators moving along roads may be more significant by low-traffic roads.

Various large mammals tend to have lower population densities within 100–200 m of roads (72, 93, 108). Other animals that seem to avoid roads include arthropods, small mammals, forest birds, and grassland birds (37, 47, 73, 123). Such road-effect zones, extending outward tens or hundreds of meters from a road, generally exhibit lower breeding densities and reduced species richness compared with control sites (32, 101). Considering the density of roads plus the total area of avoidance zones, the ecological impact of road avoidance must well exceed the impact of either roadkills or habitat loss in road corridors.

Barrier Effects and Habitat Fragmentation

All roads serve as barriers or filters to some animal movement. Experiments show that carabid beetles and wolf spiders (*Lycosa*) are blocked by roads as narrow as 2.5 m wide (73), and wider roads are significant barriers to crossing for many mammals (11, 54, 90, 113). The probability of small mammals crossing lightly traveled roads 6–15 m wide may be <10% of that for movements within adjacent habitats (78, 119). Similarly, wetland species, including amphibians and turtles, commonly show a reduced tendency to cross roads (34, 67).

Road width and traffic density are major determinants of the barrier effect, whereas road surface (asphalt or concrete versus gravel or soil) is generally a minor factor (34, 39, 73, 90). Road salt appears to be a significant deterrent to amphibian crossing (28, 42). Also, lobes and coves in convoluted outer-roadside boundaries probably affect crossing locations and rates (39).

The barrier effect tends to create metapopulations, e.g. where roads divide a large continuous population into smaller, partially isolated local populations (subpopulations) (6, 54, 128). Small populations fluctuate more widely over time and have a higher probability of extinction than do large populations (1, 88, 115, 122, 123). Furthermore, the recolonization process is also blocked by road barriers, often accentuated by road widening or increases in traffic. This well-known demographic threat must affect numerous species near an extensive road network, yet is little studied relative to roads (6, 73, 98).

The genetics of a population is also altered by a barrier that persists over many generations (73, 115). For instance, road barriers altered the genetic structure of small local populations of the common frog (*Rana temporaria*) in Germany by lowering genetic heterozygosity and polymorphism (97, 98). Other than the barrier effect on this amphibian and roadkill effects on two southern Florida mammals (20, 54), little is known of the genetic effects of roads.

Making roads more permeable reduces the demographic threat but at the cost of more roadkills. In contrast, increasing the barrier effect of roads reduces roadkills but accentuates the problems of small populations. What is the solution to this quandary (122, 128)? The barrier effect on populations probably affects more species, and extends over a wider land area, than the effects of either roadkills or road avoidance. This barrier effect may emerge as the greatest ecological impact of roads with vehicles. Therefore, perforating roads to diminish barriers makes good ecological sense.

WATER, SEDIMENT, CHEMICALS, STREAMS, AND ROADS

Water Runoff

Altering flows can have major physical or chemical effects on aquatic ecosystems. The external forces of gravity and resistance cause streams to carve channels, transport materials and chemicals, and change the landscape (68). Thus, water runoff and sediment yield are the key physical processes whereby roads have an impact on streams and other aquatic systems, and the resulting effect-distances vary widely (Figure 2).

Roads on upper hillslopes concentrate water flows, which in turn form channels higher on slopes than in the absence of roads (80). This process leads to smaller, more elongated first-order drainage basins and a longer total length of the channel network. The effects of stream network length on erosion and sedimentation vary with both scale and drainage basin area (80).

Water rapidly runs off relatively impervious road surfaces, especially in storm and snowmelt events. However, in moist, hilly, and mountainous terrain, such

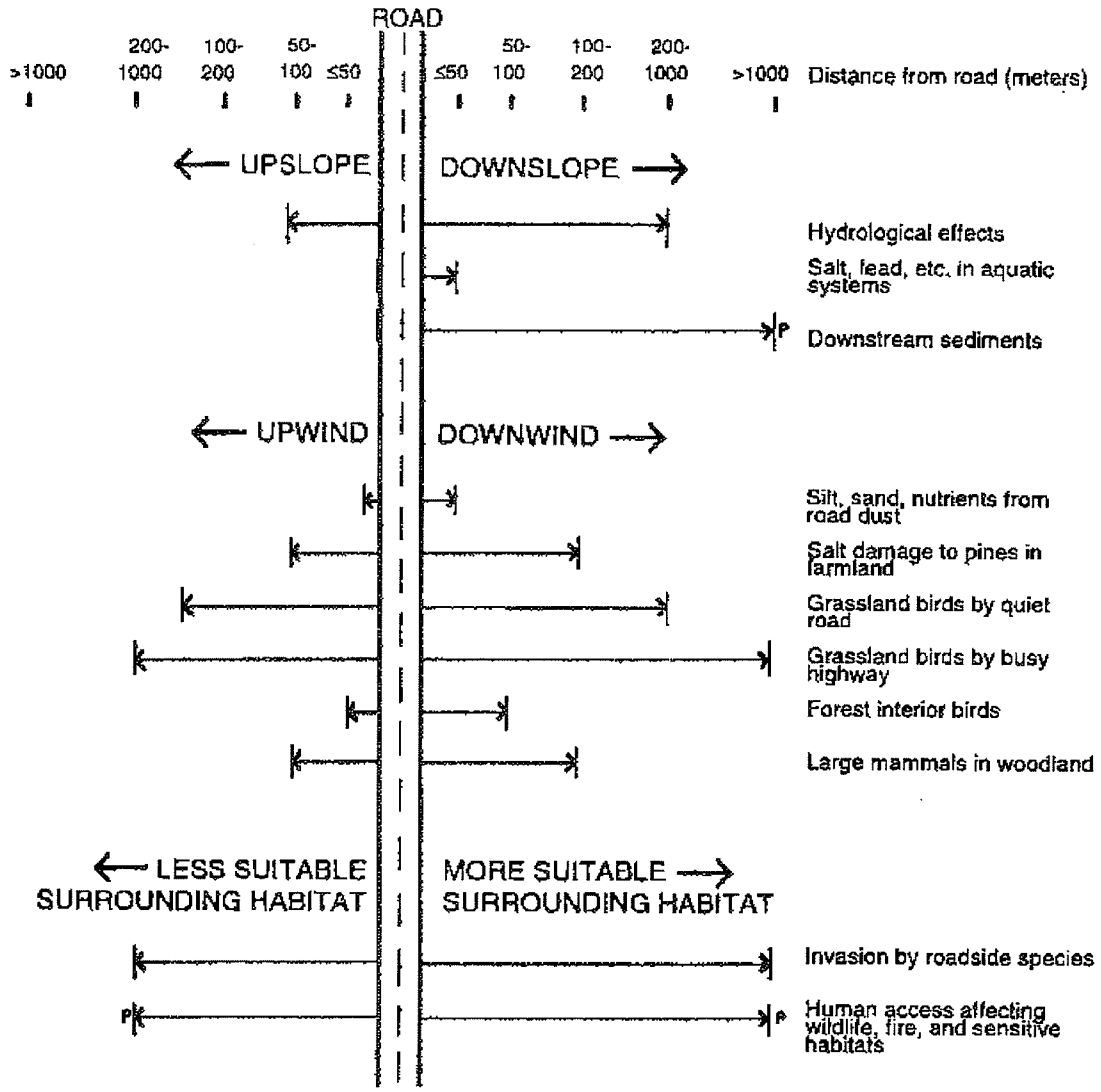


Figure 2 Road-effect zone defined by ecological effects extending different distances from a road. Most distances are based on specific illustrative studies (39); distance to left is arbitrarily half of that to right. (*P*) indicates an effect primarily at specific points. From Forman et al (43).

runoff is often insignificant compared with the conversion of slow-moving groundwater to fast-moving surface water at cutbanks by roads (52, 62, 132). Surface water is then carried by roadside ditches, some of which connect directly to streams while others drain to culverts with gullies incised below their outlets (132). Increased runoff associated with roads may increase the rates and extent of erosion, reduce percolation and aquifer recharge rates, alter channel morphology, and increase stream discharge rates (13, 14). Peak discharges or

floods then restructure riparian areas by rearranging channels, logs, branches, boulders, fine-sediment deposits, and pools.

In forests, the combination of logging and roads increases peak discharges and downstream flooding (62, 132). Forest removal results in lower evapotranspiration and water-storage capabilities, but roads alone may increase peak discharge rates (62). Also, flood frequency apparently correlates with the percentage of road cover in a basin (52, 62, 110).

Roads may alter the subsurface flow as well as the surface flow on wetland soils (116). Compacted saturated or nearly saturated soils have limited permeability and low drainage capacity. Wetland road crossings often block drainage passages and groundwater flows, effectively raising the upslope water table and killing vegetation by root inundation, while lowering the downslope water table with accompanying damage to vegetation (116, 118).

Streams may be altered for considerable distances both upstream and downstream of bridges. Upstream, levees or channelization tend to result in reduced flooding of the riparian zone, grade degradation, hydraulic structural problems, and more channelization (17). Downstream, the grade change at a bridge results in local scouring that alters sedimentation and deposition processes (17, 49). Sediment and chemicals enter streams where a road crosses, and mathematical models predict sediment loading in and out of reaches affected by stream crossings (5). The fixed stream (or river) location at a bridge or culvert reduces both the amount and variability of stream migration across a floodplain. Therefore, stream ecosystems have altered flow rates, pool-riffle sequences, and scour, which typically reduce habitat-forming debris and aquatic organisms.

Sediment

The volume of sediment yield from a road depends on sediment supply and transport capacity (5). Sediment yield is determined by road geometry, slope, length, width, surface, and maintenance (5, 51), in addition to soil properties and vegetation cover (59). Road surfaces, cutbanks, fillslopes, bridge/culvert sites, and ditches are all sources of sediment associated with roads. The exposed soil surfaces, as well as the greater sediment-transport capacity of increased hydrologic flows, result in higher erosion rates and sediment yields (99).

Road dust as a little-studied sediment transfer may directly damage vegetation, provide nutrients for plant growth, or change the pH and vegetation (109). Effect-distances are usually <10–20 m but may extend to 200 m downwind (Figure 2). In arid land, soil erosion and drainage are common road problems (61).

Arctic roads also are often sources of dust. Other ecological issues include change in albedo, flooding, erosion and thermokarst, weed migration, waterfowl and shorebird habitat, and altered movement of large mammals (129).

Landsliding or mass wasting associated with roads may be a major sediment source (13, 117). Some of this sediment accumulates on lower slopes and is subject to subsequent erosion. The rest reaches floodplains or streams, where it alters riparian ecosystems, channel morphology, or aquatic habitat. Although gradual sediment transport and episodic landslides are natural processes affecting streams, elevated levels caused by roads tend to disrupt aquatic ecosystems. Indeed, logging roads commonly produce more erosion and sediment yield, particularly by mass wasting, than do the areas logged (45, 51, 104, 117).

Buffer strips between roads and streams tend to reduce sediments reaching aquatic ecosystems (77, 91). Buffers may be less effective for landslides than for arresting water and sediment from culverts and roadside ditches. Good road location (including avoiding streamsides and narrow floodplains for many ecological reasons), plus good ecological design of roadsides relative to slope, soil, and hydrology, may be a better strategy than depending on wide buffers to absorb sediment.

Water from road ditches tends to deposit finer sediment in streams, whereas landslides generally provide coarser material. Fine sediment increases turbidity (51), which disrupts stream ecosystems in part by inhibiting aquatic plants, macro-invertebrates, and fish (14, 16, 31, 99). Coarse deposits such as logs and boulders help create deep pools and habitat heterogeneity in streams. During low-flow periods, fine-sediment deposits tend to fill pools and smooth gravel beds, hence degrading habitats and spawning sites for key fish (13, 14, 31). During high-discharge events, accumulated sediment tends to be flushed out and redeposited in larger water bodies.

In short, roads accelerate water flows and sediment transport, which raise flood levels and degrade aquatic ecosystems. Thus, local hydrologic and erosion effects along roads are dispersed across the land, whereas major impacts are concentrated in the stream network and distant valleys.

Chemical Transport

Most chemical transport from roads occurs in stormwater runoff through or over soil. Runoff pollutants alter soil chemistry, may be absorbed by plants, and affect stream ecosystems, where they are dispersed and diluted over considerable distances (16, 50, 66, 137, 138). Deicing salt and heavy metals are the two main categories of pollutants studied in road runoff.

The primary deicing agent, NaCl, corrodes vehicles and bridges, contaminates drinking water supplies, and is toxic to many species of plants, fish, and other aquatic organisms (4, 16, 84). Calcium magnesium acetate (CMA) is a more effective deicer, less corrosive, less mobile in soil, biodegradable, and less toxic to aquatic organisms (4, 84, 89). Also, CaCl used to decrease dust may inhibit amphibian movement (28).

Airborne NaCl from road snowplowing may cause leaf injury to trees (e.g. *Pinus strobus*) up to 120 m from a road, especially downwind and downslope (58, 84). Trees seem to be more sensitive to chloride damage than are common roadside shrubs and grasses. Sodium accumulation in soils, mainly within 5 m of a road, alters soil structure, which affects plant growth (84). Road salt has facilitated the spread of three coastal exotic plants as much as 150 km in The Netherlands (1).

Deicing agents tend to increase the mobility of chemical elements in soil, such as heavy metals (by NaCl) and Na, Cl, Ca, and Mg (by CMA) (4). This process facilitates contamination of groundwater, aquifers, and streams. Because of dilution, the chemical effects of road runoff on surface water ecosystems may be primarily confined to small streams, particularly where they run adjacent to roads (36, 84).

Heavy metals are relatively immobile and heterogeneously distributed in roadsides, especially due to drainage ditch flows (15, 55, 80). Soils adjacent to the road surface typically contain the greatest mass (136). Elevated concentrations in grass tissue may occur within 5–8 m of a road, although high lead levels have been found in soil out to 25 m (30, 65, 82). Elevated lead concentrations were found in tissue of several small-mammal species in a narrow zone by roads, with higher lead levels by busy roads (48).

Highway roadsides of 5–15-m width next to traffic densities of 11,000–124,000 veh/day in The Netherlands had somewhat higher heavy-metal accumulations on the downwind side, but no correlation with traffic density was found (30). All average levels of Pb, Cd, Zn, Cr, Ni, and As in cut grass (hay) from these roadsides were below the Dutch maximum-acceptable-levels for livestock fodder and "clean compost." Only Zn in some roadsides studied exceeded the maximum for "very clean compost."

Many other chemicals enter roadsides. Herbicides often kill non-target plants, particularly from blanket applications in drifting air. For polycyclic aromatic hydrocarbons from petroleum (136), the preliminary conclusion for the Dutch highways was that levels in roadside hay "do not seem to give cause for alarm" (30). Fertilizer nutrients affect roadside vegetation (19, 86, 92), and nitrogen from vehicular NOX emission altered vegetation up to 100–200 m from a highway in Britain (7). Acidic road runoff may have impacts on stream ecosystems (36, 81). Of the hazardous materials transported on roads, e.g. >500,000 shipments moved each day in the United States, a small fraction is spilled, although occasional large spills cause severe local effects (85).

Typical water-quality responses to road runoff include altered levels of heavy metal, salinity, turbidity, and dissolved oxygen (16, 23, 81). However, these water-quality changes, even in a wetland, tend to be temporary and localized due to fluctuations in water quantity (23). Road runoff is a major source of heavy

metals to stream systems, especially Pb, Zn, Cu, Cr, and Cd (16, 50, 64, 137). Fish mortality in streams has been related to high concentrations of Al, Mn, Cu, Fe, or Zn, with effects on populations reorded as far as 8 km downstream (81). Both high traffic volume and high metal concentration in runoff have correlated with mortality of fish and other aquatic organisms (59). Floodplain soil near bridges may have high heavy-metal concentrations (138). Although highway runoff generally has little adverse effect on vegetation or plant productivity, it may change the species composition of floodplain plant communities, favoring common species (138).

Overall, terrestrial vegetation seems to be more resistant than aquatic organisms to road impacts (59, 138). Drainage of road runoff through grassy channels greatly reduces toxic solid- and heavy-metal concentrations (59). Furthermore, dense vegetation increases soil infiltration and storage. Therefore, instead of expensive detention ponds and drainage structures to reduce runoff impacts, creative grassland designs by roads, perhaps with shrubs, may provide both sponge and biodiversity benefits. The wide range of studies cited above lead to the conclusion that chemical impacts tend to be localized near roads.

THE ROAD NETWORK

New Roads and Changing Landscape Pattern

Do roads lead to development, or does development lead to roads? This timeless debate in the transportation community has greater ramifications as environmental quality becomes more important in the transportation–land-use interaction (114). For example, new roads into forested landscapes often lead to economic development as well as deforestation and habitat fragmentation (22).

At the landscape scale, the major ecological impacts of a road network are the disruption of landscape processes and loss of biodiversity. Interrupting horizontal natural processes, such as groundwater flow, streamflow, fire spread, foraging, and dispersal, fundamentally alters the way the landscape works (40, 53). It truncates flows and movements, and reduces the critical variability in natural processes and disturbances. Biodiversity erodes as the road network impacts interior species, species with large home ranges, stream and wetland species, rare native species, and species dependent on disturbance and horizontal flows.

A new road system in the Rondonia rainforest of Brazil illustrates such effects. By 1984, road construction and asphalt paving had stimulated a major influx of people and forest clearing (25). A regular pattern of primary roads plus parallel secondary roads 4 km apart was imposed on the land. Commonly, small forest plots of ~5 ha were gradually converted to grass and joined with neighboring plots to form large pastures (26). Simulation models of this typical scenario were compared with models of a worst-case scenario and an "innovative

farming" scenario with perennial crops and essentially no fire or cattle (25, 26). Species requiring a large area and having poor "gap-crossability" disappeared in all model scenarios after road construction. Species with moderate requirements for area and gap-crossability persisted only in the innovative farming scenario. Reestablishing the connectivity of nature with a network of wildlife corridors was proposed as a solution to maintain the first group of species, which are of conservation importance.

The closure and removal of some roads in the grid is an alternative ecological approach. Natural landscape processes and biodiversity are both inhibited by a rigid road grid. Closing and eliminating some linkages would permit the reestablishment of a few large patches of natural rainforest (39, 41, 43). Such a solution helps create a road network with a high variance in mesh size. Large natural-vegetation patches in areas remote from both roads and people are apparently required to sustain important species such as wolf, bear, and probably jaguar (*Canis lupus, Ursus, Felis onca*) (39, 76). Temporary road closures could, for example, enhance amphibian migration during the breeding phase (67). In contrast, road closure and removal could eliminate motorized vehicle use, thus reducing numerous disturbance effects on natural populations and ecosystems.

A general spatial-process model emphasizes that roads have the greatest ecological impact early in the process of land transformation (39, 41). They dissect the land, leading to habitat fragmentation, shrinkage, and attrition. Forest road networks may also create distinctive spatial patterns, such as converting convoluted to rectilinear shapes, decreasing core forest area, and creating more total edge habitat by roads than by logged areas (79, 96).

Forest roads as a subset of roads in general are characterized as being narrow, not covered with asphalt, lightly traveled, and remote (98). Among the wide range of ecological effects of roads (39, 95), forest roads have a distinctive set of major ecological effects: (*a*) habitat loss by road construction, (*b*) altered water routing and downstream peak flows, (*c*) soil erosion and sedimentation impacts on streams, (*d*) altered species patterns, and (*e*) human access and disturbance in remote areas (43, 45, 62, 132). Thus, an evaluation of logging regimes includes the ecological effects of both the road network and forest spatial patterns (45, 69). In conclusion, a road network disrupts horizontal natural processes, and by altering both landscape spatial pattern and the processes, it reduces biodiversity.

Road Density

Road density, e.g. measured as km/km^2, has been proposed as a useful, broad index of several ecological effects of roads in a landscape (39, 43, 44, 95). Effects are evident for faunal movement, population fragmentation, human access, hydrology, aquatic ecosystems, and fire patterns.

A road density of approx. 0.6 km/km^2 (1.0 mi/mi^2) appears to be the maximum for a naturally functioning landscape containing sustained populations of large predators, such as wolves and mountain lions (*Felis concolor*) (43, 76, 124). Moose (*Alces*), bear (*Ursus*) (brown, black, and grizzly), and certain other populations also decrease with increasing road density (11, 43, 72). These species are differentially sensitive to the roadkill, road-avoidance, and human-access dimensions of road density. Species that move along, rather than across, roads presumably are benefitted by higher road density (12, 39).

Human access and disturbance effects on remote areas tend to increase with higher road density (39, 72, 76). Similarly, human-caused fire ignitions and suppressions may increase, and average fire sizes decrease (111).

Aquatic ecosystems are also affected by road density. Hydrologic effects, such as altered groundwater conditions and impeded drainage upslope, are sensitive to road density (116, 118). Increased peak flows in streams may be evident at road densities of 2–3 km/km^2 (62). Detrimental effects on aquatic ecosystems, based on macro-invertebrate diversity, were evident where roads covered 5% or more of a watershed in California (75). In southeastern Ontario, the species richness of wetland plants, amphibians/reptiles, and birds each correlated negatively with road density within 1–2 km of a wetland (38).

Road density is an overall index that averages patterns over an area. Its effects probably are sensitive to road width or type, traffic density, network connectivity, and the frequency of spur roads into remote areas. Thus network structure, or an index of variance in mesh size, is also important in understanding the effect of road density (39, 76, 79, 96). Indeed, although road density is a useful overall index, the presence of a few large areas of low road density may be the best indicator of suitable habitat for large vertebrates and other major ecological values.

TRANSPORTATION POLICY AND PLANNING

Environmental Policy Dimensions

Ecological principles are increasingly important in environmental transportation policy, and Australia, The Netherlands, and the United States highlight contrasting approaches. Australian policy has focused on biodiversity, including wildflower protection. An enormous network of road reserves with natural-vegetation strips 10–200 m wide (Figure 1) stands out in many agricultural landscapes (66, 92, 111). Public pressure helped create this system, which "helps to prevent soil erosion" and "where wildflowers can grow and flourish in perpetuity" (111). Diverse experimental management approaches involve burning, weed control, planting native species, and nature restoration. Ecological

scientists commonly work side by side with civil engineers in transportation departments at all levels of government.

In contrast, Dutch policy has focused on the open roadside vegetation, roadkills, animal movement patterns, and nature restoration (1, 21, 29, 86). This approach reflects the stated national objectives of (*a*) recreating "nature, including natural processes and biodiversity; and (*b*) enhancing the national ecological network," mainly composed of large natural-vegetation patches and major wildlife and water corridors (1, 46). An impressive series of mitigation overpasses, tunnels, and culverts provide for animal and water movement where interrupted by road barriers (24, 43, 44, 86). Environmental activities in transportation revolve around a group of environmental scientists in the national Ministry of Transport who work closely with engineers and policy-makers at both local and national levels.

In the United States, environmental transportation policy focuses on vehicular pollutants, as well as engineering solutions for soil erosion and sedimentation (85). A few states have built wildlife underpasses and overpasses to address local roadkill or wildlife movement concerns. A 1991 federal law—the Intermodal Surface Transportation Efficiency Act (ISTEA)—establishes policy for a transportation system that is "economically efficient and environmentally sound," considers the "external benefits of reduced air pollution, reduced traffic congestion and other aspects of the quality of life," considers transportation in a region-wide metropolitan area, and links ecological attributes with the aesthetics of a landscape (43). Thus, US transportation policy largely ignores biodiversity loss, habitat fragmentation, disruption of horizontal natural processes, natural stream and wetland hydrology, streamwater chemistry, and reduction of fish populations, a range of ecological issues highlighted in the transportation community in 1997 (85).

Of course, many nations use ecological principles in designing transportation systems (21, 33, 63, 95, 134), and environmental scientists, engineers, and policy-makers in Europe have united to "conserve biodiversity and reduce ...fauna casualties" at the international level (21; H van Bohemen, personal communication). The successful removal of lead from petroleum led to less lead in roadside ecosystems worldwide. Nevertheless, the huge Australian road-reserve system and the Dutch mitigation system for animal and water flows are especially ambitious and pioneering.

Spatial Planning and Mitigation

Most existing roads were built before the explosion in ecological knowledge, and many are poorly located ecologically (43). Yet the Dutch have developed a promising transportation planning process for the movement of both people and natural processes across the land (40, 44, 86). In essence, the ecological network, consisting of large natural-vegetation patches plus major corridors for

water and wildlife movement, is mapped. The road network is then superimposed on the ecological network to identify bottlenecks. Finally, mitigation or compensation techniques are applied to eliminate designated percentages of bottlenecks in a time sequence. The earlier such spatial planning begins, the greater its effect (41).

Compensation is proposed where bottlenecks apparently cannot be overcome by mitigation. The principle of no-net-loss has been used internationally for wetlands with varying success (46, 94), whereas no-net-loss of natural processes and biodiversity by roads is a concept only beginning to be applied (1, 24, 46, 86). The loss, e.g. of biodiversity or groundwater flow, is compensated by increasing an equivalent ecological value nearby. Options include protection of an equivalent amount of high-quality habitat, reestablishment of another wildlife corridor, or creation of new habitat. Mitigation, on the other hand, attempts to minimize detrimental ecological impacts and is illustrated by the varied wildlife passages (tunnels, pipes, underpasses, overpasses) operating for animal movement (21, 86).

Diverse tunnel designs focus on small and mid-sized animals. Amphibian tunnels, generally 30–100 cm wide and located where roads block movement to breeding ponds or wetlands, are widespread in Europe and rare in the United States (33, 43, 67). "Ecopipes," or badger tunnels, are pipes ~40 cm in diameter mainly designed for movement of mid-sized mammals across Dutch roads, and located where water can rarely flow through (9, 44, 46, 86). In contrast, Dutch wildlife culverts are ~120 cm wide, with a central channel for water flow between two raised 40-cm-wide paths for animal movement. "Talus tunnels" are designed for a mid-sized mammal that lives and moves in rock talus slopes in Australia (74).

Wildlife underpasses, generally 8–30 m wide and at least 2.5 m high, have been built for large mammals in southern Florida and scattered locations elsewhere in the United States, Canada, and France (33, 43, 54, 63, 93, 113). Wildlife overpasses, also designed for large mammals, range in width up to 200 m and are scarce: approximately 6 in North America (New Jersey, Utah, Alberta, British Columbia) (33, 43; BF Leeson, personal communication) and 17 in Europe (Germany, France, The Netherlands, Switzerland) (44, 46, 63, 86, 134). The minimum widths for effectiveness may be 30–50 m in the center and 50–80 m on the ends (33, 46, 86). The two Swiss overpasses of 140-m and 200-m width remind us that ultimately the goal should be "landscape connectors" that permit all horizontal natural processes to cross roads (43, 44).

These mitigation structures are normally combined with fencing and vegetation to enhance animal crossing (86). Almost all such passages are successful in that the target species crosses at least occasionally, and most are used by many other species. Florida underpasses are used by the Florida panther (*Felis concolor coryi*), nearly the whole local terrestrial fauna, and groundwater as

well (33, 54). Underpasses and overpasses are used by almost all large mammal species of a region. Yet, little information exists on crossing rates relative to population sizes, movement rates away from roads, predation rates, home range locations, and so forth. Nevertheless, mitigation passages are effective in perforating road barriers to maintain horizontal natural processes across the land.

The Road-Effect Zone

Roads and roadsides cover 0.9% of Britain and 1.0% of the United States, while road reserves (Figure 1) cover 2.5% of the State of Victoria, Australia (12, 85, 131). Yet how much of the land is ecologically impacted by roads with vehicles?

The road-effect zone is the area over which significant ecological effects extend outward from a road and typically is many times wider than the road surface plus roadsides (Figure 2) (39, 95, 101, 134). The zone is asymmetric with convoluted boundaries, reflecting the sequence of ecological variables, plus unequal effect-distances due to slope, wind, and habitat suitability on opposite sides of a road (40, 43). Knowing the average width of the road-effect zone permits us to estimate the proportion of the land ecologically affected by roads (43). For example, based on the traffic noise effect-distances of sensitive bird species described above, road-effect zones cover ~10–20% of The Netherlands (101).

Finally, a preliminary calculation for the United States was made based on nine water and species variables in Massachusetts (USA), plus evidence from the Dutch studies (42). An estimated 15–20% of the US land area is directly affected ecologically by roads. These estimates reemphasize the immensity and pervasiveness of ecological road impacts. Moreover, they challenge science and society to embark on a journey of discovery and solution.

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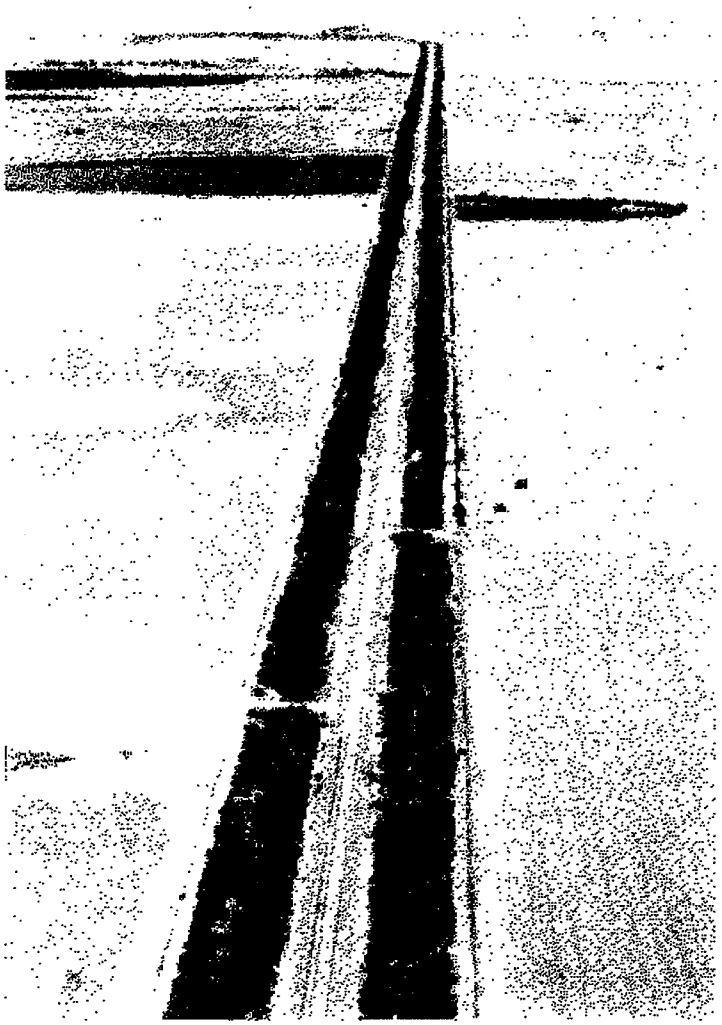

Figure 1 Road corridor showing road surface, maintained open roadsides, and roadside natural strips. Strips of relatively natural vegetation are especially characteristic of road corridors (know as road reserves) in Australia. Wheatbelt of Western Australia. Photo courtesy of BMJ Hussey.

APPLIED ECOLOGY

Habitat fragmentation and its lasting impact on Earth's ecosystems

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We conducted an analysis of global forest cover to reveal that 70% of remaining forest is within 1 km of the forest's edge, subject to the degrading effects of fragmentation. A synthesis of fragmentation experiments spanning multiple biomes and scales, five continents, and 35 years demonstrates that habitat fragmentation reduces biodiversity by 13 to 75% and impairs key ecosystem functions by decreasing biomass and altering nutrient cycles. Effects are greatest in the smallest and most isolated fragments, and they magnify with the passage of time. These findings indicate an urgent need for conservation and restoration measures to improve landscape connectivity, which will reduce extinction rates and help maintain ecosystem services.

INTRODUCTION

Destruction and degradation of natural ecosystems are the primary causes of declines in global biodiversity (*1*, *2*). Habitat destruction typically leads to fragmentation, the division of habitat into smaller and more isolated fragments separated by a matrix of human-transformed land cover. The loss of area, increase in isolation, and greater exposure to human land uses along fragment edges initiate long-term changes to the structure and function of the remaining fragments (*3*).

Ecologists agree that habitat destruction is detrimental to the maintenance of biodiversity, but they disagree—often strongly—on the extent to which fragmentation itself is to blame (*4*, *5*). Early hypotheses based on the biogeography of oceanic islands (*6*) provided a theoretical framework to understand fragmentation's effect on extinction in terrestrial landscapes composed of "islands" of natural habitat scattered across a "sea" of human-transformed habitat. Central to the controversy has been a lingering uncertainty about the role of decreased fragment size and increased isolation relative to the widespread and pervasive effects of habitat loss in explaining declines in biodiversity and the degradation of ecosystems (*7*). Observational studies of the effects of fragmentation have often magnified the controversy because inference from nonmanipulative studies is limited to correlation and because they have individually often considered only single aspects of fragmentation (for example, edge, isolation, and area) (*8*). However, together with these correlative observations, experimental studies reveal that fragmentation has multiple simultaneous effects that are interwoven in complex ways and that operate over potentially long time scales (*9*).

Here, we draw on findings of the world's largest and longest-running fragmentation experiments that span 35 years and disparate biomes on five continents. Their rigorous designs and long-term implementation overcome many limitations of observational studies. In particular, by manipulating and isolating individual aspects of fragmentation while controlling for others, and by doing so on entire ecosystems, they provide a powerful way to disentangle cause and effect in fragmented landscapes. Here, we present experimental evidence of unexpected long-term ecological changes caused by habitat fragmentation.

Highlighting one ecosystem type as an example, we first present a global analysis of the fragmentation of forest ecosystems, quantifying for the first time the global hotspots of intensive historical fragmentation. We then synthesize results from the set of long-term experiments conducted in a wide variety of ecosystems to demonstrate consistent impacts of fragmentation, how those impacts change over time, and how they align with predictions from theory and observation. Finally, we identify key knowledge gaps for the next generation of fragmentation experiments.

GLOBAL ANALYSIS OF THE EXTREME MAGNITUDE AND EXTENT OF FRAGMENTATION

New satellite data sets reveal at high resolution how human activities are transforming global ecosystems. Foremost among these observations are those of forest cover because of the high contrast between forest

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and anthropogenic land cover types. Deforestation, which was already widespread in temperate regions in the mid-18th to 20th centuries and increased in the tropics over the past half century, has resulted in the loss of more than a third of all forest cover worldwide (*10*, *11*). Beyond the direct impacts of forest loss and expanding anthropogenic land cover (for example, agricultural fields and urban areas), remnant forests are likely to suffer from being smaller, more isolated, and with a greater area located near the edge of the forest (*12*).

We analyzed the world's first high-resolution map of global tree cover (*13*) to measure the magnitude of forest fragmentation. This analysis revealed that nearly 20% of the world's remaining forest is within 100 m of an edge (Fig. 1, A and B)—in close proximity to agricultural, urban, or other modified environments where impacts on forest ecosystems are most severe (*14*). More than 70% of the world's forests are within 1 km of a forest edge. Thus, most forests are well within the range where human activities, altered microclimate, and nonforest species may influence and degrade forest ecosystems (*15*). The largest contiguous expanses of remaining forests are in the humid tropical regions of the Amazon and Congo River Basins (Fig. 1A). Large areas of more disjunct forest also remain in southeastern Asia, New Guinea, and the boreal biomes.

Historical data enable the study of the process of forest fragmentation over time. We reconstructed the historical forest extent and timing of fragmentation in two forested regions of Brazil that provide a stark contrast in land-use dynamics. The Brazilian Amazon is a rapidly changing frontier (*10*), yet most of its forests remain contiguous and far from an edge despite recent increases in fragmentation (Fig. 1, C and D). In contrast, the Brazilian Atlantic Forest is a largely deforested landscape, cleared for agriculture and logged for timber over the last three centuries (*11*). This remaining forest is dominated by small fragments, with most fragments smaller than 1000 ha and within 1000 m of a forest edge (Fig. 1, E and F) (*16*). In the Brazilian Amazon, the proportion of forest farther than 1 km from the forest edge has decreased from 90% (historical) to 75% (today), and in the Brazilian Atlantic, from 90% to less than 9%.

These two forested regions of Brazil define extremes of the fragmentation process and are representative of the extent of fragmentation in forested landscapes worldwide (Fig. 1), as well as many other biomes including temperate grasslands, savannas, and even aquatic systems (*17*). For example, although a spatial analysis similar to that of forest is not currently possible in grasslands, 37% of the world's grassland eco-regions are classified as "highly fragmented" (*18*, *19*).

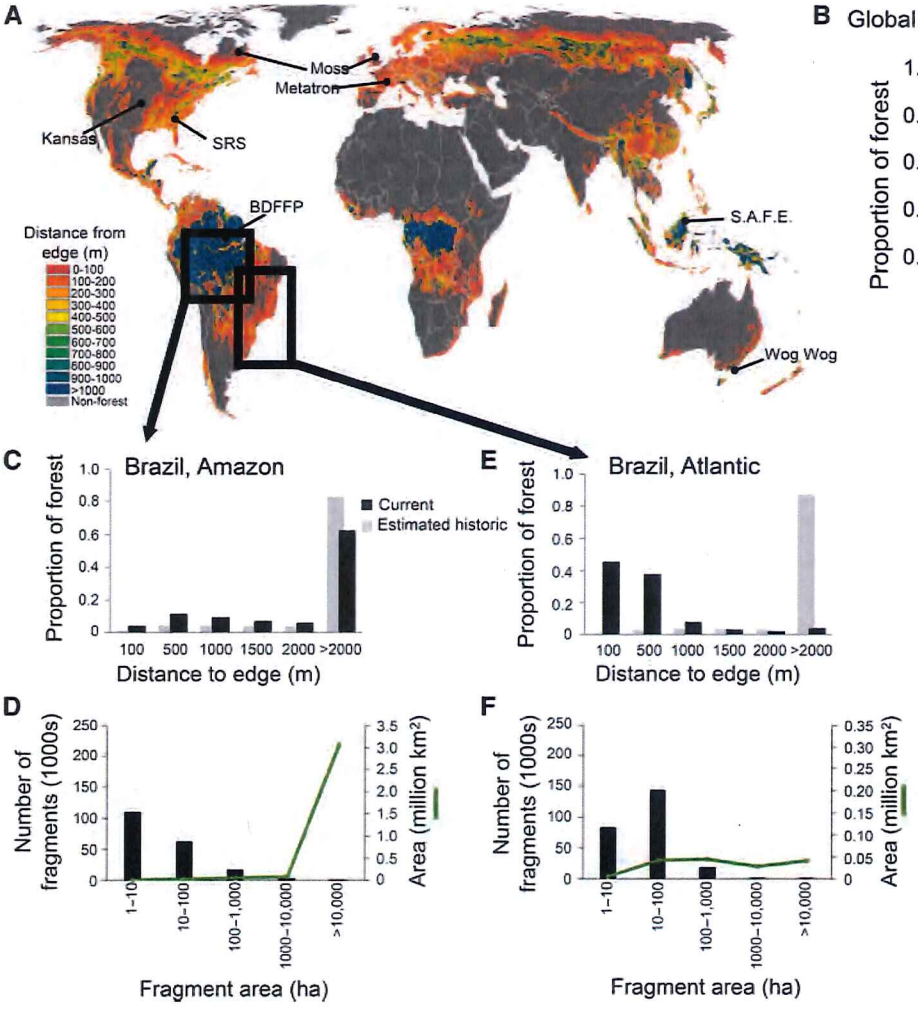

Fig. 1. The global magnitude of forest fragmentation. (**A**) Mean distance to forest edge for forested pixels within each 1-km cell. Lines point to locations of ongoing fragmentation experiments identified and described in Fig. 2. (**B**) Proportion of the world's forest at each distance to the forest edge and the cumulative proportion across increasing distance categories (green line). (**C** and **E**) In the Brazilian Amazon (C) and Atlantic Forests (E), the proportion of forest area at each distance to forest edge for both the current and estimated historic extent of forest. (**D** and **F**) In the Brazilian Amazon (D) and Atlantic Forests (F), the number of fragments and the total area of fragments of that size. The total number of fragments in the smallest bin (1 to 10 ha) is an underestimate in both the Atlantic Forest and Amazon data sets because not all of the very smallest fragments are mapped.

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Robust knowledge of how habitat fragmentation affects biodiversity and ecosystem processes is needed if we are to comprehend adequately the implications of this global environmental change.

THE VALUE OF LONG-TERM FRAGMENTATION EXPERIMENTS

Long-term experiments are a powerful tool for understanding the ecological consequences of fragmentation (*20*). Whereas observational studies of fragmented landscapes have yielded important insights (*9*, *21*), they typically lack rigorous controls, replication, randomization, or baseline data. Observational studies have limited ability to isolate the effects of fragmentation from concomitant habitat loss and degradation per se (*4*, *7*, *22*). Remnant fragments are embedded in different types and qualities of surrounding habitat, complicating interpretation because the surrounding habitat also influences biodiversity and ecosystem productivity (*23*).

The long-term fragmentation experiments we analyze here comprise the entire set of ongoing terrestrial long-term experiments. They occur in several biomes (Fig. 2 and Supplementary Materials) and were designed to manipulate specific components of fragmentation—habitat size, isolation, and connectivity—while controlling for confounding factors such as the amount of habitat lost across a landscape (Fig. 2). The largest fragments across these experiments match the size of fragments commonly created by anthropogenic activities (Figs. 1 and 2). Distances to the edge of experimental fragments range to 500 m, encompassing edge distances found in more than half of forests worldwide (Fig. 1B). In each experiment, different fragmentation treatments with replication were established, starting from continuous, nonfragmented landscapes and controlling for background environmental variation either by experimental design (blocking) or by measurement of covariates for use in subsequent analyses. Tests were conducted within fragments that varied experimentally in area or edge, within fragments that were experimentally isolated or connected, or within experimental fragments compared to the same area within continuous habitat. All treatments were replicated. Experiments were created by destroying or creating precise amounts of habitat across replicate landscapes, allowing tests of fragmentation effects independent of habitat loss. The robust

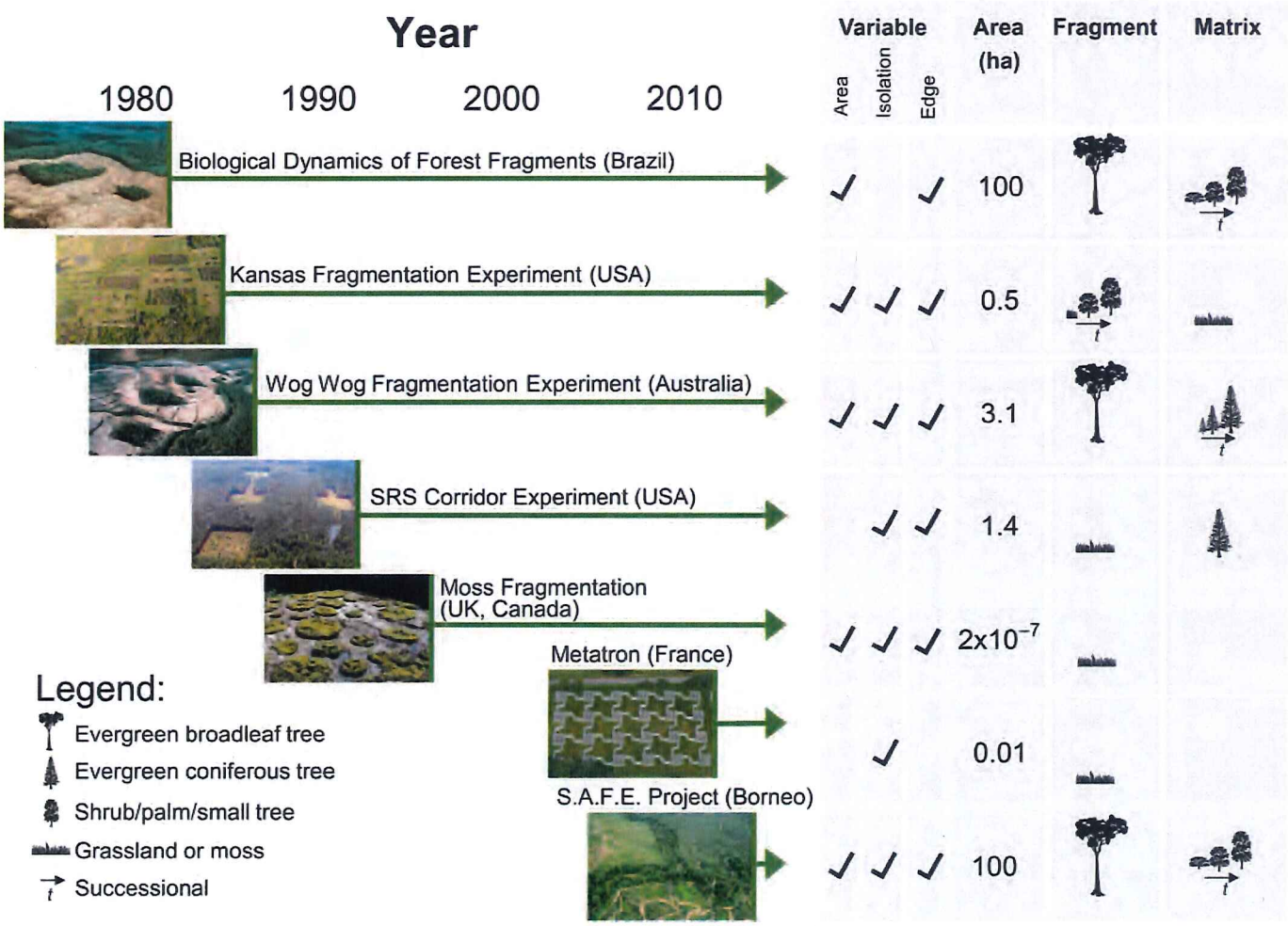

Fig. 2. The world's ongoing fragmentation experiments. All experiments have been running continuously since the time indicated by the start of the associated arrow (with the exception of the moss fragmentation experiment, which represents a series of studies over nearly two decades). The variables under study in each experiment are checked. The area is that of the experiment's largest fragments. Icons under "Fragment" and "Matrix" indicate the dominant community and its relative height, with multiple trees representing succession.

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and comparable experimental designs allow for powerful tests of the mechanisms underpinning the ecological impacts of fragmentation, and the long-term nature of ensuing studies has revealed consistent emergent effects.

These experiments mimic anthropogenic fragmentation; they are whole-ecosystem manipulations in which all species and processes experienced the same treatment (*24*). Emergent responses thus reflect the multiple direct and indirect effects of interacting species and processes. Further, because experimentally fragmented ecosystems are open to fluxes of individuals and resources, fragmentation effects can manifest across multiple levels of ecological organization (Fig. 3). Long-term experiments have the power to detect lagged and/or chronic impacts.

The first fragmentation experiments, now more than three decades old, were created to test effects of fragment area on both species persistence and patterns of immigration, reflecting concern in conservation biology about the role of fragmentation in reducing population sizes below viable levels (*25*) (Fig. 2). Subsequent experiments, created two decades ago, shifted focus to modifying habitat isolation, reflecting recognition of the potential to mitigate negative effects of fragmentation by recreating habitat—specifically with corridors—to increase connectivity among fragments (*26*) (Fig. 2). The newest experiments test emerging questions about potentially deleterious synergies between fragmentation and global changes in climate and land use (Fig. 2).

We synthesized results available 31 January 2014 for all studies within these experiments that were conducted in all treatments and replicates, and tested fragmentation effects on dispersal, abundance, extinction, species richness, community composition, and ecosystem functioning. We first calculated effect sizes of fragmentation as log response ratios (Fig. 3). Data from 76 different studies across the five longest-running experiments were drawn from published and unpublished sources (table S1). We synthesized results according to three fragmentation treatments: reduced fragment area [the focus of Biological Dynamics of Forest Fragments Project (BDFFP), Wog Wog, and Kansas; see Fig. 2 for identifiers of experiments], increased fragment isolation [Savannah River Site (SRS) and Moss], and increased proportion of edge (all experiments). Fragmented treatments were compared directly to non- or less-fragmented habitats that were either larger or connected via structural corridors (table S1).

Strong, consistent, and accumulating effects of habitat fragmentation

Our synthesis revealed strong and consistent responses of organisms and ecosystem processes to fragmentation arising from decreased fragment area, increased isolation, and the creation of habitat edges (Fig. 3).

Community and ecosystem responses emerge from observed responses at the level of populations. Reduced area decreased animal

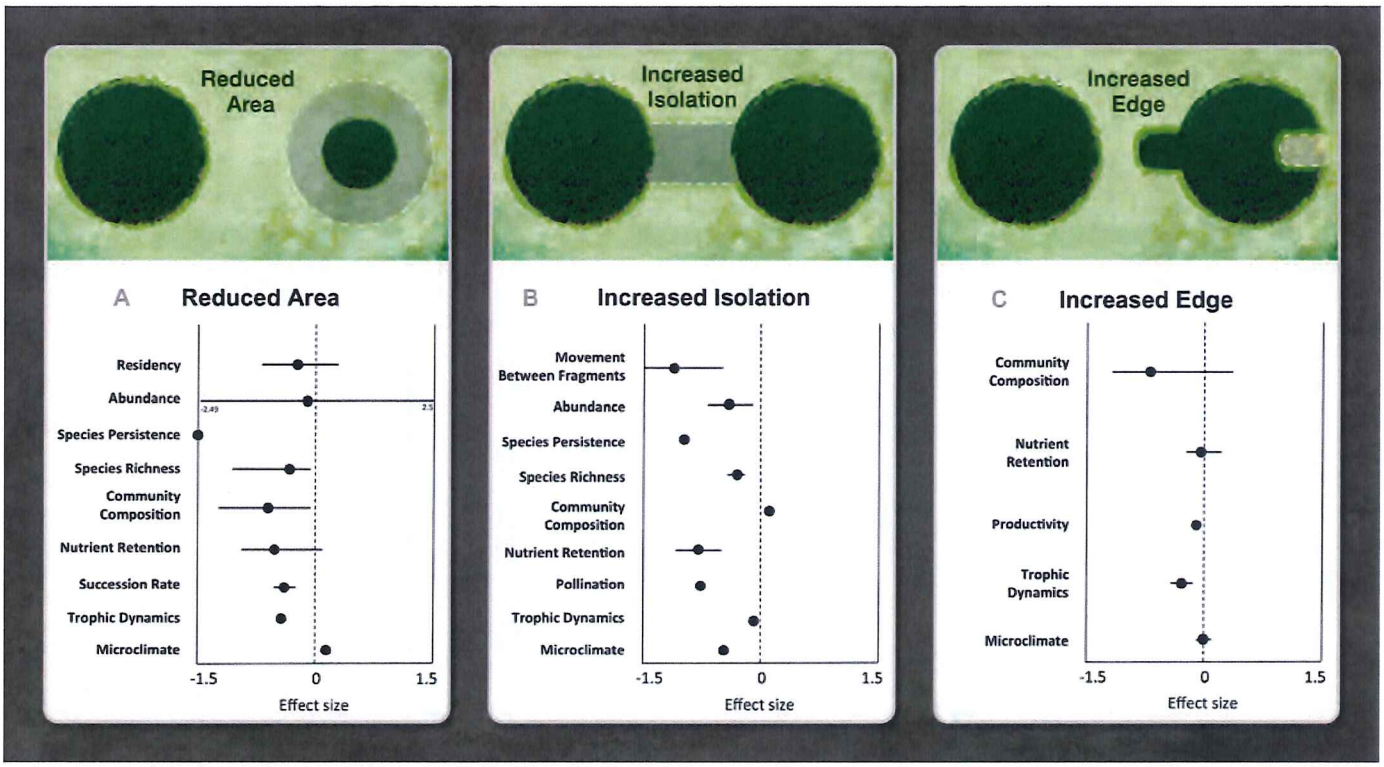

Fig. 3. Fragmentation effects propagate through the whole ecosystem. (**A** to **C**) For each fragmentation treatment [reduced area in BDFFP, Wog Wog, Kansas (A); increased isolation in SRS and Moss (B); and increased edge in all experiments (C)], we summarize major findings for ecological processes at all levels of ecological organization. Each dot represents the mean effect size [computed as log response ratio: ln(mean in more fragmented treatment/mean in non- or less-fragmented treatment)] for an ecological process. Effect sizes are statistical, such that negative or positive values could represent degrading function. Horizontal bars are the range when a dot is represented by more than one study. Details, including individual effect sizes for each study, are reported in table S1.

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residency within fragments, and increased isolation reduced movement among fragments, thus reducing fragment recolonization after local extinction (Fig. 3, A and B). Reduced fragment area and increased fragment isolation generally reduced abundance of birds, mammals, insects, and plants (Fig. 3, A and B). This overall pattern emerged despite complex patterns of increases or declines in abundance of individual species (Fig. 3A) with various proximate causes such as release from competition or predation, shifts in disturbance regimes, or alteration of abiotic factors (*14*, *27*–*29*). Reduced area, increased isolation, and increased proportion of edge habitat reduced seed predation and herbivory, whereas increased proportion of edge caused higher fledgling predation that had the effect of reducing bird fecundity (represented together as trophic dynamics in Fig. 3, A to C). Perhaps because of reduced movement and abundance, the ability of species to persist was lower in smaller and more isolated fragments (Fig. 3, A and B).

As predicted by theory (*6*, *30*, *31*), fragmentation strongly reduced species richness of plants and animals across experiments (Fig. 3, A and B), often changing the composition of entire communities (Fig. 3, A to C). In tropical forests, reduced fragment size and increased proportion of edge habitat caused shifts in the physical environment that led to the loss of large and old trees in favor of pioneer trees (Fig. 3, A and C), with subsequent impacts on the community composition of insects (*32*). In grasslands, fragment size also affected succession rate, such that increased light penetration and altered seed pools in smaller fragments impeded the rate of ecological succession relative to that of larger fragments (*33*) (Fig. 3A).

Consistently, all aspects of fragmentation—reduced fragment area, increased isolation, and increased edge—had degrading effects on a disparate set of core ecosystem functions. Degraded functions included reduced carbon and nitrogen retention (Fig. 3, A to C), productivity (Fig. 3C), and pollination (Fig. 3B).

In summary, across experiments spanning numerous studies and ecosystems, fragmentation consistently degraded ecosystems, reducing species persistence, species richness, nutrient retention, trophic dynamics, and, in more isolated fragments, movement.

Long-term consequences of fragmentation

To synthesize all time series of species richness and ecosystem functioning gathered across experiments, we measured effects of fragmentation over the course of each study. The effect of fragmentation was calculated over time as the proportional change in fragmented relative to non- or less-fragmented treatments (Fig. 4).

In most cases, the large and consistent effects of fragmentation revealed by the experiments were predicted from theory. However, we were struck by the persistence of degradation to biodiversity and ecosystem processes and by the increase in many of the effects over time (Fig. 4). For example, extreme rainfall events at Wog Wog appeared to delay the decline in plant species richness for 5 years after fragmentation. In the Kansas Experiment, a lag of 12 years occurred before fragmentation effects on plant succession were detected. Our results thus reveal long-term and progressive effects of fragmentation and provide support for three processes proposed by recent studies in spatial ecology: extinction debt, immigration lag, and ecosystem function debt (Fig. 4).

First, we found strong evidence for temporal lags in extinction [that is, "extinction debt" (*30*)] in fragments. Species richness of plants, arthropods, and birds sampled in the experiments conducted in mature forest fragments and replicated moss landscapes showed decreases of

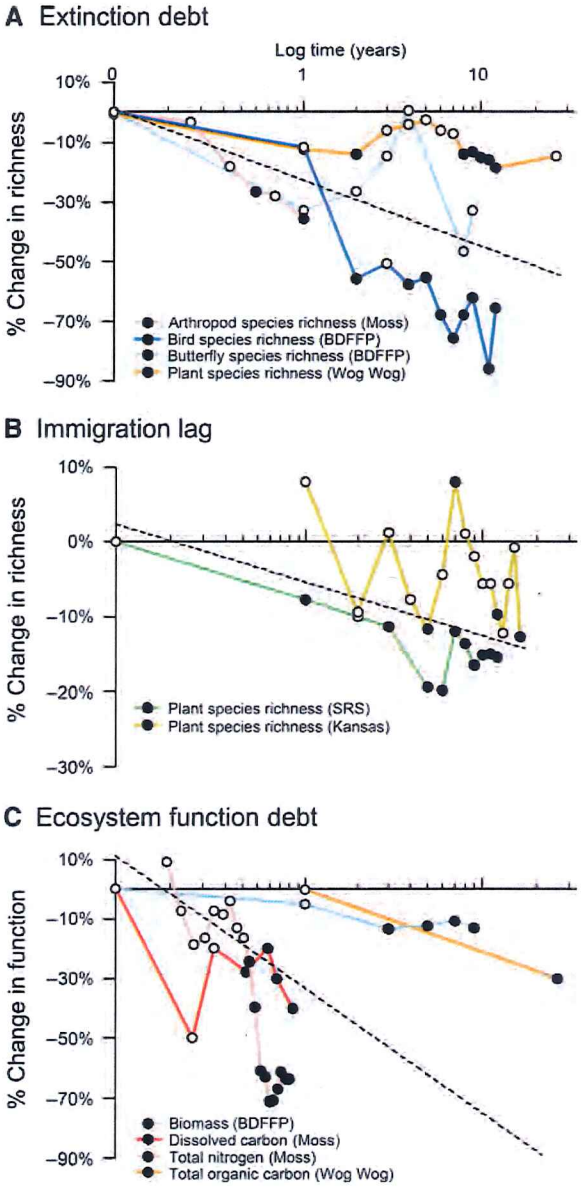

Fig. 4. Delayed effects of fragmentation on ecosystem degradation. (**A**) The extinction debt represents a delayed loss of species due to fragmentation. (**B**) The immigration lag represents differences in species richness caused by smaller fragment area or increased isolation during fragment succession. (**C**) The ecosystem function debt represents delayed changes in ecosystem function due to reduced fragment size or increased isolation. Percent loss is calculated as proportional change in fragmented treatments [for example, (no. of species in fragment − no. of species in control)/(no. of species in control) × 100]. Fragments and controls were either the same area before and after fragmentation, fragments compared to unfragmented controls, or small compared to large fragments. Filled symbols indicate times when fragmentation effects became significant, as determined by the original studies (see table S2). Mean slopes (dashed lines) were estimated using linear mixed (random slopes) models. Mean slope estimates (mean and SE) were as follows: (A) −0.22935 (0.07529); (B) −0.06519 (0.03495); (C) −0.38568 (0.16010).

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20 to 75% after fragmentation (Fig. 4A). Some declines were evident almost immediately after fragmentation, whereas others increased in magnitude over the experiment's duration. Across experiments, average loss was >20% after 1 year, >50% after 10 years, and is still increasing in the longest time series measured (more than two decades). The rate of change appears to be slower in larger fragments [in BDFFP, 50% decline in bird species after 5 years in 1-ha fragments, but after 12 years in 100-ha fragments; in Moss, 40% decline in arthropod species richness of small fragments and 26% reduction in large fragments after 1 year (*34*, *35*)]. As predicted by theory (*36*), the extinction debt appears to take longer to pay in larger fragments.

Second, we observed that reduced richness was coincident with an "immigration lag" (*37*), whereby small or isolated fragments are slower to accumulate species during community assembly (*33*, *38*) (Fig. 4B). Immigration lags were observed in experiments conducted in successional systems that were initiated by creating new habitat fragments, rather than by fragmenting existing habitats. After more than a decade, immigration lags resulted in 5% fewer species after 1 year, and 15% fewer species after 10 years in small or isolated fragments compared to large or connected fragments (Fig. 4B).

Third, we observed an ecosystem function debt caused by fragmentation (*39*) in forest and moss fragments (Fig. 4C). An ecosystem function debt is manifest both as delayed changes in nutrient cycling and as changes to plant and consumer biomass. Loss of function amounted to 30% after 1 year, rising to 80% after a decade in small and isolated fragments when compared to larger and more connected fragments (Fig. 4C). Functional debts can result from biodiversity loss, as when loss of nutrients and reduction in decomposition are caused by simplification of food webs. Alternatively, the impact is exhibited through pathways whereby fragmentation changes biotic (for example, tree density in successional systems) or abiotic conditions (for example, light regimes or humidity) in ways that alter and potentially impair ecosystem function [for example, biomass collapse in fragments; Figs. 3 and 4; altered nitrogen and carbon soil dynamics (*40*)].

A new understanding of the effects of fragmentation

By testing existing theory, experiments play a pivotal role in advancing ideas and developing new theory. We draw on experimental evidence to highlight two ways that the understanding of fragmentation has been enriched by the interplay between long-term experiments and development of theory.

First, island biogeography (*6*) was among the earliest theories to predict extinction and immigration rates and patterns of species richness in isolated biotas, which were later used to predict the effects of fragmentation on these variables. Experiments in continental settings tested the theory and gave rise to fresh perspectives. For example, islands are surrounded by sea, a thoroughly inimical matrix for island-dwelling species. Habitat islands, or fragments, are surrounded by a matrix that may not be so unsuitable for some species. In terms of all of the ecological variables studied in our long-term experiments, our results support the conclusion that ecological dynamics in human-modified fragments are a stark contrast to the dynamics in intact habitats that remain. Observational studies that have devoted more detailed consideration to the countryside within which fragments are embedded explain the diversity of ecological responses in remaining fragments (*41*). At the same time as experiments supported the core predictions of classical theories about effects of fragment size and isolation (Figs. 3 and 4), they spurred and tested new theories such as metacommunity theory (*42*) to account for variation in connectivity and habitat quality within and between fragments (*33*, *43*–*45*), spatial dynamics (*14*, *46*), and spatially varying interspecific interactions (*47*).

Second, experiments have demonstrated that the effects of fragmentation are mediated by variation in traits across species. More realistic predictions of community responses to fragmentation emerged after explicit consideration of species traits such as rarity and trophic levels (*48*, *49*), dispersal mode (*50*–*52*), reproductive mode and life span (*29*, *53*), diet (*54*), and movement behavior (*55*, *56*). Increasingly, the simple theoretical prediction that fragmentation reduces species richness is being modified to account for species identity through models that focus on how species vary in their traits (*4*, *21*, *36*, *48*, *57*, *58*). Consideration of traits may help to interpret variation around the overarching pattern that fragmentation consistently reduces species richness across many species and biomes (Figs. 3 and 4).

A NEW GENERATION OF FRAGMENTATION EXPERIMENTS

New foci are emerging for studying ecosystem fragmentation, including (i) synergies between fragmentation and global changes, (ii) eco-evolutionary responses of species to fragmentation, and (iii) ecological responses to fragmentation in production landscapes—that is, ecosystems whose services are under extreme appropriation by humans (*59*).

First, conclusions from experiments thus far are likely to have been conservative because impacts from other environmental changes have been mostly excluded. Most forms of global change known to reduce population sizes and biodiversity will be exacerbated by fragmentation (*58*, *60*), including climate change (*61*), invasive species (*62*, *63*), hunting (*64*), pollution [including light, noise, and chemicals (*65*)], and altered disturbance regimes (*66*).

More complex experiments with unparalleled control and capacity to simultaneously manipulate fragmentation and other global changes are now under way (*53*). The Metatron, created in 2011 in southern France (*67*), enables ecologists to assess effects of variation in temperature and other abiotic factors in addition to habitat isolation. The SAFE Project is being created in the rainforest of Borneo (*68*) and will embed a fragmentation experiment within a production agricultural plantation in which poaching will occur. Other synergies should be investigated experimentally, including the interaction between fragmentation and hunting, fire, infectious disease outbreaks, or nitrogen deposition. Within these experiments, fragmentation and loss of habitat can then be varied independently.

Second, current experiments have stopped short of examining how fragmentation drives evolution through genetic bottlenecks, ecological traps, changing patterns of selection, inbreeding, drift, and gene flow (*69*–*72*). Extensive fragmentation has occurred over many years, and in some regions over millennia (*11*). Changes caused by fragmentation undoubtedly lead to altered patterns of selection and trait evolution. Evolutionary responses to fragmentation have already been suggested (*73*, *74*), and it is likely that such changes will, in turn, feed back to influence population persistence and ecosystem resilience in fragmented landscapes. Linking long-term experiments with the tools of landscape genetics (*75*) may provide powerful insights into the evolutionary dynamics of species inhabiting fragmented landscapes.

Third, new experiments should address the management of natural habitats in production landscapes by monitoring vegetation, networks of interacting species, and ecosystem services at ecologically relevant

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spatial and temporal scales (*76*–*78*). Some ecosystem services have global consequences, for example, local carbon sequestration affects global atmospheric CO_2. However, in many cases the benefits obtained by people depend on their proximity to habitat fragments (*79*). For example, crop pollination and biological pest control from natural areas adjacent to farms are made available by the very process of habitat fragmentation, bringing people and agriculture closer to those services. Yet, further fragmentation reduces access to many services and ultimately may push landscapes past tipping points, beyond which essential ecosystem services are not merely diminished but lost completely (*80*). This complex relationship creates a double-edged sword, for which locally optimal levels and arrangements of habitat must be sought. New fragmentation experiments should consider how multiple fragments in a landscape interact, creating an ecological network in which the collective benefit of ecosystem services may be greater than the sum of services provided by individual fragments (*81*, *82*). Experimental inferences may then be tested beyond their spatiotemporal domains and, if successful, extrapolated across scales. Such research will be aided by satellite monitoring of ecosystems and human land use across the globe. The most powerful research programs will integrate experiments, observational studies, air- and space-borne imaging, and modeling.

CONCLUSIONS

Fragmentation experiments—some of the largest and longest-running experiments in ecology—provide clear evidence of strong and typically degrading impacts of habitat fragmentation on biodiversity and ecological processes. The findings of these experiments extend to a large fraction of the terrestrial surface of the Earth. Much of the Earth's remaining forest fragments are less than 10 ha in area, and half of the world's forest is within 500 m of the forest edge—areas and distances matched to existing long-term experiments (Figs. 1 and 2) from which consistent effects of fragmentation have emerged (Figs. 3 and 4).

Reduced fragment area, increased isolation, and increased edge initiate changes that percolate through ecosystems (Fig. 3). Fragmentation has the capacity to generate persistent, deleterious, and often unpredicted outcomes, including surprising surges in abundance of some species and the pattern that long temporal scales are required to discern many strong system responses. In light of these conclusions and ongoing debates, we suggest that fragmentation's consistency, pervasiveness, and long-term degrading effect on biodiversity and ecosystem function have not been fully appreciated (*9*).

Without gains in yield and efficiency of agricultural systems (*83*), the expansion of human populations will inevitably continue to reduce and fragment natural areas. The area of Earth's land surface devoted to cropland already occupies 1.53 billion hectares (*83*) and may expand 18% by the middle of this century (*84*), and the area committed to urban centers is predicted to triple to 0.18 billion hectares by 2030 (*85*). The capacity of the surviving forests and other natural habitats to sustain biodiversity and ecosystem services will hinge upon the total amount and quality of habitat left in fragments, their degree of connectivity, and how they are affected by other human-induced perturbations such as climate change and invasive species. Long-term experiments will be even more needed to appreciate, explain, and predict long-term effects. New efforts should work in concert, coordinating a network of experiments across ecosystems and spatial extents.

The effects of current fragmentation will continue to emerge for decades. Extinction debts are likely to come due, although the counteracting immigration debts may never fully be paid. Indeed, the experiments here reveal ongoing losses of biodiversity and ecosystem functioning two decades or longer after fragmentation occurred. Understanding the relationship between transient and long-term dynamics is a substantial challenge that ecologists must tackle, and fragmentation experiments will be central for relating observation to theory.

Experimental results to date show that the effects of fragmentation are strong and markedly consistent across a diverse array of terrestrial systems on five continents. Increasingly, these effects will march in concert with other global changes. New experiments should be coupled with emerging technologies, landscape genetics, and detailed imagery of our planet, and should be coordinated with current ecological theory to understand more deeply the coupled dynamics of ecological and social systems. These insights will be increasingly critical for those responsible for managing and prioritizing areas for preservation and ecological restoration in fragmented landscapes.

SUPPLEMENTARY MATERIALS

Supplementary material for this article is available at http://advances.sciencemag.org/cgi/content/full/1/2/e1500052/DC1

Materials and Methods

Fig. S1. Map of the BDFFP experiment and location within Brazil.

Fig. S2. Map of the Kansas fragmentation experiment.

Fig. S3. Map of the Wog Wog experiment and location within Australia.

Fig. S4. Map of the SRS experiment showing locations of the eight blocks in the second SRS Corridor Experiment within the SRS, South Carolina, USA.

Fig. S5. Design of the Moss experiment.

Fig. S6. Design of the Metatron experiment with 48 enclosed fragments and adjoining enclosed corridors.

Fig. S7. Map of the SAFE experiment and location within Borneo [after Ewers *et al.* (*68*)].

Table S1. Metadata for Fig. 3 in the main text.

Table S2. Metadata for Fig. 4 in the main text.

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RESEARCH NOTE

ROAD RUNOFF POLLUTION BY POLYCYCLIC AROMATIC HYDROCARBONS AND ITS CONTRIBUTION TO RIVER SEDIMENTS

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Abstract—Particle-bound pollutants from road runoff and their entry into the river system were investigated and compared to river bottom sediments. The intensity of rainfall is responsible for the wash load, whereas the grain size distribution is controlled by the amount of rainfall and sorting processes near the sink traps of the streets. While the concentrations of suspended heavy metals show a familiar inverse relationship to particle size both in road runoff and river bottom sediments, the situation for polycyclic aromatic hydrocarbons (PAHs) is less clear. They are bimodally distributed. In street runoff, small molecules such as three-ring PAHs tend to be enriched in the fine sand fraction. Six-ring molecules show maximum concentrations in the fine silt fraction. In addition to chemical properties, the activation of both particle and PAH sources play an important role. After the input in the river system this pattern changes again. The chemical composition and structure of organic material become more significant than the sources, whereas its amount is only of minor importance. © 2000 Elsevier Science Ltd. All rights reserved

Key words—sediments, urban runoff, PAH, heavy metals, elutriation

INTRODUCTION

Traditional analysis of particle size distribution in soil or sediment samples involves removal of the organic material and chemical dispersion of the remaining solids (Day, 1965). This procedure should not be applied to studying the partitioning of pollutants to natural sediment particle size fractions because the results could considerably differ from the "effective particle size" due to the aggregation or flocculation of particles under natural conditions (Wall *et al.*, 1978; Walling and Moorehead, 1989). Furthermore, the destruction of the organic material would produce an erroneous distribution of the pollutants to the different fractions as part of the organic contaminants is sorbed with natural organic substances. Therefore, the fractionation should be performed under conditions as undisturbed as possible (Kukkonen and Landrum, 1996). The distribution of pollutants to different material and different particle size fractions is of overriding importance because:

- different particle sizes are remobilised and transported by different hydraulic conditions;
- the organic matter can be decomposed, and then their associated pollutants will be bioavailable;
- selective-feeding benthic organisms preferentially consume particles with higher organic concentration and smaller size.

One of the most important factors which controls the accumulation of heavy metals in sediments is the grain-size. Only a few studies discuss the behaviour of organic micropollutants and the influence of different grain-size fractions. Even within these studies, the lack of standardisation in particle fractionation methods aggravates the comparison and generalisation of acquired data (Karickhoff *et al.*, 1979; Readman *et al.*, 1984; Umlauf and Bierl, 1987; Evans *et al.*, 1990; Kukkonen and Landrum, 1996). In the present investigation, particle size classes ranging from <2 μm to 200 μm were examined in order to determine the relationships between the organic material, particle size, PAH and heavy metal concentrations in urban runoff, street dust and river bottom sediment.

MATERIALS AND METHODS

Study area

The study area which is located in the northern part of

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the Hunsrück mountains (Germany) contains the drainage basin of the Olewiger Bach with an area of approximately 35 km^2. The basin is predominantly used for agriculture; settlements cover about 10%. Bedrock consists of quartzite and Devonian schist, the gentle slopes of the basin are stocked with woods or, under more favourable conditions, planted with grapevines. The total length of the Olewiger Bach is approximately 14 km and the difference in altitude between source and mouth is about 300 m. Runoff from numerous roads increases PAH and heavy metal concentrations in river bottom sediments. This process is outlined in our investigations.

Sampling and fractionation

Freshwater surface sediments, street dust and street runoff material were sampled at the Olewiger Bach catchment. Particles from road runoff were collected with nets of silk fabric, which were fastened into sink traps. Street dust was gathered with a special low vacuum pump. For sediment sampling, several concrete slabs (each 0.1 m^2 in area) were placed into the river at the sampling site. Care was taken to keep the slab surface even with the river sediment. Interactions with the underlying material were prevented by the complete removal of the sediments from the slabs after each sampling (weekly). The samples were placed directly into solvent-washed, 2-l glass bottles with glass cutting lids. The fine sand fraction (63–200 μm) was wet sieved. To separate the fraction smaller than 63 μm from the aqueous phase the suspension was centrifuged. Afterwards, the different particle sizes were obtained using an elutriation system (Muller and Tisue, 1977; Umlauf and Bierl, 1987). They were separated into the following size fractions: <2 μm (clay), 2–6.3 μm (fine silt), 6.3–12.5 μm (finer middle silt), 12.5–20 μm (coarser middle silt) and 20–63 μm (coarse silt).

Elutriation involves suspending the sample in an upward water flow. Particles that settle at velocities greater than the upward velocity remain in the separation chamber; those that settle at lower velocities are carried out upward to the next separation chamber. The separation apparatus consists of a magnetic stirrer to keep the initial sample in suspension. A peristaltic pump, which can be set at different speeds and is linked to separation cylinders of varying sizes, provides the required upward velocities. The settling velocities for each particle size fraction can be calculated using Stoke's law. Since the settling behaviour of a particle is a function of its density, shape and other hydrodynamic parameters, an examination of the fractionation efficiency can be determined using a laser particle analyser (CIS 1, GALAI/LOT Inc.). Samples were dispersed in 0.001 M $Na_4P_2O_7$ and stirred for 1 h. After flushing the separation tubes with water, the peristaltic pump was activated. The separation is finished when the cylinders become clear (about 30 h). The isolated fractions in the cylinders are flushed through a valve at the bottom of the separation tubes and the finest fraction is centrifuged using a continuous flow centrifuge. All fractions of street dust, runoff material and river bottom sediments were freeze dried and weighted.

Analyses

Each freeze dried fraction of the sample was investigated for selected heavy metals (lead, copper, zinc, iron, manganese), the 16 PAHs of the United States Environmental Protection Agency list and organic carbon content. Heavy metals were analysed with an atomic absorption spectrometer (SPEKTRA A 640, VARIAN) after the sample material was decomposed under pressure with concentrated nitric acid. Organic carbon was determined with an element analyser (RC 412, LECO). For the analysis of PAHs the samples were spiked with internal standards and solvent extracted with acetone/hexane (1:1) in a Soxhlet system for 8 h. After rotary evaporation almost to dryness, the solvent extracts were purified by packed microcolumn–chromatography. Glass columns (6 ml, BAKER) were filled with 1 g silica-gel (63–200 μm, 5% w/w H_20, MERCK), 1 g cyanophase (40 μm, BAKER) and 0.5 g silver-perchlorate monohydrate adsorbed to aluminiumoxide (FLUKA) to remove sulphur. The columns were eluted with 10 ml hexane and 10 ml dichloromethane. The dichloromethane was exchanged to hexane and reduced to 100 μl prior to analysis by gas chromatography/mass spectrometry. PAHs were analysed using a HEWLETT PACKARD 5890 GC coupled to a HP 5970B mass selective detector. The column was a 30-m to 0.25-mm i.d. with a 0.2-μm HP-5 MS film. The mass spectrometer was scanned in selected ion monitoring. The column temperature was programmed from 80°C (1 min) up to 180°C at 15°C per minute and up to 280°C with 3°C per minute. At 280°C the temperature was kept constant for 16 min. Two deuterated PAHs (anthracene-d10, benzo(a)anthracene-d12) and benzo(b)chrysene were used as internal standards.

RESULTS AND DISCUSSION

The distribution of particle associated heavy metals shows the well known inverse relationship between concentration and medium particle size. The overall patterns of road runoff material and river bottom sediment appear similar. Concerning PAHs the situation is different. Table 1 shows the average PAH and organic carbon concentrations with corresponding standard deviations (in parentheses) of this study. They are divided into different grain-size fractions of road runoff material and river bottom sediments in the Olewiger Bach basin. The mean values of street runoff material contain eight samples. These were taken from eight neighbouring street sinks, during a precipitation event on the 12 September 1997. One day later, the eight sediment samples were taken along a 200-m section of the Olewiger Bach beginning directly below the storm drainage overflow of the street being investigated. The standard deviations of all the measured fractions are all below 6%. This fact shows the stable conditions of the PAH distributions in the fractions. Therefore a comparison of road runoff material and river bottom sediment in different grain-size fractions can legitimately be made. Correlation analyses of the temporal behaviour of PAHs in road runoff distinguish five groups which correspond to the molecular size and the affinity to different grain-size classes. Acenaphtylene and acenaphtene behave rather independently due to their high fugacity. Small three-ring molecules such as fluorene, phenanthrene and anthracene are enriched in the fine sand fraction, as Fig. 1 shows. A distinct bimodal distribution can be found for four- and five-ring molecules. The six-ring molecules have their concentration maximum in the fine and finer middle silt fraction (Fig. 2). The clay fraction is always poor in PAHs. The coarse sand fraction with a particle size of more than 630 μm contains much organic debris and shows a wide variety of

Table 1. Average concentrations along with standard deviations of selected PAHs and the organic carbon content in different grain-size fractions of eight road runoff material samples and eight river bottom sediment samples

	Grain size (μm)					
	< 2	2–6.3	6.3–12.5	12.5–20	20–63	63–200
Road runoff material 12 September 1997 (n = 8)						
Fluorene ($\mu g \cdot kg^{-1}$)	21 (1.1)	47 (2.1)	51 (2.5)	60 (2.6)	32 (1.5)	74 (3.3)
Anthracene ($\mu g \cdot kg^{-1}$)	24 (1.2)	61 (3.1)	65 (3.3)	72 (3.2)	64 (3.3)	147 (7.4)
Phenanthrene ($\mu g \cdot kg^{-1}$)	183 (7.7)	733 (37.5)	763 (37.7)	766 (34.3)	580 (23.2)	1022 (52.1)
Fluoranthene ($\mu g \cdot kg^{-1}$)	350 (16)	1622 (83)	1554 (67.6)	1155 (48.7)	1078 (39.9)	1958 (93.3)
Indeno(cd)pyrene ($\mu g \cdot kg^{-1}$)	86 (3.8)	402 (22.2)	271 (12.6)	76 (3.2)	127 (5.4)	146 (6.8)
Dibenz(ah)anthracene ($\mu g \cdot kg^{-1}$)	20 (0.9)	83 (3.8)	66 (3.5)	11 (0.39)	34 (1.8)	41 (2.1)
Benzo(ghi)perylene ($\mu g \cdot kg^{-1}$)	139 (6.9)	710 (31.9)	541 (27.8)	217 (9.8)	287 (12.3)	281 (13.7)
Organic carbon (%)	14 (0.1)	22 (0.3)	25 (0.2)	27 (0.3)	19 (0.1)	30 (0.2)
River bottom sediment 13 September 1997 (n = 8)						
Fluoranthene ($\mu g \cdot kg^{-1}$)	232 (9.6)	380 (17.7)	516 (22.2)	620 (28.7)	288 (12.6)	813 (41.1)
Benzo(ghi)perylene ($\mu g \cdot kg^{-1}$)	121 (5.2)	152 (4.4)	138 (5.9)	161 (7.7)	97 (4.6)	206 (9.9)
Organic carbon (%)	2.9 (0.1)	4.3 (0.2)	3.6 (0.3)	2.5 (0.2)	0.9 (0.1)	5.7 (0.2)

concentrations between the runoff events. These findings are corroborated by Hoffman *et al.* (1984) who explain the bimodal distribution by two major sources of PAH input. The coarse fraction originates from the asphalt of the streets and from the tyres and breaks of cars. Fine particles apparently come from combustion or central heating and are transported by wind.

But that is not the only explanation. With increasing precipitation the particle source area is enlarged and extends over the immediate surroundings of the sink traps, where mainly coarse particles have been deposited during the recession stages of former events. As additional sources of fine material are consequently tapped, the sand fraction becomes less and the silt fraction becomes more important. High amounts of precipitation, however, combined with the erosive force of high intensities mobilize all kinds of material, which leads to a relative decrease of the smaller-than-6-μm fraction. Using element ratios and the analysis of the temporal behaviour of major elements, at least three different particle sources can be distinguished. Top soil material and weathering products from concrete and bricks are the main sources for inorganic material. The third source delivers mainly organic material. Its location is less clear.

Particle-bound pollutants from sealed surfaces, e.g. streets, are quickly exhausted by precipitation events. Renewed contamination begins immediately afterwards. Figure 3 illustrates the daily measured concentrations of particle-bound lead, copper and the total concentration of PAH. Tested were the lanes of a heavily used street. On the 12 September 1997, a heavy precipitation event caused a sharp decrease in concentrations. The following dry period allowed an increase in substance concentrations. The regressions of the

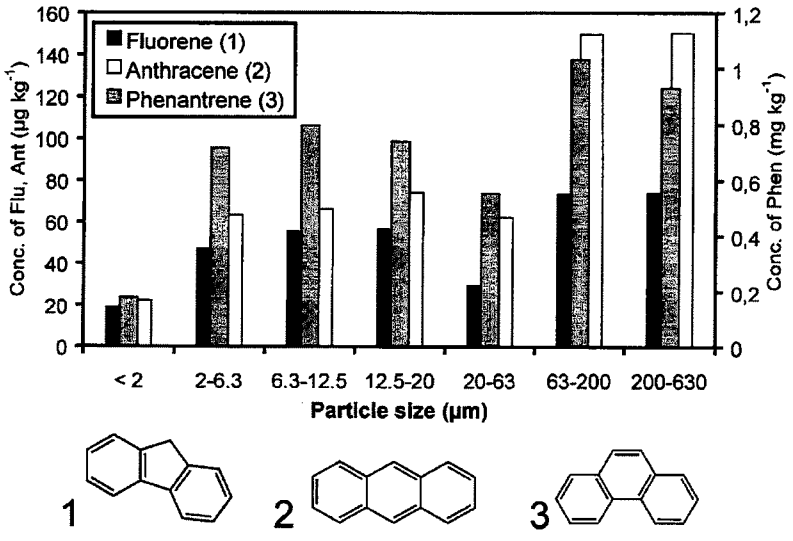

Fig. 1. Road runoff material 12 September 1997—concentrations of fluorene, anthracene and phenanthrene in different grain sizes of a selected sample.

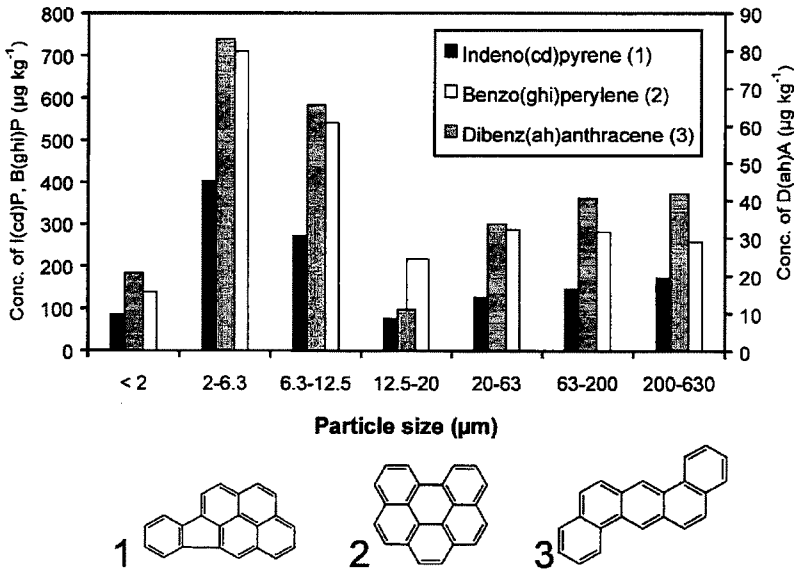

Fig. 2. Road runoff material 12 September 1997—concentrations of indeno(cd)pyrene, benzo(ghi)perylene and dibenz(ah)anthracene in different grain sizes of a selected sample.

rising arms illustrate differentially large increases in concentrations. Here, lead and PAHs originating from street carpets increase more rapidly than copper. Copper's dominant source lies in the residential areas, as well as in the vineyards, and therefore is not as heavily influenced by street dust in its increase in concentration. The regression analysis of the rising arms results in a very clear correlation. Here, lead and the total PAH concentrations of the dry mass increase logarithmically, the copper concentration potentially.

Increase lead:

$$c(\mathrm{Pb})(\mathrm{mg}\cdot\mathrm{kg}^{-1}) = 97\cdot\ln(x) + 249$$

where x is the number of days, $R^2 = 0.98$.

Increase PAH:

$$c(\mathrm{PAH})(\mathrm{mg}\cdot\mathrm{kg}^{-1}) = 4.52\cdot\ln(x) + 4.5$$

where x is the number of days, $R^2 = 0.98$.

Increase copper:

$$c(\mathrm{Cu})(\mathrm{mg}\cdot\mathrm{kg}^{-1}) = 172\cdot(x)^{0.314}$$

where x is the number of days, $R^2 = 0.97$.

A large local community event with a great num-

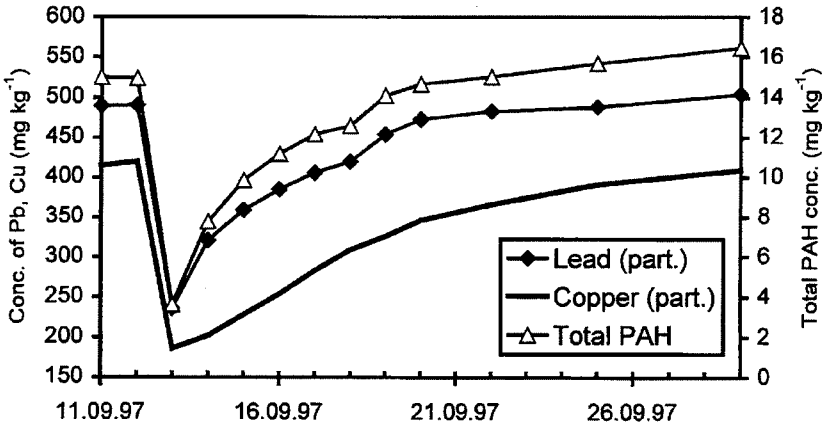

Fig. 3. Chemographs of selected pollutants in street dust.

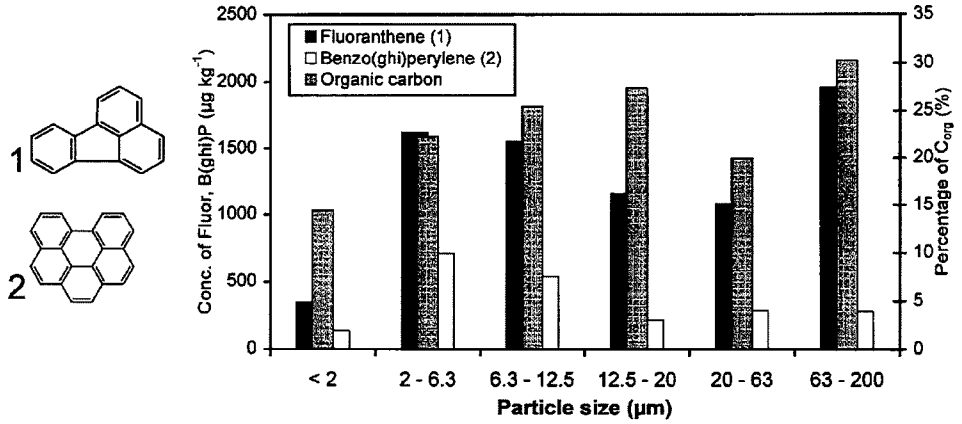

Fig. 4. Road runoff material 12 September 1997—concentrations of fluoranthene benzo(ghi)perylene and organic carbon in different fractions of a selected sample.

ber of vehicles from 18 to 19 September 1997 also appears in the graphs. The concentrations of lead and the PAHs undergo a sharp increase, copper on the other hand increases steadily.

On the whole, smaller PAHs accumulate more rapidly than larger polycycles. The new particles are comparatively coarse due to the abrasion of the street carpet. Fresh PAH profiles point to the proximity of the source, specifically the street traffic. It can be assumed that during the process of transport the fine particles are deposited and remobilised several times, whereas the mobilisation of coarse particles is limited to events of high intensity. During remobilisation, low molecular PAHs can be transferred to a dissolved state or, being volatile, leave the system. This can additionally explain the relative enrichment of three-ring PAHs in the coarse fractions.

In Figs 4 and 5, PAHs of road runoff material and river bottom sediment are compared. Although both fluoranthene and organic carbon show a bimodal distribution in the river bottom sediments, there are striking differences in the medium silt fraction. It is obvious that PAHs during transport tend to be enriched in the coarser fractions. The more volatile the PAHs are, the more distinct this tendency becomes. It can be assumed that the wash load mobilised by urban runoff will be temporarily stored several times on its way to the storm drainage. In this case the bimodal distribution of PAHs would be the result of a sorting process and of a continuous immobilisation and remobilisation. This

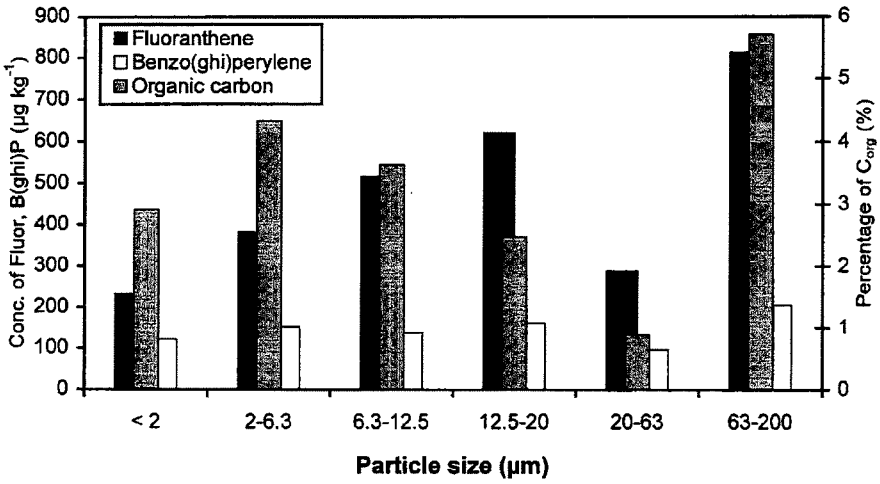

Fig. 5. River bottom sediment 13 September 1997—concentration of fluoranthene, benzo(ghi)perylene and organic carbon in different fractions of a selected sample.

conclusion is supported by investigations of Bierl *et al.* (1996), who found that the temporal variations of PAH contents in suspended particles during high floods are explained by PAHs that are temporarily stored near the river.

The role of organic carbon in this process is not well understood. It is known that it plays a significant part in PAH fixation. Standardisation of particle associated PAHs by organic carbon leads to the conclusion that the type of organic material is more important than the amount. This is supported by the different chemographs of organic carbon and PAHs in river bottom sediment samples from 1993 to 1997. The basic pattern of both chemographs is controlled by flood events and looks similar. Rapid growth of biofilms can either dilute the concentration of organic contaminants or supply adsorption sites (Schorer and Eisele, 1997).

CONCLUSIONS

The most important factor for the behaviour of PAHs are the physical and chemical characteristics of the molecules. They control their solubility and volatility. Sealed areas such as streets and residential sites are rapidly exhausted and are successively again re-enriched. The input into the aquatic system is controlled by the location and activation of particle sources. Selective transport, temporary storage of the particles, and a succession of mobilisation and immobilisation of PAHs during each event leads to a redistribution until the PAHs enter the river.

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Road surface drainage, channel initiation, and slope instability

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Abstract. Field surveys of road drainage concentration at three sites in the western United States are used to test simple models relating channel initiation and shallow landsliding to ground slope and contributing area thresholds. The form of boundaries between data for locations where road drainage concentration is associated with either shallow landsliding, channel initiation by overland flow, or no observable geomorphic effect is consistent with theoretically derived drainage area–slope relations. Comparison of survey data with results of previous studies in these areas indicates that the drainage area required to support a channel head is smaller for road-related runoff than for undisturbed slopes. Contrary to current land management paradigms in the Pacific Northwest, drainage concentration from ridgetop roads may cause both landsliding and integration of the channel and road networks. Road drainage concentration increases the effective length of the channel network and strongly influences the distribution of erosional processes in each of the study areas. The approach of using field reconnaissance to establish thresholds for erosion associated with road drainage provides a useful method to define regional criteria for road design that should reduce impacts on downstream channel systems.

Introduction

Road building results in a wide variety of environmental impacts. Although virtually all road surfaces alter both drainage patterns and runoff generation, the geomorphic impact of road construction has received little attention in a quantitative theoretical framework. Significant road-related geomorphic impacts include (1) destabilization of side-cast material and hillsides downslope (Figure 1); (2) gullying and channel network expansion; (3) increased downstream sediment loads; and (4) altered streamflow and channel adjustments (see *Megahan* [1987] and *Furniss et al.* [1991] for recent reviews). Many previous workers established, for example, that erosion rates from road surfaces and road-related landslides are many times greater than from undisturbed slopes [e.g., *Megahan and Kidd*, 1972; *Swanson and Dyrness*, 1975; *Beschta*, 1978; *Rice et al.*, 1979; *Dunne and Dietrich*, 1982; *McCashion and Rice*, 1983; *Reid and Dunne*, 1984; *Schroeder and Brown*, 1984; *Amaranthus et al.*, 1985; *Anderson and Potts*, 1987]. Road-related impacts generally result from concentration of both runoff generated on road surfaces and intercepted subsurface discharge. Concentration of road drainage can have various geomorphic effects: (1) increased discharge may have no identifiable geomorphic impact, (2) the discharge increase may be sufficient to initiate or enlarge a channel, or (3) the concentrated discharge may contribute to slope instability below the drainage outfall. This paper compares models for erosion initiation by overland flow and shallow landsliding with data from field surveys of road drainage concentration in three study areas in the western United States.

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Theory

Differences in runoff generation from road surfaces and natural slopes are well known. Relatively impermeable road surfaces are a source of rapid runoff, which increases both peak rates and volumes of runoff [e.g., *Megahan*, 1972; *Harr et al.*, 1975; *King and Tennyson*, 1984]. Roadside ditches also intercept both surface and shallow subsurface runoff from upslope areas and route the accumulated discharge to culverts or other locations [e.g., *Burroughs et al.*, 1972; *Megahan*, 1972; *King and Tennyson*, 1984]. Such drainage alterations and diversions may alter channel network pattern, extent, and processes.

Threshold theories for channel initiation and slope instability [e.g., *Horton*, 1945; *Schaefer*, 1979; *Dietrich et al.*, 1986, 1992, 1993; *Montgomery and Dietrich*, 1989, 1994a; *Willgoose et al.*, 1991] provide a context within which to analyze erosional impacts of drainage modification. The essential principle underlying these theories is that erosion occurs once surface or subsurface discharge overcomes the erosional resistance of the ground. Many factors influence the specific timing and location of erosion, including the intensity and duration of rainfall and temporal variations in the contribution of vegetation to soil strength. Threshold models for the spatial distribution of erosional processes, however, may be developed in terms of drainage area, ground slope, and soil properties (e.g., critical shear stress, bulk density, and friction angle).

Erosion by overland flow and shallow landsliding are common channel initiation mechanisms in humid, soil-mantled landscapes. Each of the following models for erosion initiation by these mechanisms assumes a steady state rainfall and spatially uniform soil properties to relate the critical drainage area per unit contour length (a_{cr}) to local ground slope ($\tan \theta$). The steady state assumption limits these models to predicting the form of the relation between a_{cr} and $\tan \theta$.

The overland flow model considers a critical shear stress

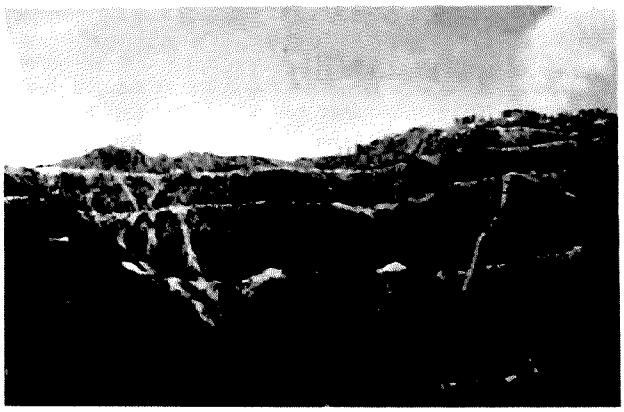

Figure 1. Road-related landsliding in the central Washington Cascades.

(τ_{cr}) to control channel initiation. *Montgomery and Dietrich* [1994a] derived expressions for a_{cr} under both laminar flow

$$a_{cr} = \frac{2(\tau_{cr})^3}{qk\nu\rho_w^3 g^2 (\sin\theta)^2} \quad (1)$$

and turbulent flow

$$a_{cr} = \frac{(\tau_{cr})^{5/3}}{q(\rho_w g)^{5/3} n (\sin\theta)^{7/6}} \quad (2)$$

where q is the rainfall rate in excess of the infiltration capacity of the surface generating runoff, k is a dimensionless surface roughness coefficient, ν is the kinematic viscosity of water, ρ_w is the density of water, g is gravitational acceleration, and n is Manning's roughness coefficient. Each of these equations predicts an inverse critical area-slope relation; a greater drainage area is required to initiate a channel on a gentler slope. Furthermore, since road construction generates a topographic surface with a decreased infiltration capacity, (1) and (2) predict that channel initiation by runoff generated on road surfaces requires smaller drainage areas than for undisturbed ground.

While Hortonian overland flow occurs only rarely on soil-mantled hillslopes in humid regions [*Dunne*, 1978], it is the dominant runoff mechanism for road surfaces. Discharge intercepted by roads, however, may be better modeled using the analogous model for laminar saturation overland flow [*Dietrich et al.*, 1993]:

$$a_{cr} = \frac{2(\tau_{cr})^3}{qk\nu\rho_w^3 g^2 (\sin\theta)^2} + (T/q)\sin\theta \quad (3)$$

where T is the transmissivity of the saturated soil. Rainfall rates typically are less than infiltration capacities for landscapes that generate saturation overland flow [*Dunne*, 1978]. In this case, q is simply the rainfall rate.

Analogous topographic controls on shallow landsliding may be developed through coupling simple hydrologic and slope stability models [see *Montgomery and Dietrich*, 1989, 1994a, b; *Dietrich et al.*, 1993]. The coupled model essentially relies on an expression for the convergence of shallow through-flow to predict the proportion of the soil thickness that is saturated, which is then input into the infinite-slope stability model. Following *Dietrich et al.* [1993], the model assumes infiltration of steady state rainfall and runoff by shallow subsurface flow through cohesionless soil overlying less conductive bedrock. For cohesionless soils the critical drainage area per unit contour length required to initiate a shallow landslide is given by

$$a_{cr} = (T/q)\sin\theta\,(\rho_s/\rho_w)[1 - (\tan\theta/\tan\phi)] \quad (4)$$

where ρ_s is the soil bulk density and ϕ is the friction angle of the soil. The implicit assumption of slope parallel flow precludes consideration of pore pressures greater than hydrostatic. Thus (4) is only valid for steep slopes where $\tan\theta \geq [(\rho_s - \rho_w)/\rho_s]\tan\phi$, a condition that generally can be approximated by $\tan\theta > 0.5$.

Equations (1)–(4) predict different drainage area–slope relations for channel or landslide initiation. Comparison of field-mapped channel networks in natural landscapes (i.e., no road drainage influence) with topographic thresholds defined using digital elevation models indicates that such thresholds can be used to define drainage area–slope relations below which channels do not develop [*Montgomery and Dietrich*, 1992]. Derivations of these models and more detailed discussions of their assumptions and limitations are presented elsewhere [*Montgomery and Dietrich*, 1989, 1994a, b; *Dietrich et al.*, 1992, 1993].

Study Areas and Methods

Road alignments and drainage patterns were mapped onto topographic maps in three study areas in the western United States: near Oiler Peak in the southern Sierra Nevada, California; on Mettman Ridge in the Oregon Coast Range; and along Huelsdonk Ridge on the Olympic Peninsula, Washington (Figure 2). Previous field mapping of channel network extent in portions of the southern Sierra and Mettman Ridge study areas that are uninfluenced by road drainage documented drainage area–slope thresholds that define channeled and unchanneled portions of the landscape [*Montgomery and Dietrich*, 1988, 1992]. Road drainage patterns and the associated drainage diversions were mapped in the field. Discharge points were identified as locations where (1)

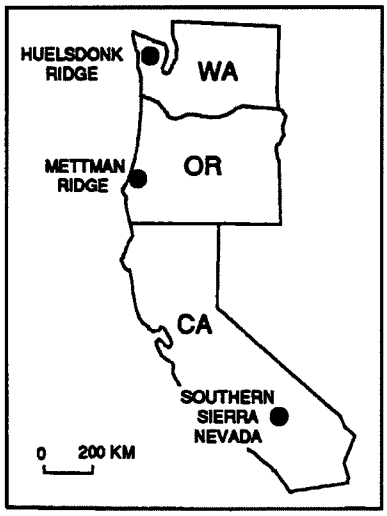

Figure 2. Location map for the study areas.

flow was directed from the road surface either onto a hillside or into a channel, (2) roadside ditches delivered flow to culverts, or (3) road surface drainage ponded and spilled over road margins and onto hillsides. In each study area, average ground slopes were measured in the field over a distance of about 5 m downslope from locations where road drainage was concentrated. Drainage areas were determined differently in each study area, as discussed further below.

Mapping road drainage and determining contributing areas are subject to error because of uncertainty associated with partitioning road surface runoff between different potential discharge points. L. Reid (personal communication, 1993), for example, estimated that surface mapping of road drainage was accurate to about ±30% of the actual contributing area when conducted at times when runoff was not occurring. She also found that mapping road surface drainage patterns during or immediately after runoff-producing events improved the accuracy of contributing area estimates to about ±10%.

Southern Sierra Nevada, California

The drainage system associated with a paved two-lane highway near Oiler Peak provides an example of the effects of road drainage diversions on gully development and channel network expansion. The area is underlain by deeply weathered granitic rocks with thick (i.e., >2 m) colluvial soils developed in topographic hollows. Most slopes in this area are gentle (i.e., tan $\theta < 0.5$), and vegetation consists of open oak forest and grasslands. The road system is located approximately halfway downslope from the drainage divide to natural channel head locations. Road cuts truncate colluvial fills in topographic hollows and weathered bedrock in noses and divert both surface and subsurface flow into an in-board ditch system that drains through culverts into valley bottoms.

Roadside ditches contributing runoff to culverts were mapped along a 2-km stretch of road. Identification of drainage diversions was based on delineating the upslope drainage areas contributing runoff to roadside ditches and assuming that the runoff from these areas is delivered to culverts. Drainage areas both prior and subsequent to road construction then were determined from the mapped pattern of drainage diversions.

At each of the culvert outfalls, road drainage concentration has integrated the road and channel networks, allowing the road surface to act as an extension of the channel network. Within the area shown in Figure 3, four hollows (A, C, E, and G) lost drainage area through drainage diversions. In each of these cases the channel begins significantly downslope of the road. In contrast, three hollows (B, D, and F) receive additional drainage from the road system and the channels begin at or immediately downslope of culverts. In the area shown, 570 m of the road drainage network is integrated with channels, increasing the effective drainage density (here used in the sense of the channel density of *Montgomery and Dietrich* [1994a]) by a factor of 1.67, or from 5.2 to 8.7 km^{-1}. For the whole 1.2-km^2 basin in which the extent of the channel network was mapped, integration of the road and channel networks increased the drainage density by a factor of 1.6, or from 2.8 to 4.4 km^{-1}. These minimum estimates of the increase in drainage density neglect the length of any new channels incised between culverts and previous channel heads.

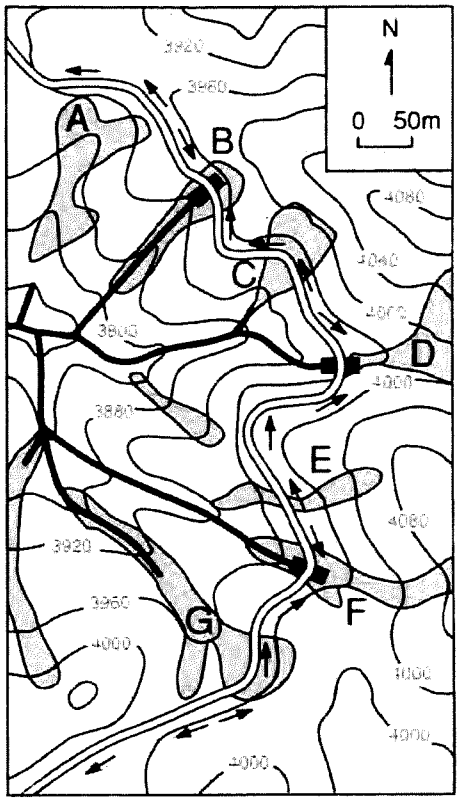

Figure 3. Map of a portion of the southern Sierra Nevada study site; channels represented by thick lines, colluvial deposits in topographic hollows by shading, and road drainage by arrows. Contour interval is in feet (1 foot equals 0.3048 m). Culverts indicated by solid boxes.

In addition to redistributing discharge, road drainage influences the threshold for channel initiation in this area. While the transition from channeled to unchanneled slopes exhibits the same inverse form for both natural and road-altered drainage (Figures 4a and 4b), less drainage area appears to be required to initiate a channel for hollows receiving road drainage (Figure 4c). A test for the equivalence of the regressions [*Berenson et al.*, 1983] of log area on log slope for each of the two data sets shown in Figure 4c allows rejection at the 0.05 significance level of the hypothesis that the two data sets are drawn from the same population. The similar form (i.e., slope) to the lower bound of the unchanneled data, however, implies that road drainage has not altered the dominant channel initiation process.

Huelsdonk Ridge, Washington

Recently constructed logging roads on Huelsdonk Ridge provide an example of the effect of ridgetop road drainage on channel network extension and slope stability. Steep clear-cut slopes drain to narrow tributary channels that empty into a wide alluviated valley along the South Fork Hoh River. Most shallow landslides in this area originate in topographic hollows, and landslide inventories from historical aerial photographs indicate that the rate of landslide initiation increased dramatically following road construction and clear-cutting [*Schlichte*, 1991].

A 7.8-km stretch of the gravel road system along Huels-

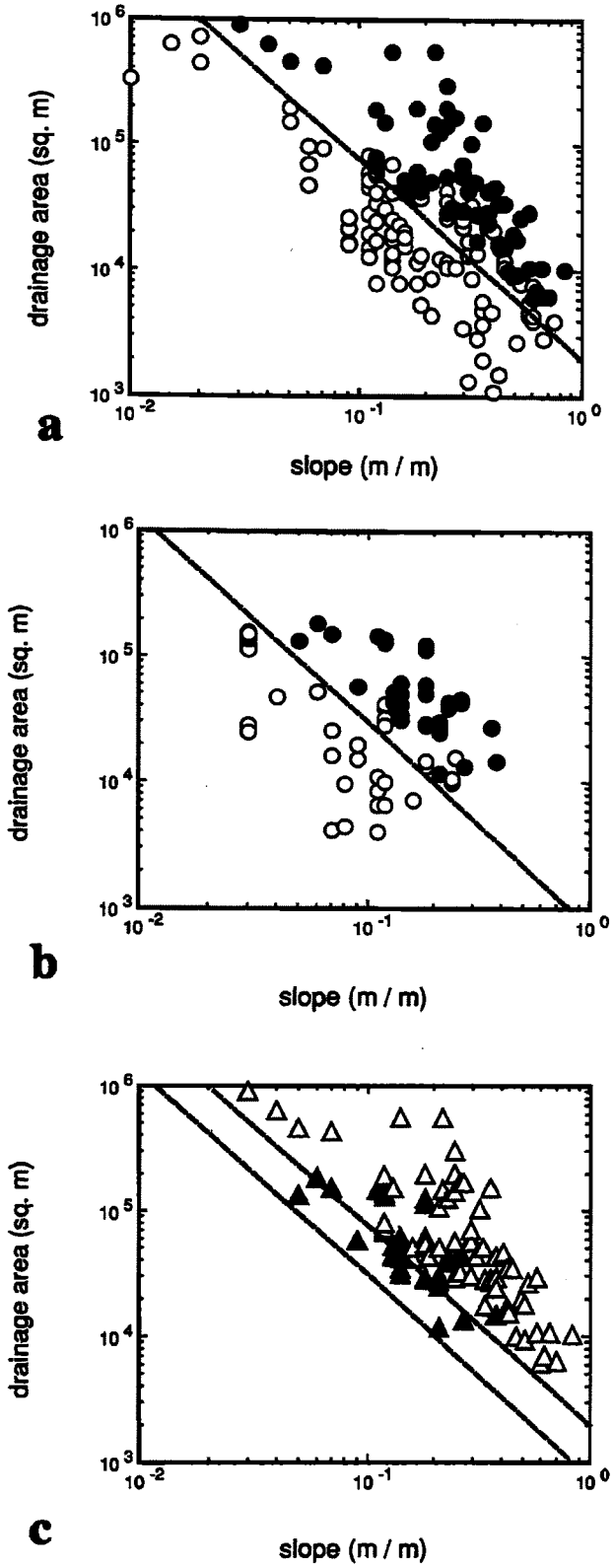

Figure 4. (a) Plot of drainage area versus local slope for channeled (solid circles) and unchanneled locations (open circles) in the southern Sierra Nevada study site for natural drainage. (b) Same as Figure 4a for road-related drainage diversions. (c) Similar plot showing only channeled data for natural drainage (open triangles) and road-related drainage (solid triangles). Dashed lines are approximate thresholds defining the lower bound to channeled data.

donk Ridge was mapped onto a 1:4800 scale topographic map. Road drainage divides, culverts, and other locations where road drainage discharged onto the slopes were mapped. Road surface widths measured in the field consistently were 5.6 m. As is typical throughout the Pacific Northwest, ridgetop road drainage generally is focused into the heads of topographic hollows (Figure 5). Each discharge point was classified as either not influencing erosion, causing channel formation immediately downslope, or producing a shallow landslide scar. The Huelsdonk Ridge survey was conducted during the summer, and drainage areas contributing to each location where road drainage was concentrated were calculated as the product of the contributing road length and the road width; diversion of upslope drainage was minimal because of the ridgetop location.

Data from these classes appear to define distinct fields on a plot of drainage area versus slope (Figure 6). Data from locations where road drainage does not influence downslope erosion (unchanneled) plot at the lowest drainage areas and slopes. Data from locations where road drainage initiates a channel (channeled) plot at higher drainage areas. Road drainage–associated landslides plot at the highest drainage areas and steepest slopes. Although the sample sizes are small, the significance of this interpretation is supported by Kolmogorov-Smirnov tests [*Sprent*, 1989] of the null hypothesis that each population (unchanneled, channeled, and landslide) of the variables (drainage area and slope) are drawn from identical distributions (Table 1). Unchanneled sites appear to have significantly smaller drainage areas than either channeled or landslide sites; landslide sites appear to be steeper than channeled sites.

These data also are consistent with the form of relations predicted by (2) and (4) (Figure 6). Channeled and unchanneled data are reasonably segregated by

$$A = 400 \text{ m}^2/\sin\theta \quad (5)$$

a relation similar to the form predicted for channel initiation by turbulent overland flow, such as might be expected where road drainage is discharged onto natural slopes. Using estimates of $T = 65$ m^2/d, $\rho_s = 1800$ kg/m^3, and $\phi = 45°$ [*Montgomery and Dietrich*, 1994b] and varying the steady

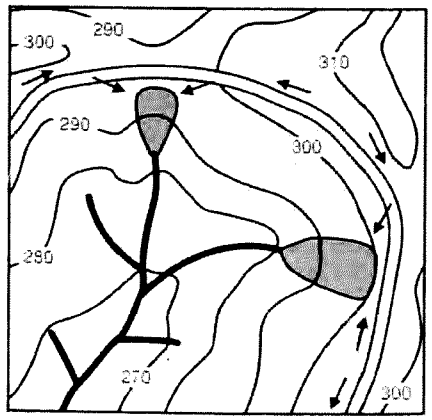

Figure 5. Schematic illustration of ridgetop road drainage concentration into topographic hollows. Landslides represented by shading, channels by thick lines. Modified from a sketch by W. E. Dietrich.

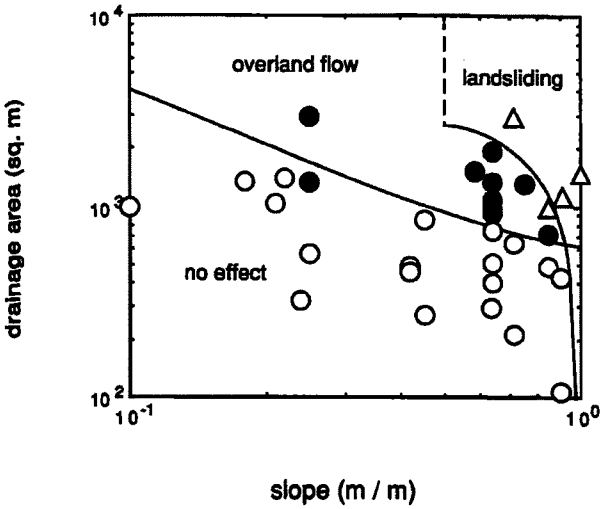

Figure 6. Contributing road drainage area versus slope at the discharge point for the ridgetop road system on Huelsdonk Ridge. Locations immediately downslope of the discharge point were either unchanneled (open circles), channeled (solid circles), or a shallow landslide scar (triangles). Lines indicate fitted form of models for turbulent overland flow and for landsliding; dashed vertical line indicates lower-gradient limit to applicability of landslide model.

state rainfall q in (4), I calculated a lower bound to landsliding (curved line) that fits the observed data well.

Mettman Ridge, Oregon

The forest road system on Mettman Ridge provides another example of the effect of ridgetop road drainage on erosional processes. The gravel road system is located along narrow ridge crests separating steep slopes, which are divided by regularly spaced hollows that indent ridgetop drainage divides. At many locations, road drainage is discharged into the heads of topographic hollows. Road surface widths measured in the field consistently were 3.5 m. Landslides are a major channel initiation mechanism in this area [*Montgomery and Dietrich*, 1988], and landslide-related sediment transport accelerated dramatically after road building and forest clearance, with most of the increase coming from failures associated with road drainage concentration or logging landings [*Montgomery*, 1991].

A total of 3.2 km of the gravel road system was mapped onto 1:4800 scale topographic maps (Figure 7). Road drainage flow directions, drainage divides, culverts, and other points of drainage concentration were mapped immediately after rainfall that produced copious runoff from road surfaces. In a number of cases, distinct channels on either side of the road crown drained to opposite sides of a ridge. Moreover, flow down the road surface sometimes bypassed culverts. These and other observations were used to allocate road surface area to each discharge point; upslope drainage diversions were minimal along this ridgetop road. Each discharge point was classified according to its association with either (1) no apparent geomorphic effect, (2) channel incision by overland flow, or (3) shallow landslide scars. Integration of the ridgetop road network with the channel network in the three Mettman Ridge basins mapped in my previous studies would increase the drainage density by a factor of 1.23, or from 9.9 to 12.2 km^{-1}.

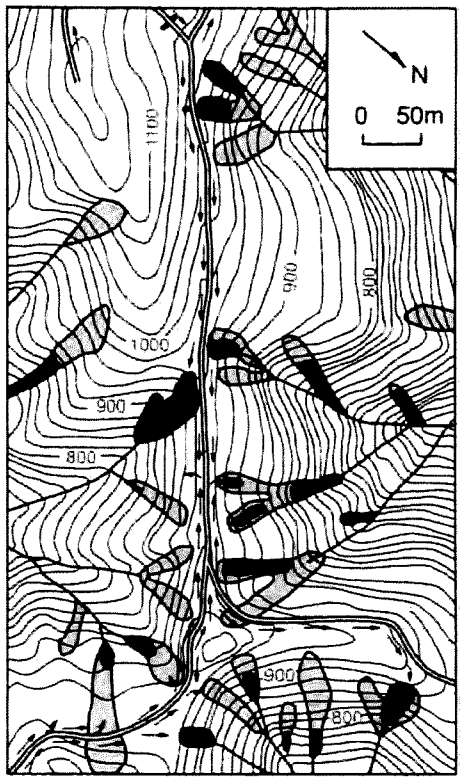

Figure 7. Map of a portion of the Mettman Ridge study area showing road drainage patterns, landsliding (solid areas), channels (thick lines), and colluvial deposits (shaded areas). Contour interval is in feet.

Table 1. Results of Kolmogorov-Smirnov Tests for Huelsdonk Ridge Data

	Channeled Versus Unchanneled	Unchanneled Versus Landslide	Channeled Versus Landside
Area	differ	differ	same
Slope	same	same	differ

Paired slope and area distributions were tested against the null hypothesis that the distributions are the same at the 0.05 significance level.

Data from Mettman Ridge exhibit general relations similar to the Huelsdonk Ridge data (Figure 8). Locations where drainage concentration has no observable geomorphic effect plot at the smallest drainage areas and slopes. Locations where road drainage initiates a channel plot at higher drainage areas and slopes, while those locations where road drainage is associated with landsliding plot at the highest drainage areas and are restricted to steep slopes (i.e., tan $\theta >$ 0.5). Again sample sizes are small, but these interpretations are supported by Kolmogorov-Smirnov tests [*Sprent*, 1989] of the null hypothesis that each of the variables are drawn from populations with identical distributions (Table 2). Although not particularly powerful, these tests imply that unchanneled sites have smaller drainage areas than channeled or landslide sites and that the population of landslide

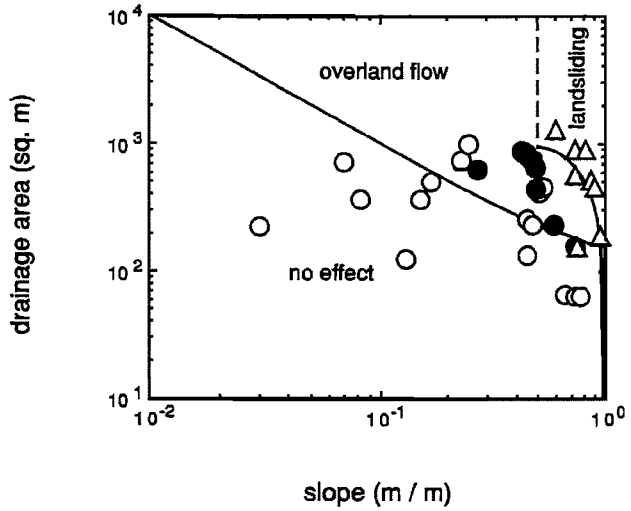

Figure 8. Plot of contributing road drainage area versus local slope at discharge points for ridgetop roads in the Mettman Ridge study area for unchanneled locations (open circles), channels extending to the drainage outfall (solid circles), and landslides immediately downslope of the drainage outfall (triangles). Lines indicate fitted models for channel initiation by overland flow and landsliding; dashed vertical line indicates lower-gradient limit to applicability of landslide model.

sites is steeper than those for both channeled and unchanneled sites.

Equations (2) and (4) also provide reasonable boundaries to unchanneled, channeled, and landslide data from the Mettman Ridge road drainage survey (Figure 8). The lower bound to the data from channeled road drainage locations along Mettman Ridge can be approximated by

$$A = 100 \text{ m}^2/\sin \theta \quad (6)$$

This is significantly lower than for the Huelsdonk Ridge data, presumably reflecting differences in climate and soil properties between these study areas. This difference illustrates that a single relation is not applicable to all landscapes. Appropriate relations need to be developed for application in different areas. Again, adjusting the rainfall rate and using field derived estimates of $T = 65$ m^2/d, $\rho_s = 1600$ kg/m^3, and $\phi = 45°$ [*Montgomery and Dietrich*, 1994b] in (4) provides a reasonable lower bound to data from sites of observed landsliding (Figure 8).

Comparison of these road drainage surveys with a field survey of channel head locations in this area of Mettman Ridge [*Montgomery and Dietrich*, 1992] reveals that overland flow–initiated channel heads associated with road drainage plot at lower drainage areas than natural channel heads (Figure 9). This presumably reflects the lower infiltration capacity for road surfaces than for natural slopes. Many of the steepest natural channel heads in this area are associated with small landslide scars [*Montgomery and Dietrich*, 1988, 1992]. Contributing areas for road-related landsliding plot within the range of data for natural (i.e., not related to road runoff) channel heads. Drainage area and slope are the main control on landslide occurrence because landsliding depends on subsurface flow. The difference in runoff generation mechanisms between road surfaces and natural slopes does not appear to be as great an influence on the susceptibility to landsliding as does the total drainage area. The small sample size of the available data preclude greater exploration of this issue.

Table 2. Results of Kolmogorov-Smirnov Tests for Mettman Ridge Data

	Channeled Versus Unchanneled	Unchanneled Versus Landslide	Channeled Versus Landside
Area	differ	differ	same
Slope	same	differ	differ

Paired slope and area distributions were tested against the null hypothesis that the distributions are the same at the 0.05 significance level.

Discussion

The lower limit to the data for channel initiation by overland flow and landsliding from road drainage concentration is consistent with the trends described by (2) and (4). The relations reported above apply only to geomorphic impacts on locations immediately downslope of roads; they do not consider a wide array of other road-related impacts that warrant further research. These include more detailed assessments of the integration of road and channel networks, the attendant effects on downstream hydrologic and geomorphic response, and the influence of sediment eroded from road surfaces on substrate sizes in downstream channels. In particular, drainage density increases of the magnitude reported here are likely to have major effects on peak discharges in low-order channels.

Both the uncertainty associated with partitioning road runoff among potential discharge points and the natural variability of soil and road surface properties will contribute

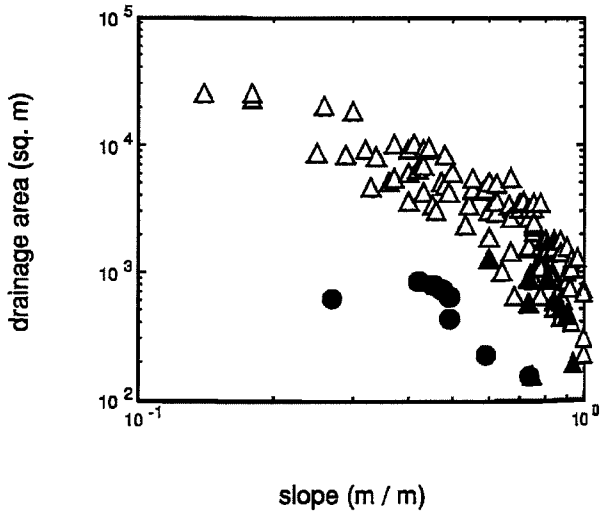

Figure 9. Plot of contributing area versus local slope for channeled data from natural channel heads (open triangles) and road drainage–related landslides (solid triangles) and channel heads (solid circles).

to scatter in data of the type reported here. The Huelsdonk Ridge data, for example, were collected when road runoff was not occurring; drainage area estimates for this study area could have errors as high as ±30% for some data points. The Mettman Ridge data, on the other hand, were collected during and immediately after a small storm; potential errors are likely to be about ±10%. While these errors will not significantly influence the estimated increase in drainage density, they could influence individual data points in Figures 6 and 8. The significant variance expected for data derived from road drainage surveys implies both that empirical thresholds based on such surveys should be fit to as large a data set as possible and that such thresholds provide only a guide to anticipating erosional response to road drainage concentration.

This study has important implications for assessing current road designs. Ridgetop roads presently are recommended as a means to avoid both direct road connection to channels and construction of potentially unstable fill berms across low-order channels [e.g., *Furniss et al.*, 1991]. Ridgetops, however, are generally indented at the heads of even subtle valleys. Thus ridgetop road drainage typically is focused into steep unchanneled valleys, locations prone to shallow landsliding. While recent improvements in road construction practices (e.g., end-hauling) should decrease some road-related impacts, road drainage concentration still may destabilize downslope hillsides or integrate channel and road networks.

The survey results reported here document that incorporating empirical drainage area–slope thresholds into road drainage designs would help to minimize adverse effects of road drainage concentration. This requires determining relations appropriate for the area of interest from field surveys. Fortunately, such surveys are simple and quick. Collecting data from Huelsdonk Ridge, for example, required two people for one day; the Mettman Ridge data required two people for two days. Collecting the necessary data entails a fraction of either the cost of repairing a single landslide or the value associated with resource loss. Such procedures could be readily integrated into road condition surveys conducted during watershed restoration efforts [e.g., *Harr and Nichols*, 1993].

In areas where road surface runoff is of primary concern, the drainage area–slope threshold defines (assuming a road of constant width) a relation between the road length, L, and the gradient of the slope onto which road drainage is discharged. Equations (1), (2), and (4) indicate that the specific relations should reflect the road surface material (infiltration capacity), rainfall characteristics, and soil properties (critical shear stress, friction angle, bulk density, thickness, and conductivity). For the Huelsdonk Ridge data, the empirical relation is approximated by (Figure 10)

$$L = 70 \text{ m/sin } \theta \quad (7)$$

and for the Mettman Ridge data by

$$L = 30 \text{ m/sin } \theta \quad (8)$$

Adverse erosional impacts associated with ridgetop road construction could be minimized by a drainage system designed to keep the road length contributing to each discharge location less than the criteria defined by relations like (7) and (8). In areas where subsurface flow interception is of primary importance, the total upslope drainage area should be used to define relations like (5) and (6).

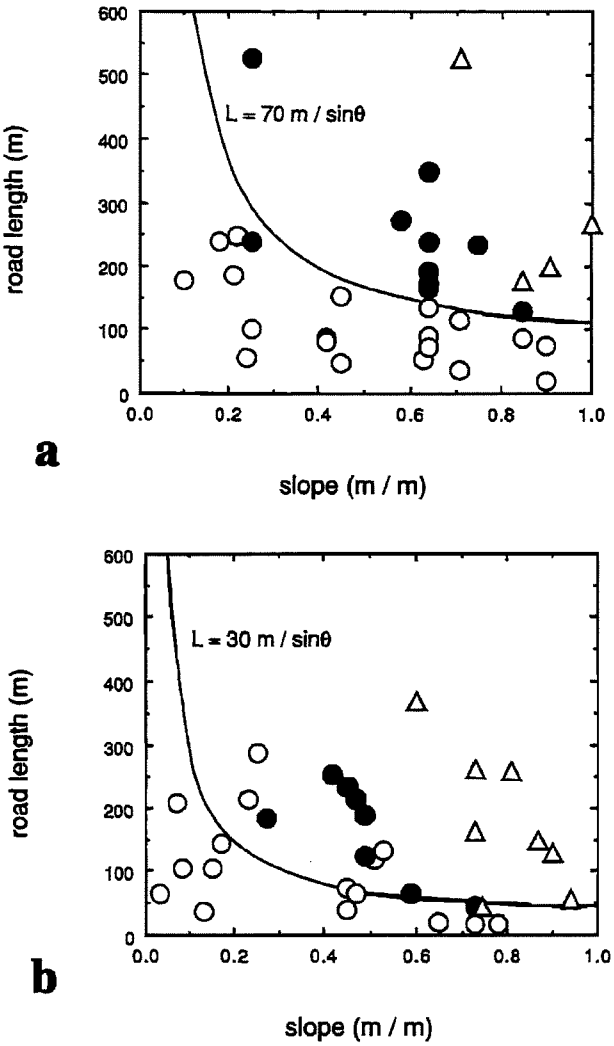

Figure 10. Plot of contributing road length versus ground slope at the point of drainage concentration for (a) Huelsdonk Ridge and (b) Mettman Ridge; data are for unchanneled locations (open circles), channels extending to the drainage outfall (solid circles), and landslides immediately downslope of the drainage outfall (triangles).

The results discussed above highlight the need to include in evaluations of road-related environmental impacts both the frequency along a road that drainage is discharged and the gradient of the slope onto which it is discharged. At present, management regulations generally prescribe culvert spacing based either on delivery of road runoff to natural drainages or a design culvert spacing that varies with the road gradient (e.g., Washington Administrative Code 222-24-025). Road designs or codes that do not take both drainage frequency and ground slope into consideration inadequately address the potential for downslope geomorphic impacts from road drainage concentration.

Conclusions

Road construction fundamentally alters the hydrologic and erosional processes operating in a drainage basin. Con-

centration of road drainage is associated with both integration of the channel and road networks and landsliding in steep terrain. Many existing road designs, including ridgetop roads, can have significant geomorphic impacts. Simple changes in road design that would reduce drainage concentration, however, could minimize road-related adverse impacts on slope stability and downslope stream channels. Collecting field data to calibrate theoretical thresholds for erosion initiation could be used to generate empirical regional relations for allowable drainage concentration that could reduce road drainage–related impacts.

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Journal of Ecology (1988), **76,** 1219–1231

THE INFLUENCE OF AIRBORNE ROAD DUST ON THE CHEMISTRY OF *SPHAGNUM* MOSSES

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SUMMARY

(1) Chemical analysis of *Sphagnum* moss samples collected from a raised *Sphagnum* bog along a transect at right angles to and away from a gravel road at Pointe Escuminac, New Brunswick, Canada, shows that concentrations of the elements Al, Cr, Fe, La, Ni, Sc, Sm and V are strongly correlated with one another, and their concentrations decrease logarithmically away from the road to a distance of 200 m. These elements are deposited primarily in wind-borne soil dust. Concentrations of Na and Cl are correlated; their primary source is precipitation enriched by sea spray. Amounts of As, Cd, Pb, and Zn are also intercorrelated and vary independently of other elements; their primary source is air pollution.

(2) Enrichment factors (EF)—(element concentration:Al concentration in sample divided by the same ratio in the earth's crust)—help to distinguish the primary sources of elements. Both the average enrichment factor and the degree of slope to the regression line of log(EF) vs. log[Al] indicate the degree to which the element is dependent on soil dust or some other factor as a primary source of atmospheric input to the bog, or is concentrated by the *Sphagnum* moss.

INTRODUCTION

Sphagnum mosses, abundant on ombrotrophic bogs receiving chemical inputs only from atmospheric deposition, have very high ratios of surface to mass. They are, therefore, unusually efficient at trapping deposited materials. Their chemistry provides information about the atmospheric deposition of soil dust (Gorham & Tilton 1978) and some inorganic and organic pollutants (Sillanpaa 1972; Pakarinen & Tolonen 1976; Glooschenko *et al.* 1981; Ferguson *et al.* 1984; Rapaport *et al.* 1985; Glooschenko 1986). Such chemical data can provide information concerning the relative magnitude of deposition of these elements, their fate in the environment, and geographical relationships between sources and sinks.

Living *Sphagnum* records present atmospheric deposition, whereas the deeper peat contains a stratigraphic record of past deposition (Aaby & Jacobsen 1979). Thus, one can compare current rates of deposition of an element in precipitation and its accumulation in recent peat with past rates of accumulation of that element, in order to infer past rates of deposition.

The chemical data must be interpreted with caution because comparison of element concentrations between sites or within a core can be misleading. For example, some stratigraphic patterns of element concentration may be caused mainly by changes in the rate of deposition over time, but patterns may also be caused by variation in processes such as decomposition, adsorption and leaching (Damman 1978). Differences in rates of moss growth at different sites with the same influx also affect concentrations. Moreover, for elements such as Pb or V, the presence of the element in peat may be the result of

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deposition from more than one source. Pb and V are components of rock and soil (and thus of wind-borne dustfall), but are also released to the atmosphere as pollutants during combustion of fossil fuels. A high concentration of Pb in a moss sample may result from a high concentration of natural soil-dust particles in the sample (owing perhaps, to local soil erosion) or from enrichment of the sample with lead from combustion of leaded petrol, or from a combination of the two. It is not possible to attribute high concentrations of the element in moss or peat largely to a single source without partitioning the element concentration by source.

Soil-enrichment factors (compound quotients of *element: Al* concentrations in the sample to *element: Al* concentrations in the earth's crust) have been used to separate the influences of soil and wind-borne soil-dust, and to determine whether an additional source is responsible for the enrichment of elements such as Pb, Zn, and Cd in atmospheric aerosol (Rahn 1976) and in ice caps (Boutron & Patterson 1986). Normalization is made to Al on the assumption that it is supplied entirely from the soil. Enrichment factors have been especially helpful in determining whether atmospheric pollution is the major source of an element. Marine enrichment factors have also been calculated, with normalization to Na (National Research Council 1978).

Although enrichment factors are useful for interpreting the chemistry of atmospheric aerosols, they have only recently been applied to the study of atmospheric depositon to mosses. Gorham (1987) found four major groups of elements in his studies of moss chemistry: a group of biophile elements such as P, N, and K; a group of lithophile elements (i.e. elements whose primary source is the earth's crust) such as Al, Fe, and Cr; a group of marine elements such as Na, Cl, and Mg; and a group of pollutants elements such as Pb, Zn and Cd. He has used enrichment factors to demonstrate accumulations of marine, pollutant and biophile elements in *Sphagnum fuscum* beyond concentrations expected from deposition of soil dust, whereas the lithophile elements were not significantly enriched (E. Gorham, unpublished data). However, data from samples that have received heavy local deposition of soil dust have not been used to test current hypotheses about factors influencing moss chemistry.

The present study had two purposes. The first was to determine the influence of wind-blown dust from a road on the chemical composition of moss samples, in order to establish the minimum distance from such a road at which practically uncontaminated samples may be obtained. The second was to compare moss samples known to be heavily contaminated by soil dust with relatively uncontaminated samples collected at the same site, in order to test conclusions of earlier studies on moss chemistry.

The specific questions to be considered were: (i) Are the elements in each of the four groups described by Gorham (1987) strongly correlated with one another in this data set? (ii) Do the elements described by Gorham (1987) as lithophile decline in concentration with distance from the road, as would be expected? (iii) Do enrichment factors successfully distinguish elements derived primarily from soil dust from elements supplied predominantly from other sources? (iv) Do enrichment factors suggest dual or multiple sources of elements, for example from soil dust and atmospheric pollution?

METHODS

Samples of living *Sphagnum* moss were collected in August 1983, from a raised *Sphagnum* bog at Pointe Escuminac, New Brunswick, Canada (47°04′N, 64°49′W), along a transect at right angles to a gravel road at the following distances from its edge: 10, 25, 50, 75, 100,

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150, 200, 300, 400 and 500 m. The road ends at a lighthouse and is lightly travelled; on four visits totalling 25–30 hours there were never observed more than one or two cars passing per hour. *Sphagnum fuscum* was collected from hummocks, of which it was the major component, and *Sphagnum rubellum* was collected from hollows. Samples of *Sphagnum flavicomans* were also collected from hummocks, especially near the road (*S. fuscum* was absent where the effect of road dust was greatest, within about 15 m from the road). Only the uppermost, obviously living portion of each moss was taken, the length of which varied among species (*S. fuscum* and *S. flavicomans*, 3 cm; *S. rubellum*, 5 cm). Paired samples of hummock and hollow moss were taken at each point along the transect to investigate differences between moss species of hummocks and hollows. Two *S. fuscum* samples taken from Ranger Bog (53°55′N, 59°50′W), a remote site in Labrador, were analysed as relatively uncontaminated samples for comparison with the dustfall transect samples. Voucher specimens of each sample were collected, and identifications were confirmed by Dr J. A. Janssens, University of Minnesota. Nomenclature follows Isoviita (1966).

Samples were collected in plastic bags. They were later cleaned of twigs and leaves of vascular plants, dried in plastic bags at 65 °C and ground in a Wiley mill with blades of grade 440C stainless steel. Ground samples (1·0 g dry mass) were heated in covered quartz crucibles at 485 °C for 10–12 hours to determine percentage ash. The ash was dissolved in 2N HCl and boiled to dryness, then redissolved in 10 ml of 2N HCl. The digest was decanted and analysed for fifteen elements by inductively-coupled plasma emission spectroscopy (ICP) in the Soil Sciences Research Analytical Laboratory at the University of Minnesota, St. Paul. A subsample of each ground sample was analysed for additional elements by neutron-activation analysis (NAA) at the University of Wisconsin, Madison. The NAA analyses were calibrated with National Bureau of Standards (NBS) orchard leaves, widely used by agricultural chemists; NBS pine needles and a single sample of well-mixed *Sphagnum* (SMS) from one of our own sites were also run with each set of samples to provide an internal comparison. The ICP analyses were calibrated with spectroscopic-grade chemicals of ultra-high quality; SMS was also run with these analyses.

Of eighty-five elements available from NAA only ten (Sm, V, As, Br, Cl, Co, Cs, La, Rb, Sc), were selected according to two criteria: (i) occurrence at greater than detection limit in all samples; and (ii) coefficient of variation (C.V.) for that element in NBS pine needles and our internal *Sphagnum* standard (SMS) was within an arbitrarily acceptable limit (C.V. $<0{\cdot}60$). We allowed such a high limit because elements analysed by NAA are difficult to determine by other means, and data on their concentrations are scarce.

Coefficients of variation (in the standards) are as follows, in order of increasing reliability: Cs 0·59, V 0·38, Co 0·35, Cl 0·33, Br 0·20, As 0.19, Sc 0·19, Sm 0·18, La 0·17, Rb 0·14. Elements analysed by short-irradiation NAA (Cl, V) were probably less affected by analytical error than the standard data, because samples had much shorter dead times (1·8–6·8%) than the standards (4·1–40·8%). Dead time is the percentage of the time in which the analyser is in the process of counting, and will not be counting other decay events that may be occurring at the same time. Long dead times underestimate concentration unpredictably (R. J. Cashwell, personal communication), so analyses with dead times over 20% were rejected.

Where data were available from both ICP and NAA, the ICP results were used because they were more precise in our analyses of internal *Sphagnum* and NBS pine needle standards (Table 1). The coefficients of variation for elements determined by ICP were less than 0·05 in the internal *Sphagnum* standard except as follows: C.V. 0·06–0·10: B, Cr, Fe,

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TABLE 1. Comparison of coefficients of variation of elements measured in standard samples of plant material by two different analytical methods (neutron activation analysis (NAA) and inductively-coupled plasma emission spectroscopy (ICP)).

	Standard			
	Sphagnum		NBS Pine needles	
Element	NAA CV (%)	ICP[c] CV (%)	NAA CV (%)	ICP[c] CV (%)
Al[a]	26	2·9	N.D.[d]	3·0
Ca[a]	29	2·1	N.D.	2·3
Cr[b]	30	7·4	23	6·0
Na[a]	49	3·6	N.D.	9·8
Na[b]	39	3·6	15	9·8
K[a]	42	3·1	N.D.	3·0
K[b]	60	3·1	21	3·0
Fe[b]	26	7·1	17	4·6
Mg[a]	32	4·0	N.D.	4·0
Mn[a]	23	2·7	N.D.	2·2
Zn[b]	85	5·4	27	18·1

[a] NAA data are from short irradiation NAA, $n = 10$ (also, short irradiation data available only for *Sphagnum* standard; NBS Pine standards all had dead times > 20%).

[b] NAA data are determined by long irradiation NAA, $n = 16$.

[c] for elements determined by ICP, $n = 21$.

[d] N.D. means not determined.

Pb; C.V. 0·11–0·20: Cu, Ni, Cd. The two methods are compared in the Appendix to illustrate characteristics of methodological interest in this data set.

Cluster analysis of twenty-five elements and percentage ash was performed using the matrix of element correlations to calculate average linkage between merged groups by means of the program CLUSTER, Social Sciences Research Facilities Center, University of Minnesota (Anderberg 1973). Principal components analysis was also done using MULTREG, Version 4.3, University of Minnesota School of Statistics.

RESULTS

Table 2 presents average concentrations (per unit dry mass) of each element in all samples, and separately in samples taken near the road or distant from it. Some elements (Ca, Cl, K, Mg, Na) are relatively abundant, averaging more than 1000 $\mu g\ g^{-1}$ overall whereas others (Cd, Co, Cr, Cs, La, Sc, Sm) are very rare, averaging less than 1 $\mu g\ g^{-1}$.

Plots of element concentration vs. distance from the road show high concentrations of Al, Cr, Fe, La, Sc, Sm, and V near the road, decreasing to relatively low concentrations at > 200 m from it (Fig. 1, see also Table 2). The model that fitted the data for these elements best was the power-law regression: $E = aD^{-b}$ where E = element concentration ($\mu g\ g^{-1}$ dry mass), D = distance from road (m), and a and b are parameters. The regression line for Al vs. distance from the road is shown in Fig. 1. The slope (b) is significant ($P < 0{\cdot}001$). Plots of Cr, Fe, La, Sc, Sm, V and percentage ash vs. distance resemble that of Al. Other elements (except B) do not show significant trends of declining concentration away from the road. The dashed line at the bottom of Fig. 1 shows, for comparison, the mean concentration of Al in two *Sphagnum fuscum* samples taken from Ranger Bog in

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TABLE 2. Means and standard deviations of element concentrations per unit dry mass ($\mu g\ g^{-1}$) in all transect samples of *Sphagnum*, and in samples taken near the road ($\leqslant 25$ m) and distant from it (200–500 m), near Pointe Escuminac, New Brunswick, Canada. Element concentrations in *Sphagnum fuscum* for the remote Ranger Bog, Labrador, are shown for comparison.

	Near		All		Distant		Labrador
Element	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean
Al	793	254	373	241	189	50	86
As	1·65	0·10	1·62	0·36	1·33	0·31	0·23
B	4·45	1·12	3·15	0·94	2·50	0·41	4·43
Br	16·4	2·22	18·4	6·50	16·5	6·09	4·50
Ca	1630	337	1570	524	1330	498	1400
Cd	0·43	0·18	0·32	0·15	0·18	0·08	0·19
Cl	1080	80	1150	201	1320	218	494
Co	0·45	0·06	0·37	0·08	0·34	0·08	0·09
Cr	1·23	0·35	0·76	0·29	0·56	0·12	0·48
Cs	0·26	0·05	0·22	0·06	0·22	0·07	0·12
Cu	3·89	0·45	3·55	0·83	2·77	0·70	1·92
Fe	1080	405	553	318	318	76	84
K	2870	433	2730	422	2790	378	3120
La	0·82	0·37	0·41	0·28	0·21	0·04	0·11
Mg	1400	175	1270	187	1280	105	509
Mn	127	50	105	76	59	68	326
Na	1050	22	1070	192	1150	189	376
Ni	1·61	0·35	1·12	0·33	0·89	0·15	0·20
P	247	33	287	52	325	59	435
Pb	21·8	3·01	21·7	7·80	15·7	2·34	6·36
Rb	10·7	2·81	8·70	2·77	8·14	2·13	6·37
Sc	0·33	0·13	0·16	0·10	0·09	0·01	0·03
Sm	0·12	0·04	0·06	0·04	0·03	0·01	0·02
V	4·69	1·12	2·66	1·37	1·38	0·54	0·62
Zn	30·1	5·17	26·6	5·03	21·9	2·92	13·4
Ash	2·96	0·65	2·08	0·51	1·71	0·12	1·24
$n=$	4		23		8		2 (ICP) 1 (NAA)

Laborador, without local sources of road dust but still exhibiting a low level of soil dustfall.

STATISTICAL TREATMENT OF THE RESULTS

Cluster analysis and principal components analysis (PCA) were used to interpret the data. Because elements grouped together in the cluster analysis also occurred near each other in the first three dimensions of the PCA, only the cluster analysis will be illustrated.

Cluster analysis

Cluster analysis showed two major groups containing several elements, and several pairs of elements. A dendrogram of groups is shown in Fig. 2. Two cut-off points for identifying groups were suggested by a rapid increase in average linkage beyond them. The first cut-off distinguishes a closely linked group of nine elements—Al, B, Cr, Fe, La, Ni, Sc, Sm, V—and percentage ash. All the elements decrease with increasing distance from the road; the group is labelled lithophile in Fig. 2. This group emerged using both average linkage between merged groups (shown) and Ward's incremental-sum-of-squares method (not shown). Average linkage of elements within this group was 0·82.

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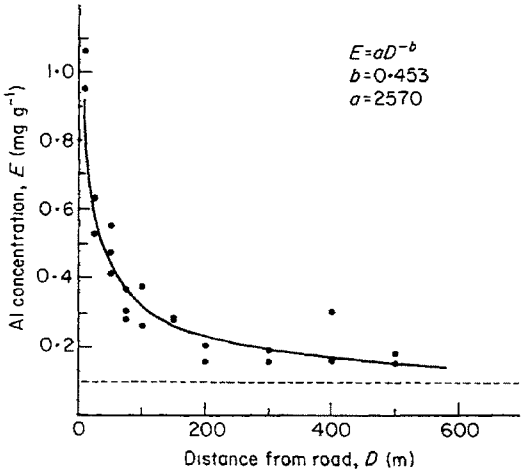

FIG. 1. Plot of Al concentration (E) per unit dry mass vs. distance (D) from the road for *Sphagnum* moss samples from a transect on a raised bog in New Brunswick, Canada. The solid line is predicted by a power-law regression ($r^2_{\log 10}=0{\cdot}87$) and the dashed line is the mean Al concentration in relatively uncontaminated *Sphagnum fuscum* samples collected in Labrador.

The elements As, Cd, Pb, and Zn were grouped together with an average linkage of 0·65, the next closest linkage including a group of more than two elements. They are not strongly correlated with the lithophile elements, and are not concentrated by plants nor in sea water. The primary atmospheric source for these elements is air pollution, probably from combustion of fossil fuels and smelting of metallic ores (Rahn 1976).

Sodium and Cl are paired in the cluster analysis; their primary source is considered to be precipitation enriched by sea-spray. Although Mg and Br are found in relatively high concentrations in sea water, they are not significantly correlated with Na and Cl here. Post-depositional processes (e.g. biological uptake of Mg) may be an important cause of variation for Mg and Br, although in data sets encompassing a larger geographic region,

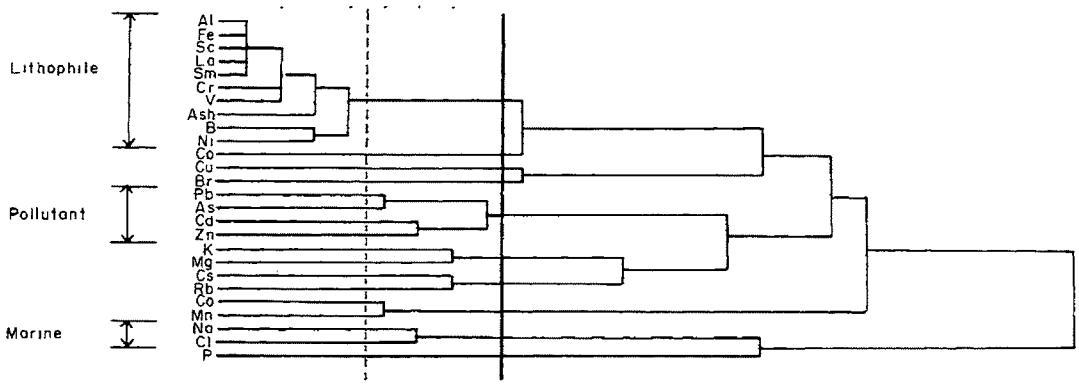

FIG. 2. Dendrogram of element clusters using average linkage between merged groups in samples of *Sphagnum* from New Brunswick, Canada. Note close grouping of Al, B, Cr, Fe, La, Ni, Sc, Sm, V, and percentage ash, labelled lithophile; the group As, Cd, Pb, and Zn, labelled pollutant; and the pairing of Na and Cl, labelled marine. Cut-off lines for groups in the figure are at levels where addition of another element causes a sharp drop in average linkage among elements in the new group. The first occurs at an average linkage of 0·82, the second at an average linkage of 0·65.

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all four elements decline below the high levels at this site with increasing distance from the ocean (E. Gorham, unpublished data).

Calcium and Mn are paired, not surprisingly, because both are divalent ions, mobile under strongly acid conditions and taken up by the moss as well as transported and concentrated passively by evaporation from the moss surface. The mobility of these elements under acid conditions makes their correlation more likely to be the result of similar post-depositional behaviour in the moss than that they come from a similar source.

Paired sample comparisons

Samples of the hummock *Sphagna* (*Sphagnum fuscum* and *S. flavicomans*) tend to have higher concentrations of six elements (Al, B, Br, Cr, Cu and Fe); four are in the lithophile group. Paired-sample comparisons revealed that this tendency is significant ($P < 0{\cdot}05$). Samples of *S. rubellum* tend to be higher in P, Cs, Mg, and K, but paired-sample comparisons show that the tendency is significant only for Cs.

Because different species of *Sphagnum* moss have different relative growth rates (Clymo & Reddaway 1971), it is not possible to tell from this data set if the greater concentrations of Al, Cr, Cu and Fe in hummock mosses result from more efficient trapping of soil-dust by hummocks. The relative growth rates of each moss species must be known in order to calculate fluxes of elements to the different moss species. A study of the growth rates of moss species in hummocks and hollows at a particular site, in conjunction with measurements of atmospheric deposition of various elements, could provide information concerning deposition of elements on different microtopographic features and post-depositional processes in the peat.

Concentrations of elements in living *Sphagnum* depend not only on atmospheric deposition of elements and moss productivity, but also on the degree of metabolic uptake from the dead moss stems beneath, evaporative concentration of dissolved ions at the moss surface, and post-depositional downwash of particulate materials (cf. Damman 1978; Norton 1983). We are examining such influences in profiles of elemental abundance within short peat-cores (0–50 cm deep) taken in bogs from Minnesota and Manitoba to Maine and the Atlantic Provinces of Canada.

DISCUSSION

Primary sources for elements in moss

Aluminium, Cr, Fe, La, Ni, Sc, Sm, and V show the same pattern of decreasing concentration with increasing distance from the road. Concentrations of these elements in the moss samples are highly correlated, as shown by the tight grouping of these elements and percentage ash in the cluster analysis. We conclude, therefore, that these elements are lithophile (cf. Gorham 1987) and are deposited primarily in wind-borne soil dust from the gravel road at the Pointe Escuminac site. Concentrations of elements such as Na and Cl, thought to be marine in origin, and of K, Mg, and P, which are actively taken up by *Sphagnum* moss, exhibit less variance, and are not correlated with distance from the road. Other elements such as As, Cd, Pb, and Zn, although present in soil, are only slightly (and not significantly) higher in concentration near the road. They do not cluster with the lithophile elements and are not highly correlated with them, nor are they marine in origin or biophile. The primary source for these elements is air pollution—most probably the combustion of fossil fuels and the smelting of metallic ores (Rahn 1976).

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Minimum sampling distance

Concentrations of the lithophile elements in these samples decrease away from the edge of the road, to a distance of 200 m from it. Concentrations of Al in samples 200–500 m from the road are similar to those in moss from areas relatively unaffected by soil contamination in other parts of eastern Canada (M. V. Santelmann & E. Gorham, unpublished data) and are only slightly greater than Al concentrations in samples from remote sites such as Labrador. Thus, uncontaminated samples representative of this site may be obtained by sampling more than 200 m from the road.

The minimum sampling distance from other gravel roads, or other sources of soil-dust contamination, will vary depending on the amount of dust emitted and factors that affect its transport. Patterns of emission and deposition of dust from gravel roads have been studied by others (Tamm & Troedsson 1955; Dyck & Stukel 1976; Everett 1980), who concluded that the proportion of fine silt in the road material, amount of traffic, weight of vehicles, and wind speed and direction were the most important factors affecting dust emission and transport. The gravel road at Pointe Escuminac is not heavily used, so that emissions of dust probably have been relatively low.

Soil-enrichment factors in moss chemistry

Soil-enrichment factors provide another way of testing the influence of windborne soil upon moss chemistry. The soil-enrichment factor (EF) for an element is calculated as follows, normalizing each element to Al because it is generally agreed to be strongly lithophile and not taken up actively by plants (and is readily and frequently measured):

$$\mathrm{EF} = \frac{[\mathrm{Element}]_{\mathrm{sample}}/[\mathrm{Al}]_{\mathrm{sample}}}{[\mathrm{Element}]_{\mathrm{earth's\ crust}}/[\mathrm{Al}]_{\mathrm{earth's\ crust}}}$$

The element concentrations in crustal rock used to calculate EF values are from Mason (1966) as reported by Rahn (1976).

If an element is present in the moss only as a result of the deposition of natural rock or soil particles, the EF will ideally be approximately one. Furthermore, the EF for such an element will be relatively constant over a wide range of Al concentrations, so that there will be little or no slope to the regression in a plot of EF vs. Al. Fractionation of elements as they become part of the atmospheric aerosol may change the quotient slightly, and differences in the composition of soil from different areas may make the calculated EF differ somewhat from the expected value. However, EF values based on average composition of crustal rock were considered adequate for our purposes. Rahn (1976) provides a more detailed discussion of the choice of reference material for calculation of EF values.

If most of the element in a moss sample is supplied by a source other than the soil (e.g. from air pollution or from the sea) the ratio of that element to Al in the sample should be much greater than the ratio of the same element to Al in the earth's crust. Biological uptake can also greatly increase the concentration ratio of elements from any source, because Al is not concentrated by plants. The EF in these instances may be greater than 10. In addition, if the concentration of a given element is relatively constant in the moss samples, the EF should change as a function of Al concentration. If the element concentration is constant and wholly independent of Al concentration, the slope of the line in a plot of log(EF) vs. log[Al] should be -1 (cf. Rahn 1976).

In Table 3, elements and average enrichment factors are listed separately for all *Sphagnum* samples, samples at < 25 m from the road, and samples $\geqslant 200$ m away. Figures

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TABLE 3. Arithmetic average of enrichment factors (EF) for all *Sphagnum* moss samples, and for samples taken near a road (≤25 m) and distant from it (200–500 m), near Pointe Escuminac, New Brunswick, Canada. Average EF values for *Sphagnum fuscum* from the remote Ranger Bog, Labrador, are shown for comparison.

	Near $n=4$	All $n=23$	Distant $n=8$	Labrador samples $n=2$ (ICP) $n=1$ (NAA)
Cl	910	2700	4600	3300
Br	750	2100	2900	1600
Pb	190	450	550	470
Cd	230	390	400	930
As	100	250	330	110
Zn	48	100	140	190
B	50	81	110	410
P	29	81	140	400
K	13	30	50	120
Mn	15	28	30	340
Rb	13	27	39	62
Cs	7·5	21	35	36
Mg	7·9	17	28	23
Cu	8·2	17	23	33
Ca	5·7	12	18	38
Na	4·8	11	18	13
V	3·7	4·5	4·6	4·0
Co	1·9	4·1	6·0	3·0
Ni	2·4	3·9	5·5	2·6
La	2·8	3·0	3·0	3·2
Fe	2·2	2·5	2·7	1·6
Sm	2·0	2·0	1·9	2·2
Cr	1·3	1·9	2·4	4·7
Sc	1·5	1·6	1·7	1·2

3 and 4 show plots of log(EF) vs. log[Al] for six elements: Fe and Cr, deposited primarily in soil dust; Pb and Zn, for which atmospheric pollution is a significant source; Cl, whose primary source is the ocean; and P, a biophile element. The two *S. fuscum* samples collected from the relatively uncontaminated Ranger Bog site in Labrador are also shown.

Elements previously characterized as lithophile, which increase significantly in concentration toward the gravel road, behave as expected from the enrichment-factor model; EF values are between 1 and 10 in all columns of Table 3. The slopes to the regressions of $\log(EF_{Fe})$ vs. log[Al] and $\log(EF_{Cr})$ vs. log[Al] are small (Figs 3 and 4, respectively). That for Cr is, however, quite distinct and congruent with the data from Labrador. The differences among the EF values of Cr in samples from different parts of the transect may well be owing to the existence of another, minor source for Cr. Air pollution is one possibility, because Cr shows intermediate enrichment in atmospheric aerosol and is concentrated on the smallest fly-ash particles emitted from coal-fired power plants (Rahn 1976). It is also possible that finer dust particles, which tend to be carried farther from the road, are slightly enriched in Cr relative to Al, or that filings from grinding the moss samples contribute some Cr. Co and Ni behave similarly to Cr, perhaps for the same reason(s). Boron, linked surprisingly to the lithophile elements by cluster analysis and PCA ordination, has a higher EF (average 81) that suggests another origin or a different chemical behaviour in the moss.

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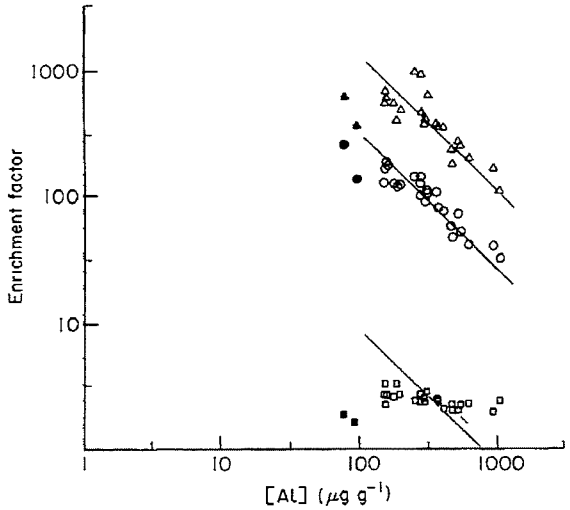

FIG. 3. Plot of enrichment factors vs. Al concentration per unit dry mass (logarithmic scale on axes) for the elements Fe (□), Zn (○), and Pb (△). Solid lines have a slope of −1·0 through the centroid of the data for each element. Open symbols are *Sphagnum* samples from the Pointe Escuminac dustfall transect, New Brunswick, Canada; the solid symbols are *S. fuscum* samples from Labrador.

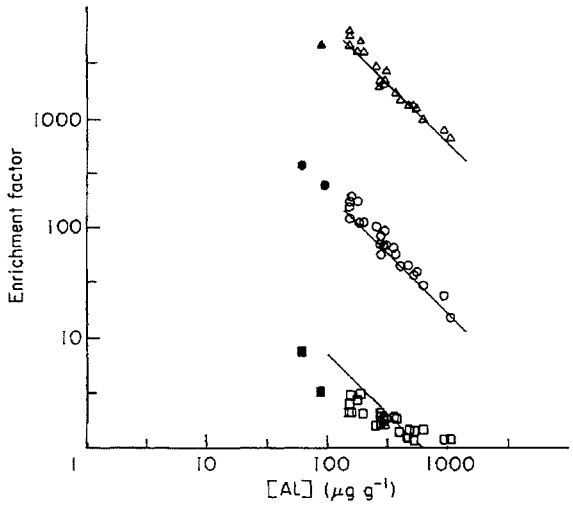

FIG. 4. Plot of enrichment factors vs. Al concentrations per unit dry mass (logarithmic scale on axes) for Cr (□), P (○) and Cl (△). Solid lines have a slope of −1·0 through the centroid of the data for each element. Open symbols are *Sphagnum* samples from the Pointe Escuminac dustfall transect, New Brunswick, Canada; solid symbols are *S. fuscum* samples from Labrador.

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EF values for Pb, Cd, As, and Zn are all $\geqslant 100$. The slope of the regression of $\log(EF_{Pb})$ on log[Al] (Fig. 3) is $-0{\cdot}84$, not very different from -1. The primary source of Pb in these samples is not soil dust, but probably atmospheric lead produced by combustion of fossil fuels and leaded petrol. Zinc behaves similarly, but shows less enrichment.

The marine element Cl shows the highest EF (averaging 2700) because it is extremely scarce in crustal rock (Bowen 1979) and is supplied by precipitation enriched in sea spray. The EF for Na is much lower (averaging 11) because Na is also an important component of rock minerals. Br, like Cl, has a very high EF, but as noted before does not cluster with it for reasons unknown.

The biophile elements K and P have EF values of 31 and 81, respectively, which vary inversely with Al concentration. The slope of the line in the regression of $\log(EF_P)$ on log[Al] is $-1{\cdot}16$, again not very different from -1, suggesting that P concentration is independent of Al concentration.

Enrichment-factor diagrams clearly distinguish biophile elements, marine elements, and elements supplied by atmospheric pollution from lithophile elements. Moreover, despite the strong signal from soil dustfall, additional inputs (from other sources) of elements such as Cr can be discerned from the slope of the regression of log(EF) on log[Al]. Enrichment factors thus provide a powerful tool for partitioning inputs of elements to mosses according to source. We are now testing the utility of EF values normalized to Na for elements primarily marine, and to Pb for elements derived largely from air pollution (E. Gorham and M. V. Santelmann, unpublished data).

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APPENDIX

ICP and NAA Analyses: Comparison of NBS Pine Needle Standards, Sphagnum *Standards, and Transect* Sphagnum *Samples*

Elements determined by ICP had coefficients of varation (C.V.) of $\leqslant 0{\cdot}05$ in the *Sphagnum* standard, except B 0·10. Cd 0·18, Cr 0·07, Cu 0·14, Fe 0·07, Ni 0·18, Pb 0·07. For the NBS Pine Needle Standard, C.V. values were also $\leqslant 0{\cdot}05$ for all but Cd 0·25, Cr 0·08, Na 0·12, Ni 0·13, Pb 0·09, Zn 0·19. The C.V. value for an element in the internal standard as determined by NAA was always greater than that for the same element in the same standard as determined by ICP, often by an order of magnitude (Table 1 in text). For elements whose C.V. values in standards as determined by NAA were less than 0·30 (Al, Ca, Mn, Fe), the ICP and NAA data for the transect samples were highly correlated (Appendix Table 1). For elements whose C.V. values in the NAA standards were greater than 0·30 (K, Na, Mg, Zn), the ICP and NAA data for the transect samples were not as well correlated, suggesting that the lack of correlation between ICP and NAA for those elements in the same sample is caused at least in part by random variation in the NAA data. For this reason, and because the 95% confidence intervals for ICP means are within the NBS certified range for these elements in the standards, the ICP data are considered more reliable.

For three elements (Al, Cr, and Fe) it could be argued that NAA data should be used rather than ICP data. Although ICP results are much more precise according to analyses of the standards (i.e. the C.V. values from ICP data for Al, Cr, and Fe in the standards are

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APPENDIX TABLE 1. Relationship between ICP and NAA data for moss samples from a roadside transect near Pointe Escuminac, New Brunswick, Canada ($n=23$).

Element	Correlation coefficient (r)	Regression coefficients from linear regression of NAA data on ICP data: Slope	Intercept
Al[a]	0·987**	1·413	−15·30
Ca[a]	0·971**	1·044	−57·85
Cr[b]	0·173	0·569	1·84
Na[b]	0·879*	0·946	55·77
K[a]	0·292	0·720	805·54
Fe[b]	0·962**	1·055	62·98
Mg[a]	0·603*	0·717	508·51
Mn[a]	0·998**	1·027	3·06
Zn[b]	0·526	1·142	7·57

** $P<0·001$; * $P<0·01$.

Abbreviations: a, NAA by short radiation; b, NAA by long irradiation.

less than 0·08, whereas the C.V. values from NAA for these elements range from 0·26 to 0·30, see Table 1 in text), the ICP data consistently underestimate mean Al, Cr and Fe concentrations in NBS pine needle standards by 14%, 10% and 14%, respectively. Because ICP uses a digestion procedure, it measures only the fraction of these elements that is soluble in the 2N HCl digestate. The NAA data are much more variable for these elements, with individual values outside the NBS certified ranges, but the mean estimates of Al, Cr and Fe concentrations in the standards are within the NBS certified ranges (because NAA measures the total amount of the element present). Thus, ICP gives a precise but biased estimate of Al, Cr, and Fe concentrations in the standards, whereas NAA gives a less precise but unbiased estimate of the concentrations of these elements in standards. Because the transect sample data are so highly correlated for Al and Fe, data from either analytical method would give the same qualitative results for these elements. The ICP results were chosen because precision of individual data points (relative to each other) was considered more important than unbiased estimation of mean Al and Fe concentrations in this study. Also, the ICP results are more comparable with those obtained in other studies, because relatively few studies use expensive NAA to determine elements such as Al and Fe. For Al and Fe, the regression coefficients in Appendix Table 1 could be used to estimate the NAA values from the ICP data. The ICP values for Al are about 74% of the NAA values for *Sphagnum* samples along the transect. The ICP values for Fe are about 85% of the NAA values. Moss samples from bogs with less or more deposition of large soil-dust particles from local sources will probably differ in the relative proportion of these elements determined by ICP and NAA.

It is possible that for Cr, which shows the least correlation in Appendix Table 1, some of the difference between the NAA and ICP results may result from the greater sensitivity of NAA to the presence of metal filings produced during grinding. The stainless steel blades of Wiley mills increase significantly the Cr content of samples ground several times (Munter *et al.* 1984). In ICP, Cr from the filings might not dissolve completely in the digestate, and thus the contamination would be underestimated, whereas NAA would detect more completely the presence of such contaminants.

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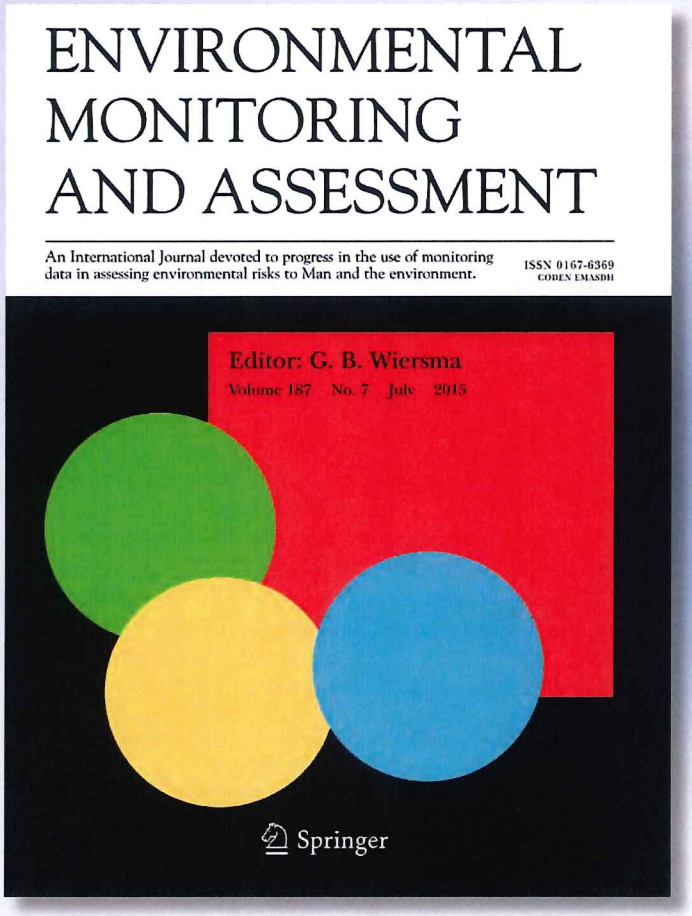

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Landscape level estimate of lands and waters impacted by road runoff in the Adirondack Park of New York State

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Abstract Road runoff is understood to be a significant stressor in terrestrial and aquatic ecosystems, yet the effects of this stressor are poorly understood at large spatial scales. We developed an efficient method for estimating the spatial impact of road runoff on lands and waters over large geographic areas and then applied our methodology to the 2.4 million ha Adirondack Park in New York State. We used TauDEM hydrologic modeling and a series of ESRI GIS processes to delineate surface flow downslope of paved roads, illustrating the potential movement of pollutants originating from paved roads through the USGS 10 m DEM topography. We then estimated the land and surface water areas, number of water bodies, and total stream length potentially impacted by road runoff from paved roads. We found that as much as 11 % of land area, 77 % of surface water area, 1/3 of the water bodies, and 52 % of stream length in the Adirondack Park may be impacted by road runoff. The high degree of hydrologic association between paved roads and the lands and waters of this region strongly suggests that the environmental impacts of road runoff should be evaluated along with other regional stressors currently being studied. Being able to estimate the spatial impact of road runoff is important for designing monitoring programs that can explicitly monitor this stressor while also providing opportunities to understand the interaction of multiple environmental stressors.

Keywords Road runoff · Road salt · GIS · TauDEM · Multiple environmental stressors · Adirondack Park

Introduction

The 2.4 million ha Adirondack State Park in northern New York State, USA, encompasses the world's largest intact temperate forest which contains a globally unique landscape of wetlands, northern hardwood and boreal forests, alpine tundra, and vast fresh water resources (Jenkins and Keal 2004). This large rural landscape is exposed to multiple environmental stressors operating at varying spatial scales and often in interacting ways that are poorly understood (Allan 2004; Palmer and Yan 2013). Historically, the principal environmental stressors studied in the region have been acid deposition and climate change (Ito et al. 2002; Stager et al. 2009). In recent years, road runoff has been identified as a significant threat to aquatic and terrestrial ecosystems in the region, comparable to acid deposition (Kaushal et al. 2005; Kelting and Laxson 2010). Over 8000 km of paved roads traverse the Adirondack Park; therefore, the potential land and surface water area receiving road runoff pollutants may be significant and likely also occurs on protected state lands which represent 45 % of the area.

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The main categories of pollutants found in road runoff are road de-icing salts, heavy metals, herbicides, and polycyclic aromatic hydrocarbons (Trombulak and Frissell 2000; Fay and Shi 2012; Tang et al. 2013). Road runoff pollutants have been shown to induce tree mortality (Fan et al. 2014), shift the composition of floral and faunal communities (Kaspari et al. 2010; Ke et al. 2013; Neher et al. 2013; Snell-Rood et al. 2014), promote establishment of terrestrial and aquatic invasive species (Johnston and Johnston 2004; Crooks et al. 2011), and elevate Na concentrations in roadside soils, displacing base cations (Ca, Mg, K) essential to ecosystem function (Norrström and Bergstedt 2001). Flux of displaced cations and Cl into streams has been reported downslope of salted roads (Daley et al. 2009; Price and Szymanski 2013; Corsi et al. 2015), and Na and Cl concentrations in lakes correlate positively with paved road density (Kelting et al. 2012). Road runoff pollutants in lakes and rivers can increase fish and amphibian mortality (Yousef et al. 1983; Karraker et al. 2008) and may induce top-down (Sloman et al. 2003) and bottom-up trophic cascades (Hodkinson and Jackson 2005). Road runoff pollutants can affect ecosystem function similarly to other regional stressors (Norrström and Bergstedt 2001) and can often interact synergistically, enhancing their effects on terrestrial and aquatic communities (Holmstrup et al. 2010). Pollutants commonly found in road runoff have been shown to exacerbate the effects of warming temperatures (Qiang et al. 2012), drought (de Silva et al. 2012), acid deposition (Rosfjord et al. 2007), eutrophication (Ferreira et al. 2008), and disease (Kiesecker 2002).

Although the impacts of road runoff on terrestrial and aquatic ecosystems are well known, no studies have been published that model the spatial extent of road runoff over large geographic areas. Accurate knowledge of the spatial extent of road runoff is essential to understanding and managing the interacting impacts of road runoff and other regional stressors on aquatic and terrestrial ecosystems (Soranno et al. 2014). Our objectives were to develop an efficient method of estimating the spatial extent of road runoff impacts on lands and waters over large geographic extents and to quantify the land area and surface water areas, number of water bodies, and total length of streams potentially impacted by road runoff from state and federal, county, and local roads within the Adirondack Park.

Methods

Study area

The Adirondack Park (Park) is located in New York State, USA (Fig. 1). The Park is 2.4 million ha in size and is roughly divided equally between private and public lands that are dominated by natural forest cover. The Park contains over 8000 km of paved roads, broken out into 1965 km of state and federal roads, 1803 km of county roads, and 4421 km of local roads (Table 1). The Park also contains about 103,000 ha of surface water (lakes and ponds) and over 13,000 km of streams.

Estimating spatial extent of road runoff

Spatial data for depth to bedrock and groundwater flow was lacking for the Adirondack region, so we used surface topography to delineate the potential flow of runoff downslope of paved roads. We used ArcGIS - ArcMap 10.2 (Esri, Redlands, CA) with a hydrologic terrain analysis toolset TauDEM 5.1.1 (TauDEM Toolbox 5.1.1, www.hydrology.usu.edu/taudem) to develop a series of parameters: a hydrologically relevant surface based on the D-infinity flow direction algorithm (Tarboton 1997), indicator grids of rasterized road networks, effective precipitation weights, and decay multipliers (Fig. 2). TauDEM 5.1.1's "D-Infinity concentration limited accumulation" tool used these parameters to delineate flow downslope of the rasterized road networks. We then used a series of ArcGIS processes to quantify the total land area represented by the downslope accumulations, as well as to identify the hydrologically connected water bodies, and to quantify the length of rivers and streams downstream of road runoff. We used Adirondack Park Agency (APA) land use classification shapefiles to determine the estimated lands and waters impacted by road runoff in the Park's forest preserves. Our methods are briefly described here, a more detailed description is provided in the Appendix.

Producing a hydrologically relevant surface

We obtained 202 USGS 10 m New York State 7.5-min Digital Elevation Models (DEMs) from the Cornell University Geospatial Information Repository (cugir.mannlib.cornell.edu). These DEMs were mosaicked; then, sinks were removed by raising their elevation to the lowest pour point using the TauDEM

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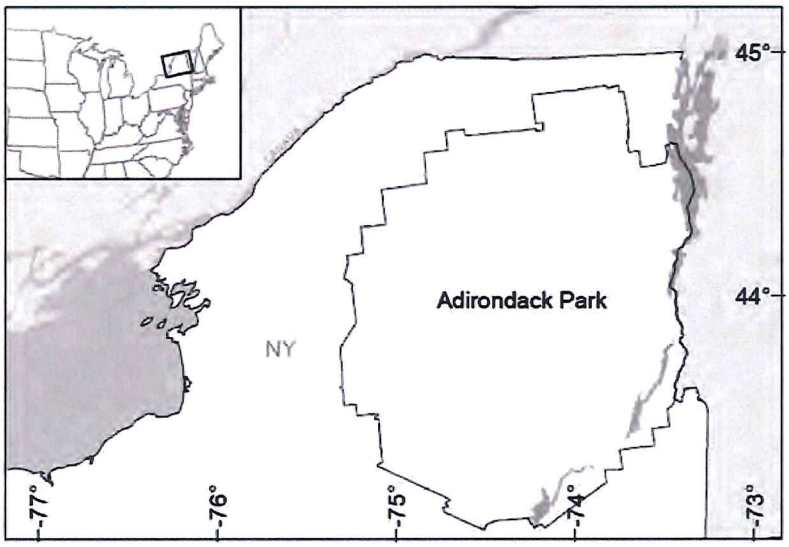

Fig. 1 Location of Adirondack Park in New York State, USA

5.1.1 Pit Remove tool (TauDEM Toolbox 5.1.1, www.hydrology.usu.edu/taudem). Pits often occur due to deficiencies in DEM production (Jenson and Domingue 1988). A D-infinity flow direction grid was derived from the pit removed DEM using the TauDEM D-infinity flow direction algorithm (Tarboton 1997).

Producing road disturbance grids

Road disturbance grids indicate the spatial location of road runoff inputs in the flow delineation process. Road polyline shapefiles were created by extracting road polylines from NYSDOT Local Highway Inventory datasets by three separate road categories: state and federal (SF), county (C), and local (L) roads (apa.ny.gov/gis). The ESRI "buffer" tool was used to create 100 m road spray influence shapefiles for each category, including a combined dataset of all paved roads (SFCL). The buffer added 100 m to each side of the road. These eight shapefiles (SF, C, L, and SFCL and 100 m SF, 100 m C, 100 m L, and 100 m SFCL) were converted into 10 m cell size raster datasets using the ESRI "polyline to new raster" tool and the "polygon to new raster" tool. Field experiments have shown vehicular spray, and wind can transport pollutants hundreds of meters from the road (e.g., Zechmeister et al. 2005; Bernhardt-Roemermann et al. 2006), so the 100 m buffer was selected as a conservative estimate of road spray.

Table 1 Total road length by category, total area of surface water, and total length of streams in the Adirondack Park, New York

Landscape parameter	Total park
State and federal roads (km)	1965
County roads (km)	1803
Local roads (km)	4421
Surface water (ha)	102,792
Stream length (km)	13,153

Producing input weights

An effective runoff grid and a first-order decay multiplier grid were required model parameters. Effective runoff grids represent the precipitation over an area. For simple contributing area delineations such as this, the weighting field was a constant raster set to 1 (Tarboton et al. 2009). The decay multiplier grid value was an exponential decay factor. The decay factor for road runoff was set to a constant raster of 1; this value was arbitrary for we were only interested in the spatial extent of runoff, not any quantitative accumulation values.

Delineating overland flow grids

TauDEM's "D-Infinity concentration limited accumulation" tool was used to delineate substance accumulation downhill of the eight disturbance indicator grids, SF, C, L, and SFCL and the 100 m buffered SF, C, L, and SFCL.

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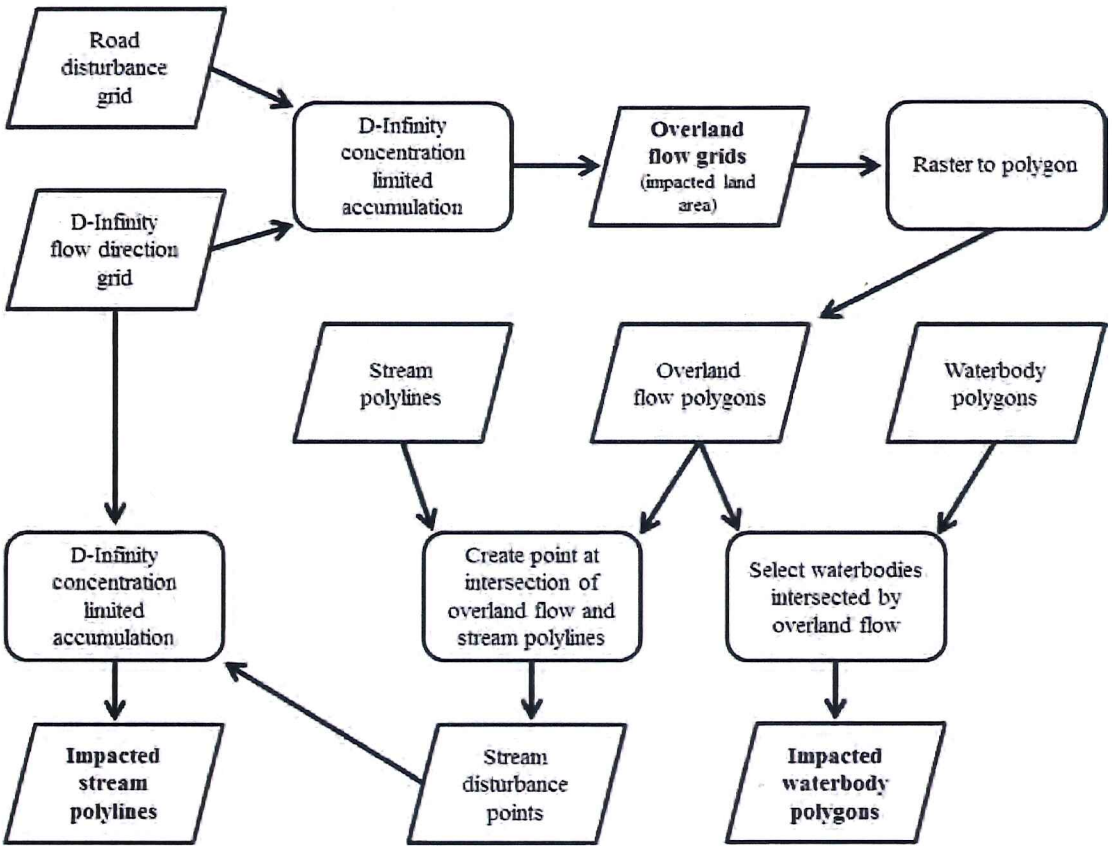

Fig. 2 Flow chart of TauDEM hydrologic modeling and ArcGIS processes used to delineate surface flow downslope of paved roads and to estimate the land area, surface water area, and total stream length impacted by road runoff from paved roads

Quantifying impacted land area

Cells with a value greater than zero represented overland flow. The >0 cells were extracted using the ArcGIS "extract by attribute" tool. To exclude overland flow cells that traversed open water areas, extracted cells were multiplied by a park wide open water raster dataset (cell values: open water=NoData, land=1) using the ArcGIS "times" tool.

Identifying simultaneous impacts of multiple road categories

Lands impacted by multiple road sources were found by multiplying the overland flow rasters by category using the ArcGIS "times" tool (SF×C, SF×L, SF×C×L, et cetera). Lands not impacted by the multiple roads in question resulted in a NoData output value.

Identifying impacted lakes and ponds

The original eight overland flow grid outputs (those without open water cells removed) were converted to polygons using the ArcGIS "raster to polygon" tool. ArcGIS's "select by location" tool was used to select lakes and ponds from the NYS area hydrography shapefile that intersected with the overland flow polygons. Intersected lakes and ponds were extracted according to the road category they intersected with. These intersected lakes and ponds were hydrologically connected to road runoff based upon the DEM-derived flow direction.

Calculating downstream length of impacted streams

The converted polygons of the eight overland flow categories were intersected with linear hydrography polylines from a NYS hydrography dataset of rivers and streams (gis.ny.gov) using the ArcGIS "intersect"

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tool. Point shapefiles were created and then converted to raster datasets using the ArcGIS "point to raster" tool and were treated as disturbance indicator grid parameters for the TauDEM "concentration limited accumulation" tool. The eight subsequent flow grids were then converted to polylines. The eight polylines shape files (SF, C, L, and SFCL and 100 m SF, C, L, and SFCL impacted streams) represented impacted stream channels.

Quantifying impacted lands and waters in APA forest preserve lands

The ArcGIS "zonal statistics as table" tool was used to categorize total impacted terrestrial area for each of the 15 APA land use types in the Adirondack Park Land Use and Development Plan dataset (apa.ny.gov/gis).

Results

A total of 156,561 ha of land area was estimated to be impacted by road runoff, which constituted 6.5 % of the land area of the Park (Table 2). Of this total, runoff from state and federal roads was estimated to impact 36,991 ha of land area, while runoff from county and local roads was estimated to impact 44,182 and 96,550 ha of land area, respectively. The total land area estimated to be impacted by road runoff increased to 254,224 ha when including the 100 m buffer on all roads, which constituted 11 % of the land area of the Park. The relative contribution to impacted land area from state and federal, county, and local roads was the same with and without the 100 m buffer and was proportionate to the length of each road type in the Park (e.g., local roads represented 54 % of total road length and 61 % of the impacted land area). An example of the relationship between the three road types and land area impacted by road runoff is provided for a 5000-ha area in the vicinity of the Village of Saranac Lake within the Park (Fig. 3). In this example, runoff from state and federal roads impacted 6 % of the land area (Fig. 3a), runoff from county roads impacted 5 % of the land area (Fig. 3b), runoff from local roads impacted 11 % of the land area (Fig. 3c), and all three road types together impacted 18 % of the land area (Fig. 3d). The close association between the road network and impacted land and surface waters is also clearly seen.

We found a total of 1787 ha of land to be impacted by state, federal, county, and local roads simultaneously (Table 3). This value increased to 4042 ha when including the 100 m buffer. State, federal, and county roads simultaneously impacted 3255 ha without the buffer and 6980 ha with the buffer. State, federal, and local roads simultaneously impacted 8378 ha without the buffer and 19,009 ha with the buffer. County and local roads simultaneously impacted 11,228 ha without the buffer and 20,837 ha with the buffer.

A total of 77,860 ha of surface waters was estimated to be impacted by road runoff, which constituted 76 % of the surface water area of the Park (Table 2, Fig. 4d). Note that two large lakes, Great Sacandaga Reservoir and Lake George, constitute 26 % of this total. Including all lakes, runoff from state and federal roads was

Table 2 Land and surface water area, number of lakes, and stream length impacted by surface runoff from paved roads with and without a 100 m buffer in the Adirondack Park, New York

Landscape parameter	Road category			Total[a]
	State and federal	County	Local	
Land area (ha)	36,991	44,182	96,550	156,561
Land area (ha) (100 m)	63,018	71,291	164,823	254,224
Surface water area (ha)	62,656	62,218	72,982	77,860
Surface water area (ha) (100 m)	62,852	62,656	73,777	78,792
Number of lakes	326	299	644	820
Number of lakes (100 m)	351	328	711	884
Stream length (km)	2795	2859	4915	5934
Stream length (km) (100 m)	3238	2976	5230	6830

[a] Total is not the sum of the land and water impact of each road category as it includes land and water values with overlap

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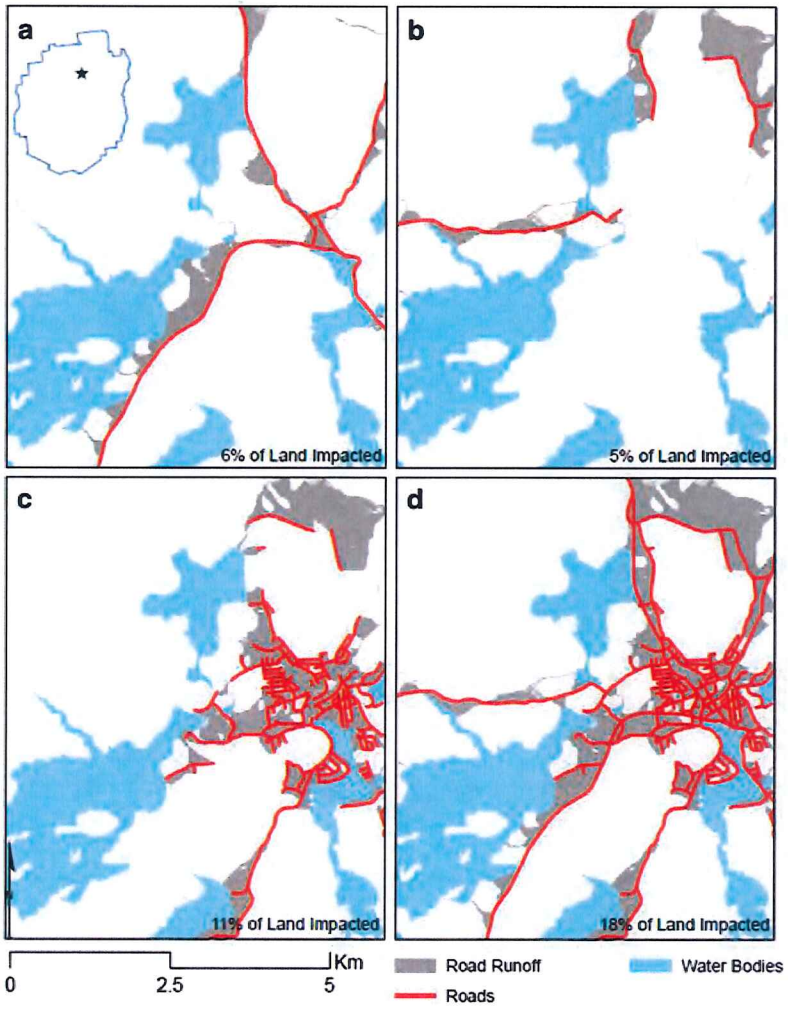

Fig. 3 Estimated land area impacted by road runoff from state and federal (**a**), county (**b**), local (**c**), and the total paved road networks (**d**) in a 5000-ha area centrally located within the Adirondack Park, New York. Location is indicated by the star symbol on map inserted into Fig. 3a

estimated to impact 62,656 ha (61 %, Fig. 4a) of surface water area, while runoff from county and local roads was estimated to impact 62,218 ha (61 %, Fig. 4b) and 72,982 ha (71 %, Fig. 4c) of surface water area, respectively. The total surface water area estimated to be impacted by road runoff increased slightly to

Table 3 Land and surface water area, number of lakes, and stream length impacted by surface runoff from multiple road categories with and without a 100 m buffer in the Adirondack Park, New York

Landscape parameter	Multiple road categories			
	State, federal, and county	State, federal, and local	County and local	State, federal, county, and local
Land area (ha)	3255	8378	11,228	1787
Land area (ha) (100 m)	6980	19,009	20,837	4042
Surface water area (ha)	61,503	63,217	63,268	59,893
Surface water area (ha) (100 m)	62,279	63,601	64,915	60,633
Number of lakes	207	287	269	184
Number of lakes (100 m)	216	312	291	194
Stream length (km)	1005	1295	2056	922
Stream length (km) (100 m)	1305	1731	2442	1222

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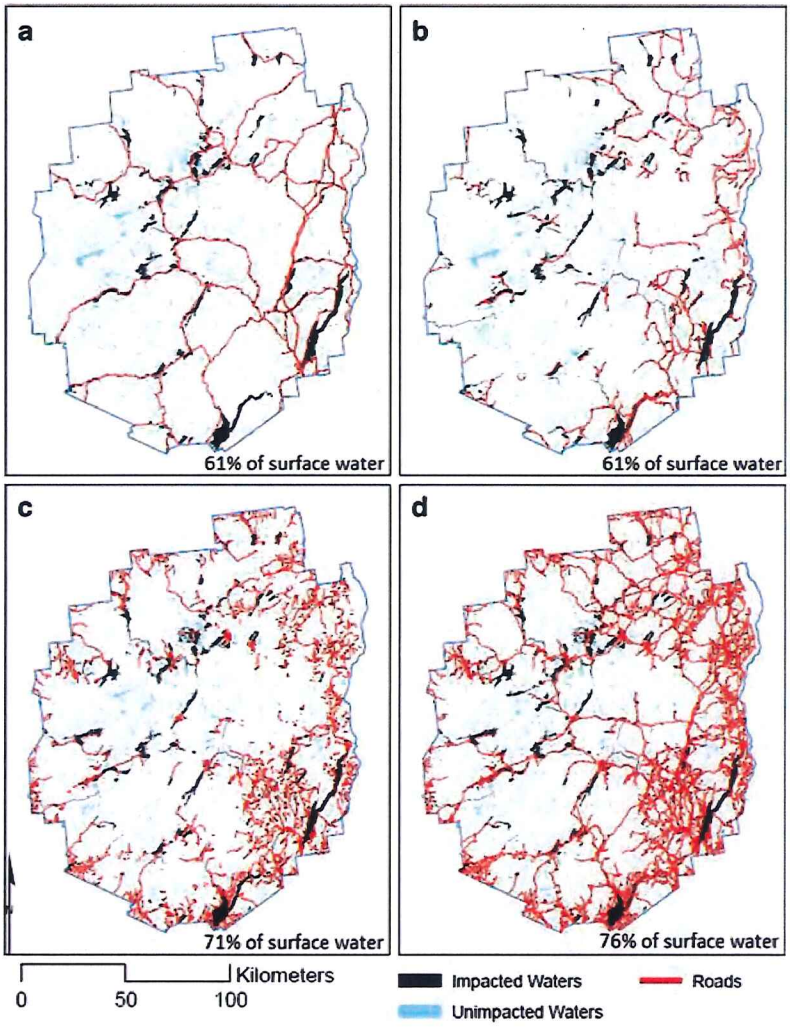

Fig. 4 Estimated surface waters impacted by road runoff from state and federal (**a**), county (**b**), local (**c**), and the total paved road networks (**d**) within the Adirondack Park, New York

78,792 ha when including the 100 m buffer on all roads, which constituted 77 % of the surface water area of the Park. There were a total of 820 waters impacted by road runoff, with 326 waters impacted by state and federal roads, 299 waters impacted by county roads, and 644 waters impacted by local roads (Table 2). The relative contribution to impacted surface water area from state and federal, county, and local roads was the same with and without the 100 m buffer.

We found a total of 59,893 ha of surface water area to be impacted by the four road types (state, federal, county, and local roads) simultaneously, with this value increasing slightly when including the 100 m buffer (Table 3). The other multiple road categories had similar areas of surface waters impacted. The four road types impacted 184 lakes and 922 km of stream length simultaneously, with these values increasing to 194 lakes and 1222 km of stream length when including the 100 m buffer. The number of lakes and stream length impacted by the other multiple road categories was more variable compared to surface water area; for example, county and local roads simultaneously impacted over twice the stream length (2056 km) compared to the four road types together (922 km).

A total of 5934 km of stream length was estimated to be impacted by road runoff, which constituted 45 % of stream length in the Park (Table 2, Fig. 5d). Of this total, runoff from state and federal roads was estimated to impact 2795 km (21 %, Fig. 5a) of stream length, while runoff from county and local roads was estimated to impact 2859 km (22 %, Fig. 5b) and 4915 km (37 %, Fig. 5c) of stream length, respectively. The total stream length estimated to be impacted by road runoff increased to 6830 km (a 15 % increase) when including the

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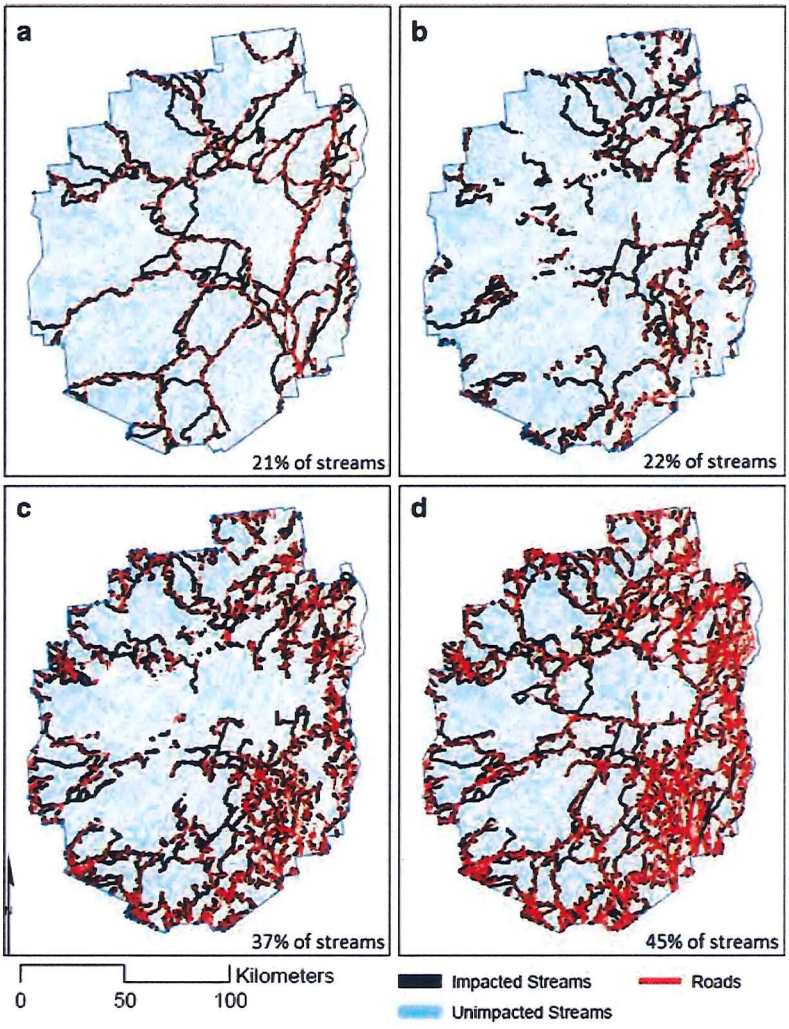

Fig. 5 Estimated streams impacted by road runoff from state and federal (**a**), county (**b**), local (**c**), and the total paved road networks (**d**) within the Adirondack Park, New York

100 m buffer on all roads, which constituted 52 % of stream length the Park.

Of the total 156,561 ha of land area estimated to be impacted by road runoff, 20,474 ha (13 %) was in the forest preserve, including the 100 m buffer which increased the impacted land area to 34,889 ha (Table 4). Of the total 78,153 ha of surface water area estimated to be impacted by road runoff, 67,496 ha (86 %) was in the forest preserve. Of the total 820 lakes estimated to be impacted by road runoff, 334 (40 %) were in the forest preserve. Of the total 5934 km of stream length estimated to be impacted by road runoff, 1152 km (19 %) was in the forest preserve. Within the forest preserve, 12 % of the impacted land area and 26 % of the impacted surface water area were located in lands classified as Wilderness, which are the most protected lands in the Park.

Discussion

Impacted lands and waters

Our results show a high degree of connectivity between paved road networks and lands and waters within the Park. Due to this high connectivity and the basic hydrologic connectivity between water and its watershed (Hynes 1975; Vannote et al. 1980), road runoff pollutants may flow through substantial land and surface water area in the Park. This area may be significantly greater than what we estimated with our 100 m buffer, as field experiments have shown vehicular spray and wind can transport pollutants hundreds of meters from the road (Zechmeister et al. 2005; Bernhardt-Roemermann et al. 2006); thus, our estimates are likely conservative. The results further show that local roads impact substantially more land area than state and federal roads;

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Table 4 Land and surface water area, number of lakes, and stream length impacted by surface runoff from paved roads with and without a 100 m buffer located in state-owned forest preserve lands within the Adirondack Park, New York

Landscape parameter	Road category			Total[a]
	State and federal	County	Local	
Land area (ha)	7118	4490	10,470	20,474
Land area (ha) (100 m)	12,360	7196	18,274	34,889
Surface water area (ha)	58,177	57,163	63,530	67,496
Surface water area (ha) (100 m)	58,306	58,426	64,002	68,216
Number of lakes	157	126	254	334
Number of lakes (100 m)	165	135	272	353
Stream length (km)	454	474	860	1099
Stream length (km) (100 m)	477	447	927	1152

[a]Total is not the sum of the land and water impact of each road category as it includes land and water values with overlap

however, the impact of state and federal roads may be more intense. For example, road salt loading is largest for state and federal roads in the Park (Kelting and Laxson 2010) and the loading of heavy metals and PAH pollutants has been shown to increase with road use intensity, giving evidence to a disproportionate impact of high-use roads (Klimaszewska et al. 2007). The impacts of road runoff may be compounded in areas hydrologically connected to multiple road categories, which represents a challenge to monitoring and management as the road categories are managed in different ways. While state and federal roads are all salted, county, town, and local roads in the Park receive a variety of winter road management treatments from salting to just plowing (Kelting et al. 2012). Modeling flow downslope of high-use roads will identify high-risk land areas for effective monitoring regimes.

A substantial area of land downslope of roads may be at risk from decreasing soil fertility and increasing toxins. Road salt (NaCl) is widely used on roads throughout the region for snow and ice control, for example the New York State Department of Transportation applies 28 t of road salt per kilometer of state and federal road annually (NYSDOT 2006). Increased Na concentrations in road runoff have similar base cation depleting effects as acid deposition (Norrström and Bergstedt 2001) and may become a more relevant stressor as public policy has greatly reduced levels of acid deposition in the northeast (Waller et al. 2012). Given that 67,496 ha of land may be impacted by runoff from 1965 km of state and federal roads, we can assume that this land area is at risk of base cation depletion and may also be experiencing the toxic effects of other associated road pollutants such as heavy metals and PAHs. Road salt discharge compounded by the northeasterly gradient of acid deposition in the Park (Ito et al. 2002) can also have implications for soil fertility (Gałuszka et al. 2011), tree physiology (Fan et al. 2014), and forest community dynamics (McEathron et al. 2013).

Aquatic ecosystems and groundwater resources hydrologically connected to paved roads may also be at risk from the toxic effects of road runoff pollutants. Regional salinization of lakes in the Park has already been documented by Kelting et al. (2012), who found state and federal road densities explained 86 % of the variation in both Na and Cl concentrations in lakes. Similar relationships between road density and salt concentration in surface waters were reported for studies in New Hampshire (Daley et al. 2009) and Rhode Island (Nimiroski and Waldron 2002). Now, through this new work, we have estimated that 76 % of surface water area and at least 45 % of stream length (dependent on buffer width) in the Park may be receiving road runoff pollutants such as salt. Salt is one of the most widely studied road runoff pollutants, and the effects of salinization on freshwater ecosystems are well documented; for example, studies have reported reduced aeration and water circulation at depth (Fay and Shi 2012), decreased spotted salamander (*Ambystoma maculatum*) and wood frog (*Rana sylvatica*) survival (Karraker et al. 2008), shifts in community structure (Collins and Russel 2009), reduced copepod density and changes in algal resources (Meter et al. 2011), and decreased productivity at all trophic levels in model freshwater communities (Dalinsky et al. 2014). A significant amount of road salt also enters groundwater where it can accumulate over years and exceed thresholds for potable water and aquatic organisms (Perera et al. 2012).

Given the large regional extent of road runoff and the potential for negative ecological effects at a large scale,

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the effects of this stressor should be more deliberately evaluated, particularly with its potential to interact with other regional stressors. Road salt, and other runoff pollutants, may confound the recovery of acidified lakes, complicating the assessment of lake management and policies on air pollution (Rosfjord et al. 2007). Jensen et al. (2014) found the biological recovery of an acidified lake receiving road salt discharge lagged behind the biological recovery of a similarly acidified lake not receiving road salt discharge. Thus, the application of road salt may create a mosaic of varying levels of lake recovery from acid deposition in the Park. Additionally, climate change may exacerbate the effects of road runoff pollutants on aquatic ecosystems (Schiedek et al. 2007). Warming spring temperatures break the diapause of aquatic invertebrates (Goddeeris et al. 2001) which corresponds temporally with high stream salt loads in snow melt (Oberts 1994). Also considering that the variability and intensity of spring storms are projected to increase in the northeastern USA (Hayhoe et al. 2007), the likelihood of physiologically active aquatic invertebrates being exposed to road salt discharge and other pollutants must increase (Silver et al. 2009). Our method for identifying areas receiving road runoff is vital to understanding the extent to which these multiple stressors of water quality interact across a large geographic area.

We can conceptualize road runoff from the road network as a geographically extensive stressor with spatially explicit inputs, and from this perspective, the ecological implications of road runoff are largely unknown. Acid deposition and climate change in the northeast are characterized at the regional scale by a smooth distribution of continuous stress inputs over an extensive geographic area, or in other words, the stress inputs of acid deposition and climate change do not vary much from hectare to hectare and thus are monitored at coarse scales (Ito et al. 2002; Hayhoe et al. 2007). Conversely, eutrophication is characterized at the watershed scale by discontinuous, but spatially explicit stress inputs (Agha et al. 2012) and therefore monitored at finer scales. Road runoff shares characteristics of each of the abovementioned stressors. Total runoff from a road network spans the entire region similar to that of acid deposition and climate change, but the stress inputs occur in spatially explicit distributions similar to eutrophication, creating a mosaic of environmental stress defined by topography and road position which is never the same from hectare to hectare.

Application of methods

Our methods create a spatially defined sampling unit that provides the framework for regional monitoring of road runoff as well as provides an estimate of aquatic and terrestrial ecosystems that may benefit from reductions in road salt applications (McDonald 2002; Kilgour et al. 2014). As mentioned above, road runoff pollutants often share similar environmental impacts as other regional stressors and often act synergistically, enhancing their effects on ecosystem function (Palmer and Yan 2013). A solid understanding of the spatial extent of road runoff stress allows researchers to focus regional monitoring efforts as well as develop study designs for experiments investigating the interactions of our significant regional stressors (Fancy et al. 2009).

Our results show that roads are hydrologically connected to a substantial area of land and water in the Park's forest preserve, which includes four categories of land use: wilderness, primitive, canoe, and wild forest. The wilderness category is the most protected land and is managed to protect or restore its natural conditions (apa.ny.gov). Yet, we find that roads connect to over 5000 ha of land and nearly 70 % of surface water in the wilderness category. Road runoff may put at risk substantial forest preserve lands given the multitude of well-studied ecological impacts of runoff pollutants. Our methods may direct management to use alternatives to road salt in these sensitive areas (Jackson and Jobbagy 2005).

There is no New York State-wide monitoring program that chooses monitoring sites based on a single, spatially sound framework. The selection of monitoring sites in the state is predominately based on voluntary cooperation of lake associations (New York DEC 2009). New York State primarily utilizes the Citizen Statewide Lake Assessment Program (CSLAP; www.dec.ny.gov) to produce data for US Environmental Protection Agency Clean Water Act reports. CSLAP monitors sites on the basis of voluntary cooperation of lake associations, although the in-lake sampling protocols used adhere to the literature (Kishbaugh 1988). The New York State Department of Conservation's Rotating Integrated Basin Studies and Lake Classification and Inventory programs monitor specific water bodies, but in a rotation of the State's 17 major basins and the methodologies of choosing sampling sites are based on random and targeted selections, but are not based upon a regional framework and may produce sampling bias

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(New York DEC 2009; Larsen et al. 2007). Few lakes are monitored by CSLAP in the Park, though two other programs monitor the Park's water quality: the Adirondack Lake Assessment Program (www.adkwatershed.org), which monitors lakes based on voluntary cooperation similar to CSLAP, and the Adirondack Long Term Monitoring Program (www.adirondacklakessurvey.org), which monitors only minimally impacted water bodies. Given that road runoff is hydrologically connected to the majority of surface water area in the Park and that road salt represents a major external pollutant load in our region (Kelting and Laxson 2010), our methods may provide a model for a useful study design that can answer real questions regarding statewide water quality.

Efficacy of methods

Subresolution variability is an inherent issue with DEM-based hydrologic modeling (Woods 2006), but for identifying impacted lakes and streams in this study area, the 10 m USGS DEMs are of sufficient resolution to meet this channel-based objective in this topographically variable study area (McMaster 2002). The total impacted area values are more subject to resolution biases. Coarser resolutions produce higher accumulation area values (Yang and Chu 2013), possibly overestimating the area impacted by overland flow. Zhang and Montgomery (1994) analyzed the effects of DEM resolution on geomorphic and hydrologic process in a moderate to steep gradient landscape. They found that 10 m resolution DEMs such as those used in this study should be sufficient to model surface flow processes, while DEMs greater than 30 m resolution produce erroneous estimates of hill slope and runoff processes.

This study quantifies total land area downslope of roads impacted by road runoff, but does not differentiate between surface and subsurface flows within this land area. Surface flow is a combination of direct runoff of salt-laden melt waters through road drainage networks (Labadia and Buttle 1996) and Hortonian flow (de Lima and Singh 2002). Hortonian flow is an important process during spring snow melt when soils are saturated and when frozen soils prevent infiltration of melt waters during thaws (Laudon et al. 2004). Surface flow removes about 50 % of road salt annually, and the remainder accumulates and moves through soils and groundwater as subsurface flow (Meriano et al. 2009), though a greater percentage of road salt may enter subsurface flow in the Adirondacks, as the region is dominated by coarse texture sandy soils with high infiltration rates (Sullivan et al. 2006; Kelting et al. 2012). Groundwater salt concentration increases every year with road salting as only a portion of salt entering in subsurface flow will flush annually (Perera et al. 2012), resulting in higher salt concentrations in streams during summer when biological activity is highest and perhaps most vulnerable to negative effects of salt (Jackson and Jobbagy 2005; Corsi et al. 2015). Given the importance of subsurface flow to road runoff impacts, landscape level modeling estimates would be enhanced by partitioning surface and subsurface flow paths when the additional soil and geologic data necessary to make these estimates exists.

Conclusions

The high degree of hydrologic association between paved roads and the lands and waters of the Park strongly suggests that the environmental impacts of road runoff should be evaluated along with other regional stressors currently being studied. Being able to estimate the spatial extent of road runoff is important for designing monitoring programs that can explicitly monitor this stressor while also providing opportunities to understand the interaction of multiple environmental stressors. Our methods provide an efficient way to estimate the spatial extent of road runoff for large geographic areas.

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Appendix

Methods

Below are detailed instructions that accompany each subsection in "Methods".

Producing a hydrologically relevant surface

The DEMs were mosaicked into a single raster dataset using the ArcGIS data management tool "workspace to new raster dataset." Missing cells within the mosaicked

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dataset were identified using the "Is Null" tool. Identified missing cells were then replaced with interpolated elevation values using a conditional statement in ArcGIS. A low pass filter was used to remove DEM artifacts and noise from the appended DEM (Gesch and Wilson 2001).

Producing road disturbance grids

The eight shapefiles (SF, C, L, and SFCL and 100 m SF, 100 m C, 100 mL, and 100 m SFCL) were converted into 10 m cell size raster datasets using the ArcGIS "polyline to new raster" tool and the "polygon to new raster" tool. The new rasters were reclassified so that roads were set to a value of 1 and non-road cells were set to a value of 0. Reclassification was necessary to create a disturbance grid input parameter for the accumulation tool. The final indicator grids were then converted to TIFF as the accumulation tool requires this file format. The disturbance grid indicates the zone of the area of substance supply (runoff) with 1 representing the zone and 0 representing the rest of the domain.

Producing input weights

The effective runoff and decay multiplier grids were created by reclassifying of one of the disturbance area grids to a constant value of 1.

Delineating overland flow grids

TauDEM's "D-Infinity concentration limited accumulation" functionality applies to a situation where an unlimited supply of a substance is loaded at a constant concentration over the cells of a value of 1 in the disturbance grid. For this paper, road runoff was the substance, and roads were the cells with a value of 1 in the disturbance grid. All inputs were clipped to a standard size to fit the needs of the tool parameters. The outputs were eight overland flow grids representing downhill flow originating from SF, C, L, and SFCL roads. These eight outputs were clipped by the extent of the Adirondack Park boundary polygon (apa.ny.gov/gis) to retain park only overland flow.

Quantifying impacted land area

Multiplying the overland flow dataset by open water cells represented by NoData excluded the original values from the output, and multiplying by 1 retained the original values in the output. The park wide open water raster data was created by clipping a NYS hydrography shapefile of lakes and ponds (gis.ny.gov) to the Adirondack Park boundary shapefile used above and then converting the clipped shapefile into a raster dataset using the ArcGIS "polygon to new raster" tool. The new raster dataset was then reclassified so that open water was represented by NoData and land area represented by a value of 1. The cell counts in the eight no-open-water overland flow grids were found and then multiplied by the cell area (100 m^2) to find the total terrestrial area impacted by road runoff. Values were reported in hectares.

Identifying impacted lakes and ponds

Total surface area (hectares) of these impacted water bodies was calculated using the calculate geometry function.

Calculating downstream length of impacted streams

Point shapefiles were created at their intersections by setting the output type in the "intersect" tool to point. The raster dataset was then reclassified so that cells represent intersection as a value of 1 and non-intersection cells as a value of 0. Input effective runoff and decay grids as well as the original D-Infinity flow direction grid were reused. The eight output flow grids were thinned using the ArcGIS "thin" tool, and flow cells over lakes and ponds were removed. Thinning accumulation rasters efficiently identifies stream channels over large geographic areas (Betz et al. 2010). This approach is aimed at sidestepping the process of using flow accumulation thresholds to identify stream channels across the entire park. We found the intersection of overland flow from roads and linear stream data was sufficient for identifying the presence of a stream. Total lengths (kilometers) of these impacted stream channels were calculated using the calculate geometry function.

Quantifying impacted land and waters in APA forest preserve lands

Forest preserve land is represented by 4 of the 15 land use types, wilderness, primitive, canoe, and wild forest. These four land use types were merged, and impacted surface waters and streams for each of the six

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disturbance categories within the preserve were calculated by ESRI's Select by Location and calculate geometry functions.

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Real-world emissions of in-use off-road vehicles in Mexico

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ABSTRACT

Off-road vehicles used in construction and agricultural activities can contribute substantially to emissions of gaseous pollutants and can be a major source of submicrometer carbonaceous particles in many parts of the world. However, there have been relatively few efforts in quantifying the emission factors (EFs) and for estimating the potential emission reduction benefits using emission control technologies for these vehicles. This study characterized the black carbon (BC) component of particulate matter and NOx, CO, and CO_2 EFs of selected diesel-powered off-road mobile sources in Mexico under real-world operating conditions

using on-board portable emissions measurements systems (PEMS). The vehicles sampled included two backhoes, one tractor, a crane, an excavator, two front loaders, two bulldozers, an air compressor, and a power generator used in the construction and agricultural activities. For a selected number of these vehicles the emissions were further characterized with wall-flow diesel particle filters (DPFs) and partial-flow DPFs (p-DPFs) installed. Fuel-based EFs presented less variability than time-based emission rates, particularly for the BC. Average baseline EFs in working conditions for BC, NOx, and CO ranged from 0.04 to 5.7, from 12.6 to 81.8, and from 7.9 to 285.7 g/kg-fuel, respectively, and a high dependency by operation mode and by vehicle type was observed. Measurement-base frequency distributions of EFs by operation mode are proposed as an alternative method for characterizing the variability of off-road vehicles emissions under real-world conditions. Mass-based reductions for black carbon EFs were substantially large (above 99%) when DPFs were installed and the vehicles were idling, and the reductions were moderate (in the 20–60% range) for p-DPFs in working operating conditions. The observed high variability in measured EFs also indicates the need for detailed vehicle operation data for accurately estimating emissions from off-road vehicles in emissions inventories.

Implications: Measurements of off-road vehicles used in construction and agricultural activities in Mexico using on-board portable emissions measurements systems (PEMS) showed that these vehicles can be major sources of black carbon and NO_X. Emission factors varied significantly under real-world operating conditions, suggesting the need for detailed vehicle operation data for accurately estimating emissions inventories. Tests conducted in a selected number of sampled vehicles indicated that diesel particle filters (DPFs) are an effective technology for control of diesel particulate emissions and can provide potentially large emissions reduction in Mexico if widely implemented.

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June 28, 2018

Via U.S. and Electronic Mail

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Re: Supplemental Environmental Impact Report for Approved Amendments to Title 19-Kern County Zoning Ordinance (2015 C) Focused on Oil and Gas Local Permitting.

Dear Director Oviatt:

This firm represents King & Gardiner Farms, LLC on matters related to the County's amended zoning ordinance for oil and gas permitting. King & Gardiner Farms is concerned with the impacts this new permitting scheme will have on rural communities and agricultural operations throughout Kern County. Our client does not seek to halt oil and gas development, but to ensure that it occurs with proper oversight and in a manner that does not unfairly burden farmers and ranchers.

King & Gardiner Farms is pleased that the Superior Court agreed with one of its central challenges to the County's oil and gas ordinance. The Superior Court found that the County adopted the ordinance without properly analyzing potential adverse impacts on rangeland or determining whether mitigation for rangeland conversions should be required. This is no small omission, as the project area encompasses over 900,000 acres of rangeland where oil and gas development could occur. King & Gardiner Farms hopes that the County will fully analyze potential impacts to rangeland and adopt common-sense protections for this important resource.

Specifically, the Supplemental EIR should include and consider the following information:

- The extent to which oil and gas companies will purchase rangeland in fee, thereby converting entire parcels to other uses.
- Instances in which oil and gas operations on split estates may conflict with ranching operations, and measures to identify and avoid those conflicts for specific permit applications.
- The importance of rangeland in Kern County. Attached are excerpts and reports from our comment letter on the draft EIR highlighting why even relatively minor conversions of rangeland would be significant in Kern County.
- The project-specific and cumulative impacts the project will have on anticipated rangeland conversions in Kern County.
- A determination of whether the project's impacts, including cumulative impacts, will be significant.
- If the project's impact's are significant, an analysis of feasible alternatives and mitigation measures that could lessen or avoid those impacts.

Thank you for taking these comments into consideration.

Very truly yours,

SHUTE, MIHALY & WEINBERGER LLP

Heather M. Minner

Attachment

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ATTACHMENT

occur for the 80,854 acres of Prime and Important Farmland and 55,000 acres of grazing lands forecast to be lost under the Kern County General Plan. The DEIR does not even disclose where these conversions would occur within the three Project Subareas, much less at a level meaningful to local communities.

In addition, as discussed in III.D.4 of this letter regarding the Project's aesthetic impacts, the DEIR fails to consider other relevant plans and projects. For example, it omits any reference to the Tier 5 specific plans, which allow oil and gas development that is not regulated under the project (DEIR at 4.2-14), or to the potential for future wind and solar development.

Nor does the DEIR consider cumulative impacts that will result from the reactivation of idle wells located on Tier 2 lands throughout the County. The DEIR must develop a map showing the location of idle and long-term idle wells and consider the potential reactivation of these wells and construction of associated infrastructure.

Finally, the DEIR must evaluate the tipping point for local agricultural economies and determine whether the projected Farmland conversions will result in a cascading decline of Kern's agricultural economy and a corresponding increase in the conversion of Farmland.

8. The DEIR Fails to Analyze or Mitigate Impacts to Rangeland.

The Project Area contains 982,166 acres of Grazing Land, even more than the 880,326 acres of Farmland within the Project Area. DEIR at 4.2-4. These rangelands are significant contributors to the local economy. Milk was the County's third highest valued agricultural commodity and cattle and calves were the sixth. DEIR at 4.2-2; *see also* Department of Agriculture and Measurement Standards, *2014 Kern County Agricultural Crop Report* (2015), attached as Exhibit Ag 14 (milk and cattle products together accounting for over $1.3 billion in 2014 crop receipts).

Not only is rangeland of special value to Kern County, but California's Legislature has also signaled its broad importance to the state. For example, the Legislature enacted the California Rangeland, Grazing Land, and Grassland Protection Program, whose purpose is to "prevent the conversion of rangeland . . . to nonagricultural uses" and to "protect the long-term sustainability of livestock grazing" through the use of conservation easements. Pub. Res. Code § 10331. In addition to providing water and wildlife benefits, rangeland produces food, medicine and other products, and provides energy savings by producing food and fiber with little expenditure of fossil fuel. U.S.

Department of Agriculture, *RCA Issue Brief #6* (Nov. 1995), attached here as Exhibit Ag 15. It also provides important social and economic benefits. William Wetzel et. al. *Analysis reveals potential rangeland impacts if Williamson Act eliminated,* University of California, 66 California Agriculture 131 (Oct.-Dec. 2012), attached as Exhibit Ag 16.

Remarkably, the DEIR provides no analysis of the Project's potential impact to this important environmental resource. Further, while the DEIR requires a 1:1 mitigation for loss of active Farmlands, it provides no mitigation whatsoever for impacts to rangeland or grazing operations.

a. Rangeland Is an Environmental Resource Under CEQA.

Under CEQA, an EIR must "identify the significant effects on the environment of a project." Pub. Res. Code § 21002.1(a). CEQA defines "environment" broadly to include "the physical conditions which exist within the area which will be affected by a proposed project, including land, air, water, minerals, flora, fauna, noise, objects of historic or aesthetic significance." Pub. Res. Code § 21060.5. Rangeland and grazing cattle are, of course, lands and fauna within this definition.

The County, however, has suggested at public workshops on the DEIR that impacts to rangeland need not be analyzed or mitigated as impacts to agriculture. To be sure, the Legislature placed a special importance on the analysis of agricultural lands when it amended CEQA to ensure that agricultural land conversions are considered in a quantitative manner. Pub. Res. Code §§ 21060.1, 21095. However, there is no evidence that the Legislature intended EIRs to ignore impacts to other agricultural or environmental resources. In fact, CEQA Guidelines Appendix G recognizes that rangelands are important environmental resources by requiring an analysis of whether a project would "conflict with existing zoning for agricultural use, or a Williamson Act contract." Grazing is an agricultural use and one that the Williamson Act seeks to protect.

Indeed, the courts have specifically recognized that EIRs must independently analyze and mitigate for the loss of rangeland and grazing when a project could impact this resource. In *Save Panoche Valley v. San Benito County*, a solar power project was proposed on a 4,885 acre site that was primarily used for cattle grazing. (2013) 217 Cal.App.4th 503, 509. The EIR's agricultural impact analysis for the project calculated the number of grazing animals per acre that the land could support as well as the number of animal unit months (AUM) that the land could support with and without the project. *Id.* at 509, 528-29. It also included mitigation measures to place

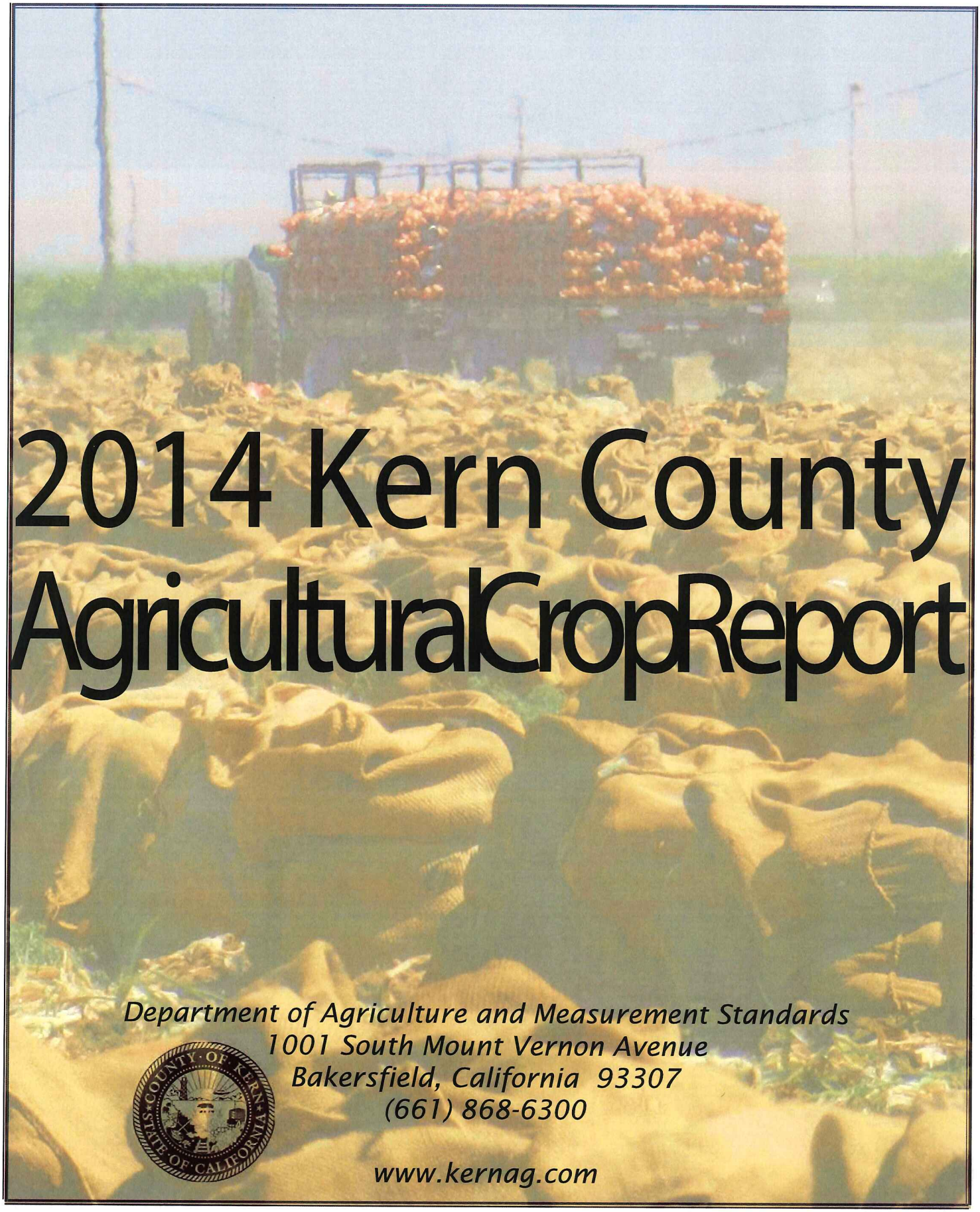
conservation easements on offsite rangeland and to introduce seasonal sheep grazing on project lands that previously supported cattle grazing. The court held that these mitigation measures "adequately addressed the potential impacts on agricultural resources, *including the impact on grazing land.*" *Id.* at 529 (emphasis added). Accordingly, impacts to loss of rangeland and grazing must be analyzed and mitigated under CEQA and in this DEIR.

b. The Project's Impacts to Rangeland and Grazing Are Significant.

Although the DEIR fails to analyze impacts to rangelands, a comparison of the Project Area's rangelands with the Core Areas for future drilling demonstrates that a significant number of new wells will convert rangeland to oil and gas uses. *See* DEIR Figure 4.2-1. These conversions are especially significant given that California is losing rangeland at an alarming rate. Every year, 20,000 acres of rangeland in California are converted to other uses. Pelayo Alvarez, *Conserving and Managing Prairie, Grassland, and Vernal Pool Landscapes Through Collaboration*, 39 Fremontia 49, 51 (2011), attached as Exhibit Ag 17.

Kern County is likely also losing significant amounts of rangeland given the high number of Williamson Act contract cancellations in the County. DEIR at 4.2-6; Exhibit Ag 16. Further, researchers have concluded that as ranchers exit the business, those that remain are negatively impacted because auction yards, where most cattle are sold, require a large volume of activity to operate efficiently. Matt Andersen, *California's cattle and beef industry at the crossroads,* 56 California Agriculture 156 (Sept. – Oct. 2002), attached as Exhibit Ag 18. In addition, the location of these rangelands in Kern County is especially important given their relatively close proximity to California's limited number of slaughter facilities. *Id.* at 153. Their location near significant amount of feed grains also makes these rangelands and especially valuable resource for grazing. *Id.* at 156; DEIR at 4.2-2. Given the importance of rangeland in the region, the DEIR must be revised to disclose and mitigate the Project's significant impact on this environmental resource.

EXHIBIT AG 14



2014 Kern County Agricultural Crop Report

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DEPARTMENT OF AGRICULTURE AND MEASUREMENT STANDARDS

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Agricultural Commissioner
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August 18, 2015

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CALIFORNIA DEPARTMENT OF FOOD AND AGRICULTURE

It is my pleasure to submit the 2014 Kern County Agricultural Crop Report. This annual report presents statistical information on acreage, yield and gross values of Kern County agricultural products in accordance with Sections 2272 and 2279 of the Food and Agricultural Code. The figures in this report represent only gross values and do not take into account the costs of production, marketing, transportation, or other ancillary costs. No attempt is made to reflect net income or loss to the producers of these commodities.

The 2014 gross value of all agricultural commodities produced in Kern County is $7,552,323,690. This represents an increase (12%) from the 2013 crop value ($6,769,855,590).

The top five commodities for 2014 are Grapes, Almonds, Milk, Citrus and Cattle & Calves, which make up more than $5 Billion (66%) of the Total Value; with the top twenty commodities making up more than 78% of the Total Value.

The 2014 Kern County Crop Report can be found on the Department of Agriculture and Measurement Standards website: www.kernag.com

I would like to thank all the members of the Agriculture and Measurement Standards staff who helped with the compilation and preparation of this report, especially Cerise Montanio, Agricultural Biologist/Inspector, and Glenn Fankhauser, Assistant Director. Most of all, I extend my thanks and appreciation to all of the agricultural producers, contributing organizations and those individuals who provided the necessary information for this report.

Respectfully Submitted,

Ruben J. Arroyo
Agricultural Commissioner/Sealer of Weights and Measures

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Note: Numbers published in this report may not compute exactly due to rounding.
Permanent Acreage may differ from actual Harvested Acreage for some commodities.

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Top 20 Commodities - 2014

	COMMODITY	VALUE	2013 RANKING
1.	Grapes, All	$ 1,718,183,000	1
2.	Almonds, Including By-Products	1,488,182,000	2
3.	Milk, Market & Manufacturing	915,124,000	3
4.	Citrus, Fresh & Processing	892,874,000	4
5.	Cattle & Calves	428,854,000	5
6.	Pistachios	401,049,000	6
7.	Carrots, Fresh & Processing	288,063,000	7
8.	Hay, Alfalfa	227,973,000	8
9.	Cotton, Including Processed Cottonseed	117,568,000	9
10.	Pomegranates, Fresh & Processing	87,313,000	11
11.	Potatoes, Fresh & Processing	84,751,000	10
12.	Apiary Products	83,737,000	15
13.	Tomatoes, Fresh & Processing	81,768,000	17
14.	Silage & Forage	81,334,000	13
15.	Bell Peppers, Fresh & Processing	77,495,000	14
16.	Eggs & Egg Product	62,689,000	18
17.	Nursery, Fruit and Nut Trees & Vines	52,390,000	16
18.	Onions, Fresh & Dehydrator	42,966,000	20
19.	Nursery, Roses	35,391,000	19
20.	Garlic, Fresh & Processing	34,447,000	23

Permanent Acreage - 2014

CROP	YEAR	BEARING	NON-BEARING	TOTAL
Almonds	2014	199,000	9,250	208,250
	2013	147,000	1,595	148,595
Apples	2014	1,515	70	1,585
	2013	1,029	4	1,033
Apricots	2014	188	2	190
	2013	538	0	538
Blueberries	2014	608	404	1,012
	2013	635	338	973
Cherries	2014	5,619	1,539	7,158
	2013	5,662	1,736	7,398
Figs	2014	459	9	468
	2013	454	0	454
Grapefruit	2014	864	33	897
	2013	827	26	853
Grapes, All	2014	106,200	3,470	109,670
	2013	105,000	2,529	107,529
Raisin	2014	16,800	0	16,800
	2013	19,200	218	19,418
Table	2014	61,600	2,210	63,810
	2013	58,600	2,030	60,630
Wine	2014	27,800	1,260	29,060
	2013	27,200	281	27,481
Kiwi	2014	48	0	48
	2013	48	0	48
Lemons	2014	3,290	30	3,320
	2013	3,170	7	3,177
Nectarines	2014	298	3	301
	2013	424	3	427
Olives	2014	688	0	688
	2013	597	37	634

Permanent Acreage - 2014

CROP	YEAR	BEARING	NON-BEARING	TOTAL
Oranges, All	2014	37,080	225	37,305
	2013	35,320	119	35,439
Navels	2014	31,400	139	31,539
	2013	28,800	119	28,919
Valencias	2014	5,680	86	5,766
	2013	6,520	0	6,520
Peaches	2014	835	3	838
	2013	1,110	9	1,119
Pears	2014	35	0	35
	2013	20	0	20
Pecans	2014	578	0	578
	2013	550	0	550
Persimmons	2014	88	205	293
	2013	151	211	362
Pistachios	2014	102,900	5,370	108,270
	2013	76,000	2,560	78,560
Pomegranates	2014	10,788	270	11,058
	2013	13,044	3,151	16,195
Prunes	2014	40	0	40
	2013	40	0	40
Tangerines & Tangelos	2014	23,000	111	23,111
	2013	15,700	24	15,724
Walnuts	2014	794	2	796
	2013	710	39	749
Miscellaneous	a/2014	119	0	119
	b/2013	98	0	98
Totals	**2014**	**495,034**	**20,996**	**516,030**
	2013	**408,127**	**12,388**	**420,515**

Note: Some bearing acres may differ from harvested acres; although fruit-bearing, not always harvested for various reasons.
a/ Includes: Avocado, Jujube, Kumquat, Lime, Plumcot, Pluot and Quince.
b/ Includes: Avocado, Cashew, Chestnut, Jujube, Kumquat, Lime, Plumcot and Pluot.



Fruit & Nut Crops - 2014

CROP	YEAR	HARVESTED ACRES	PRODUCTION PER ACRE	TOTAL PRODUCTION	UNIT	UNIT VALUE	TOTAL VALUE
Almonds	2014	199,000	1.01	a/201,000	Ton	$ 7,120.00	$ 1,432,099,000
	2013	147,000	1.14	a/168,000	Ton	$ 5,490.00	$ 922,672,000
Almond By-Products	2014	---	---	329,000	Ton	170.00	56,083,000
	2013	---	---	325,000	Ton	148.00	48,136,000
Apricots	2014	---	---	---	Ton	---	---
	2013	---	---	---	Ton	---	---
Blueberries	2014	608	7.37	4,480	Ton	5,300.00	23,757,000
	2013	635	6.72	4,270	Ton	4,520.00	19,290,000
Cherries	2014	5,180	0.83	4,300	Ton	6,840.00	29,419,000
	2013	5,540	3.09	17,100	Ton	4,690.00	80,228,000
Citrus, All	2014	64,234	14.79	949,800	Ton	---	892,874,000
	2013	55,017	15.23	837,900	Ton	---	641,691,000
Grapefruit	2014	864	15.39	13,300	Ton	706.00	9,388,000
	2013	827	18.14	15,000	Ton	703.00	10,546,000
Lemons	2014	3,290	10.49	34,500	Ton	1,270.00	43,873,000
	2013	3,170	14.79	46,900	Ton	902.00	42,305,000
Oranges, Navels	2014	31,400	10.25	322,000	Ton	942.00	303,378,000
	2013	28,800	11.18	322,000	Ton	679.00	218,777,000
Oranges, Valencia	2014	5,680	13.38	76,000	Ton	783.00	59,484,000
	2013	6,520	15.95	104,000	Ton	644.00	67,019,000
Tangerine & Tangelo	2014	23,000	10.48	241,000	Ton	1,800.00	441,821,000
	2013	15,700	11.21	176,000	Ton	1,600.00	281,286,000
Processing, All Citrus	2014	---	---	263,000	Ton	133.00	34,930,000
	2013	---	---	174,000	Ton	125.00	21,758,000
Grapes, All	2014	106,200	12.26	1,302,300	Ton	---	1,718,183,000
	2013	105,000	12.87	1,351,300	Ton	---	1,822,092,000
Raisin Variety	b/2014	16,800	14.16	237,900	Ton	---	128,559,000
	b/2013	19,200	13.00	249,600	Ton	---	252,947,000
Fresh Market	2014	---	---	64,400	Ton	1,030.00	66,251,000
	2013	---	---	124,900	Ton	1,700.00	212,404,000
Raisins	c/2014	---	---	29,900	Ton	1,770.00	53,047,000
	c/2013	---	---	13,400	Ton	1,650.00	22,047,000
Processing	2014	---	---	6,300	Ton	435.00	2,741,000
	2013	---	---	11,600	Ton	397.00	4,606,000



Fruit & Nut Crops - 2014

CROP	YEAR	HARVESTED ACRES	PRODUCTION PER ACRE	TOTAL PRODUCTION	UNIT	UNIT VALUE	TOTAL VALUE
Crushed	2014	---	---	34,400	Ton	190.00	6,520,000
	2013	---	---	51,500	Ton	270.00	13,890,000
Table	2014	61,600	12.85	791,400	Ton	---	$ 1,503,844,000
Variety	2013	58,600	13.61	797,700	Ton	---	$ 1,445,006,000
Fresh	2014	---	---	721,000	Ton	$ 2,070.00	1,490,053,000
Market	2013	---	---	719,000	Ton	$ 1,990.00	1,427,237,000
Crushed	2014	---	---	70,400	Ton	196.00	13,791,000
	2013	---	---	78,700	Ton	226.00	17,769,000
Wine	2014	27,800	9.82	273,000	Ton	---	85,780,000
Variety	2013	27,200	11.18	304,000	Ton	---	124,139,000
Crushed	2014	---	---	273,000	Ton	314.00	85,780,000
	2013	---	---	304,000	Ton	408.00	124,139,000
Nectarines	2014	295	9.76	2,880	Ton	1,300.00	3,750,000
	2013	424	8.28	3,510	Ton	1,980.00	6,958,000
Peaches	2014	---	---	---	Ton	---	---
	2013	1,110	12.97	14,400	Ton	1,130.00	16,227,000
Pistachios	2014	102,900	0.78	d/79,900	Ton	5,020.00	401,049,000
	2013	76,000	1.23	d/93,300	Ton	4,160.00	388,189,000
Plums	2014	57	9.30	530	Ton	1,220.00	645,000
	2013	---	---	---	Ton	---	---
Tomatoes,	2014	840	19.17	16,100	Ton	965.00	15,534,000
Fresh	2013	1,310	15.05	19,720	Ton	724.00	14,274,000
Tomatoes,	2014	14,000	52.86	740,000	Ton	89.50	66,234,000
Processed	2013	12,000	46.50	558,000	Ton	73.20	40,841,000
Walnuts	2014	794	1.47	d/1,170	Ton	3,390.00	3,964,000
	2013	710	1.03	d/730	Ton	4,710.00	3,437,000
Miscellaneous	e/2014	16,200	---	95,000	Ton	---	125,622,000
	f/2013	17,400	---	222,000	Ton	---	129,354,000
Totals	**2014**	**510,308**	**---**	**3,726,460**	**Ton**	**---**	**$ 4,769,213,000**
	2013	**422,146**	**---**	**3,615,230**	**Ton**	**---**	**$ 4,133,389,000**

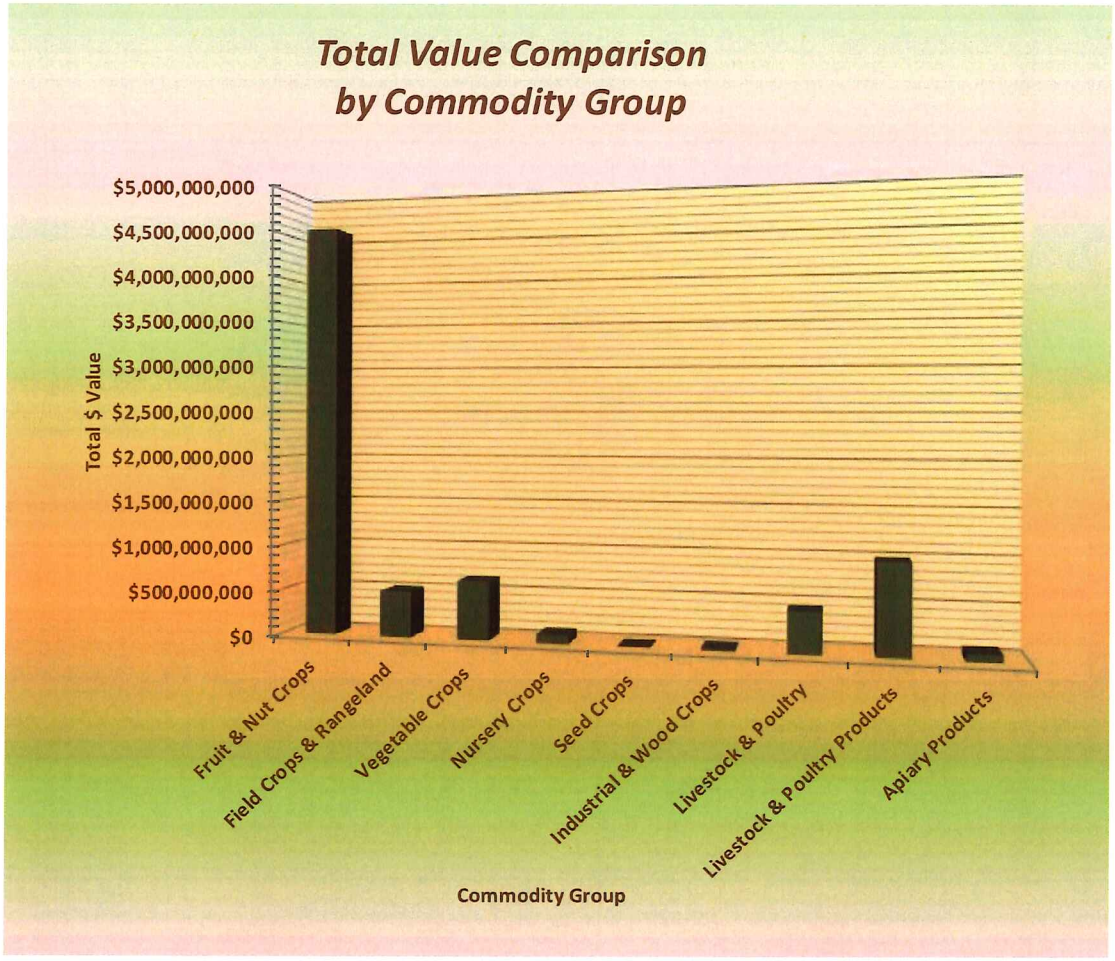
a/ Almond production stated in terms of Nut Meat Equivalents. b/ Total production includes raisins on a Fresh Equivalent basis.
c/ A combined value reflecting free tonnage and reserve tonnage: Dry Ratio: 2014 - 4.44 to 1 2013 - 4.60 to 1
d/ Pistachio and Walnut production stated in terms of In-Shell Equivalents.
e/Includes: Apple (Fresh & Processed), Apricots, Avocado, Blackberry, Blueberry (Processed), Boysenberry, Fig (Fresh & Dry), Jujube, Kiwi, Kumquat, Lime, Olive, Peach (Fresh & Processed), Pear, Pecan, Persimmon, Plumcot, Pluot, Pomegranate (Fresh & Juice), Prune, Raspberry, Strawberry, and Quince,
f/ Includes: Apple (Fresh & Processed), Apricots, Avocado, Blackberry, Blueberry (Processed), Boysenberry, Cashew, Chestnut, Fig (Fresh & Dry), Jujube, Kiwi, Ku,quat, Lime, Olive, Peach (Processed), Pear, Pecan, Persimmon, Plum, Plumcot, Pluot, Pomegranate (Fresh & Juice), Prune, Raspberry, Strawberry, and Quince.



Seed Crops - 2014

CROP	YEAR	HARVESTED ACRES	TOTAL PRODUCTION	UNIT	UNIT VALUE	TOTAL VALUE
Cotton	2014	151	180	Ton	a/$ 339.00	$ 61,000
	2013	771	900	Ton	a/$ 369.00	$ 332,000
Field	b/2014	470	390	Ton	---	264,000
	c/2013	690	380	Ton	---	1,186,000
Vegetable	d/2014	1,030	8,600	Ton	---	6,266,000
	e/2013	860	6,760	Ton	---	3,787,000
Totals	**2014**	**f/1,500**	**9,170**	**Ton**	**---**	**$ 6,591,000**
	2013	**f/1,550**	**8,040**	**Ton**	**---**	**$ 5,305,000**

a/ Includes a per acre approval.
b/ Includes: Alfalfa and Wheat Seed.
c/ Includes: Alfalfa and Wheat Seed.
d/ Includes: Broccoli, Cabbage, Carrot, Lettuce, Onion, and Potato Seed.
e/ Includes: Blackeye, Broccoli, Cabbage, Carrot, Celery, Lettuce, Melon, Onion, and Potato Seed.
f/ Does not include cotton acreage.





Field Crops - 2014

CROP	YEAR	HARVESTED ACRES	PRODUCTION PER ACRE	TOTAL PRODUCTION	UNIT	UNIT VALUE	TOTAL VALUE
Barley	a/2014	1,470	1.75	2,570	Ton	$ 213.00	$ 547,000
	a/2013	4,450	1.80	8,010	Ton	$ 244.00	$ 1,954,000
Beans, Dry Edible	2014	1,028	1.83	1,880	Ton	1,200.00	2,251,000
	2013	1,841	1.67	3,070	Ton	1,000.00	3,074,000
Cotton Lint, Upland & Acala	2014	4,175	b/1,880	15,700	Bale	d/0.90	7,053,000
	2013	10,435	b/1,560	32,500	Bale	d/0.99	16,143,000
Cotton Lint, Pima	2014	30,260	b/1,640	c/ 99,000	Bale	d/1.67	82,588,000
	2013	35,920	b/1,630	c/117,000	Bale	d/1.68	98,360,000
Cottonseed, Processing	2014	---	---	44,100	Ton	633.00	27,927,000
	2013	---	---	57,500	Ton	557.00	32,034,000
Hay, Alfalfa	2014	109,000	8.46	922,000	Ton	247.00	227,973,000
	2013	116,000	9.03	1,048,000	Ton	208.00	217,964,000
Hay, Grain	2014	9,210	5.19	47,800	Ton	212.00	10,157,000
	2013	17,000	5.53	94,000	Ton	213.00	19,977,000
Hay, Other	2014	7,400	3.41	25,200	Ton	192.00	4,831,000
	2013	7,500	3.40	25,500	Ton	175.00	4,463,000
Pasture, Irrigated	2014	7,000	---	---	Acre	140.00	980,000
	2013	7,000	---	---	Acre	140.00	980,000
Pasture, Other	2014	---	---	---	Acre	---	2,210,000
	2013	---	---	---	Acre	---	1,640,000
Pasture, Range	2014	1,450,000	---	---	Acre	15.00	21,744,000
	2013	1,488,000	---	---	Acre	12.00	17,851,000
Safflower	2014	---	---	---	Ton	---	---
	2013	---	---	---	Ton	---	---
Silage and Forage	2014	85,000	19.20	1,632,000	Ton	49.80	81,334,000
	2013	93,000	17.11	1,591,000	Ton	43.10	68,521,000
Wheat	2014	27,600	3.37	93,000	Ton	281.00	26,143,000
	2013	35,000	2.91	102,000	Ton	280.00	28,519,000
Miscellaneous	e/2014	16,700	---	64,640	Ton	---	11,564,000
	f/2013	11,600	---	45,700	Ton	---	10,885,000
Totals	**2014**	**g/298,843**	---	---	---	---	**$ 507,302,000**
	2013	**g/339,746**	---	---	---	---	**$ 522,365,000**

a/ May contain dryland. b/ Pounds Lint per Acre. c/ 500 Pound Net Weight Bale. d/ Price per Pound.
e/ Includes: Field Corn (Grain), Rape, Rye, Sorghum-Milo, Safflower, Straw, Sugar Cane, and Triticale.
f/ Includes: Field Corn (Grain), Rape, Rye, Sorghum-Milo, Safflower, Straw, Sugar Cane, and Triticale.
g/ Does not include Range acreage.



Vegetable Crops - 2014

CROP	YEAR	HARVESTED ACRES	PRODUCTION PER ACRE	TOTAL PRODUCTION	UNIT	UNIT VALUE	TOTAL VALUE
Cantaloupe	2014	---	---	---	Ton	$ ---	$ ---
	2013	560	13.39	7,500	Ton	$ 353.00	$ 2,651,000
Garlic, Fresh	2014	2,610	8.24	21,500	Ton	1,350.00	29,047,000
	2013	2,220	8.02	17,800	Ton	1,210.00	21,462,000
Garlic, Processed	2014	1,000	8.06	8,060	Ton	670.00	5,400,000
	2013	540	7.24	3,910	Ton	640.00	2,502,000
Lettuce, Head	2014	320	16.66	5,330	Ton	694.00	3,701,000
	2013	---	---	---	Ton	---	---
Onions, Fresh	2014	4,220	22.01	92,900	Ton	246.00	22,860,000
	2013	4,260	20.00	85,200	Ton	264.00	22,496,000
Onions, Dehydrator	2014	3,650	20.55	75,000	Ton	268.00	20,106,000
	2013	3,400	20.47	69,600	Ton	182.00	12,660,000
Peppers, Bell Fresh	2014	2,200	21.68	47,700	Ton	1,620.00	77,493,000
	2013	2,650	17.70	46,900	Ton	1,240.00	58,229,000
Potatoes, All	2014	13,470	27.71	373,260	Ton	---	84,751,000
	2013	12,800	29.80	381,400	Ton	---	109,222,000
Potatoes, Spring	2014	11,710	28.48	333,500	Ton	---	68,521,000
	2013	11,280	31.55	355,900	Ton	---	101,838,000
Fresh Market	2014	---	---	150,000	Ton	256.00	38,367,000
	2013	---	---	180,000	Ton	415.00	74,705,000
Processing	2014	---	---	146,000	Ton	200.00	29,217,000
	2013	---	---	131,000	Ton	200.00	26,145,000
Culls	2014	---	---	37,500	Ton	25.00	937,000
	2013	---	---	44,900	Ton	22.00	988,000
Potatoes, Winter	2014	1,760	22.59	39,760	Ton	---	16,230,000
	2013	1,520	16.78	25,500	Ton	---	7,384,000
Fresh Market	2014	---	---	31,800	Ton	504.00	16,031,000
	2013	---	---	20,400	Ton	356.00	7,257,000
Culls	2014	---	---	7,960	Ton	25.00	199,000
	2013	---	---	5,100	Ton	24.90	127,000
Watermelons, Seeded/Seedless	2014	2,380	28.53	67,900	Ton	292.00	19,824,000
	2013	2,220	29.14	64,700	Ton	380.00	24,606,000
Miscellaneous	a/2014	36,600	---	1,089,000	Ton	---	385,675,000
	b/2013	44,900	---	1,328,000	Ton	---	432,961,000



Vegetable Crops - 2014

	YEAR	HARVESTED ACRES	PRODUCTION PER ACRE	TOTAL PRODUCTION	UNIT	UNIT VALUE	TOTAL VALUE
Totals	**2014**	**66,450**	**---**	**1,780,650**	**Ton**	**---**	**$ 648,857,000**
	2013	**73,550**	**---**	**2,005,010**	**Ton**	**---**	**$ 686,789,000**

a/ Includes: Artichoke, Arugula, Asparagus, Basil, Beans Green & Succulent (Fresh & Processed), Bok Choy, Broccoli, Brussel Sprouts, Butter Lettuce, Cabbage (Fresh & Processed), Cantaloupe, Carrots (Fresh & Processed), Cauliflower, Chard, Celery, Chive, Cilantro, Collard, Corn (Sweet), Cucumber, Daikon, Dandelion Greens, Dill, Eggplant, Fennel, Gai Choy, Gai Lon, Gourd, Green Onions, Kale, Kohlrabi, Leaf Lettuce, Leeks, Melons (Other), Mustard, Napa Cabbage, Okra, Parsley (Fresh & Processed), Parsnip, Peas (Fresh & Processed), Peppers (Chili & Processed), Pumpkin, Radishes, Red Beets, Rhubarb, Romaine Lettuce, Rosemary, Rutabaga, Sage, Spinach, Squash, Sweet Potatoes, Tomatillo, Turnips and Yams.

b/ Includes: Artichoke, Arugula, Asparagus, Basil, Beans Green & Succulent (Fresh & Processed), Bok Choy, Broccoli, Brussel Sprouts, Butter Lettuce, Cabbage (Fresh & Processed), Cactus, Carrots (Fresh & Processed), Cauliflower, Chard, Celeriac, Celery, Chive, Cilantro, Collard, Corn (Sweet), Cucumber, Daikon, Dandelion Greens, Dill, Eggplant, Fennel, Gai Choy, Gai Lon, Gourd, Green Onions, Herbs, Kale, Kohlrabi, Lettuce Head, Leaf Lettuce, Leeks, Melons (Other), Mustard, Napa Cabbage, Okra, Parsley (Fresh & Processed), Parsnip, Peas (Fresh & Processed), Peppers (Chili & Processed), Pumpkin, Radishes, Red Beets, Romaine Lettuce, Rosemary, Rutabaga, Sage, Shallots, Spinach, Squash, Sweet Potatoes, Tarragon, Thyme, Tomatillo, Turnips and Yams.

Kern County Certified Farmers' Markets

LOCATION	SEASON	DAY	TIME
Brimhall Farmers' Market *NE Corner of Brimhall & Calloway, 9500 Brimhall Rd.*	Year Round	Saturday	9am - 1pm
Clinica Sierra Vista/Delano *Community Health Center, 1508 Garces Hwy.*	May through November	Wednesday	3pm - 5pm
Clinica Sierra Vista/East Bakersfield *Community Health Center, 815 Dr. Martin Luther King Jr. Blvd.*	May through November	Thursday	10am - 12pm
Clinica Sierra Vista/Lamont *Community Health Center, 8787 Hall Rd*	May through November	Tuesday	3pm - 5pm
From the Farmhouse Shafter *James & Central, 320 Central Ave.*	June through August	Wednesday	8:30am - 1pm
Haggin Oaks Farmers' Market *Corner of Ming & Haggin Oaks, 8800 Ming Ave.*	Year Round	Sunday	9am - 2pm
Lakeshore Farmers' Market *Lakeshore Lodge, 7644 Wofford Heights Blvd.*	Year Round	Saturday	9am - 1pm
Main Street Farmers' Market Tehachapi *Rail Road Park, Tehachapi Blvd.*	June through August	Thursday	4pm - 7pm
Oildale Farmers' Market *North High School, 300 Galaxy Rd.*	June through September	Thursday	5pm - 8pm
Paramount Produce Day *Lost Hills Recreation Center, Lost Hills Rd. & Hwy 46*	Year Round	Friday	4pm - 7pm
Sports Authority Bakersfield *Ming & New Stine, 4821 Ming Ave.*	January through December	Saturday	9am - 2pm
Valley Farmers' Market Bakersfield *Golden State Hwy. & F St.*	Year Round	Saturday	8am - 12pm



Nursery Crops - 2014

CROP	YEAR	HARVESTED ACRES	TOTAL PRODUCTION	UNIT	UNIT VALUE	TOTAL VALUE
Christmas Trees	2014	---	130	Tree	---	$ 6,690
	2013	---	200	Tree	---	$ 8,590
Fruit and Nut Trees & Vines	a/2014	1,600	15,553,000	Plant	---	52,390,000
	a/2013	683	25,795,000	Plant	---	56,056,000
Herbaceous Plants	2014	---	---	---	---	1,044,000
	2013	---	---	---	---	933,000
Ornamental Trees & Shrubs	a/b/2014	176	295,000	Plant	---	2,512,000
	a/2013	84	307,000	Plant	---	705,000
Propagative Material	2014	---	---	---	---	2,376,000
	b/2013	---	---	---	---	8,215,000
Roses	2014	1,580	18,812,000	Plant	$ 1.88	35,391,000
	2013	1,320	21,379,000	Plant	$ 2.13	45,353,000
Turf	2014	---	---	Sq Ft	---	---
	2013	---	---	Sq Ft	---	---
Totals	**2014**	**3,356**	---	---	---	**$ 93,719,690**
	2013	**2,087**	---	---	---	**$ 111,270,590**

a/ Includes container grown plants.
b/ Includes turf, due to disclosure rules.

Industrial & Wood Crops - 2014

CROP	YEAR	TOTAL PRODUCTION	UNIT	UNIT VALUE	TOTAL VALUE
Almond Shells	2014	214,000	Ton	---	$ 12,954,000
	2013	189,000	Ton	---	$ 9,700,000
Biomass & Composting	2014	227,000	Ton	---	4,977,000
	2013	185,000	Ton	---	3,888,000
Timber	a/2014	1,432	Brd Ft	---	167,000
	a/2013	2,655	Brd Ft	---	187,000
Wood for Fuel	2014	1,914	Cord	b/$ 209.00	400,000
	2013	1,357	Cord	b/$ 295.00	401,000
Totals	**2014**	---	---	---	**$ 18,498,000**
	2013	---	---	---	**$ 14,176,000**

a/ Production and value based on information provided by: Timber Tax Division, Property Tax Department, State Board of Equalization.
b/ Price includes U.S. Forest Service Permits for woodcutting.



Livestock & Poultry - 2014

COMMODITY	YEAR	NUMBER OF HEAD	TOTAL LIVEWEIGHT	UNIT	UNIT VALUE	TOTAL VALUE
Cattle & Calves	2014	329,000	---	Head	$ 1,300.00	$ 428,854,000
	2013	341,000	---	Head	$ 1,200.00	$ 408,897,000
Sheep & Lambs	2014	91,000	90,000	Cwt	150.00	13,500,000
	2013	95,000	90,000	Cwt	100.00	9,000,000
Hogs	2014	1,885	4,650	Cwt	76.60	356,000
	2013	1,756	4,300	Cwt	73.50	316,000
Ostriches	2014	175	---	---	---	313,000
	2013	212	---	---	---	494,000
Miscellaneous	a/2014	---	---	---	---	627,000
	a/2013	---	---	---	---	219,000
Totals	**2014**	**---**	**---**	**---**	**---**	**$ 443,650,000**
	2013	**---**	**---**	**---**	**---**	**$ 418,926,000**

a/ Includes: Game Birds for Meat, Registered Freshwater Aquaculturists and Other.

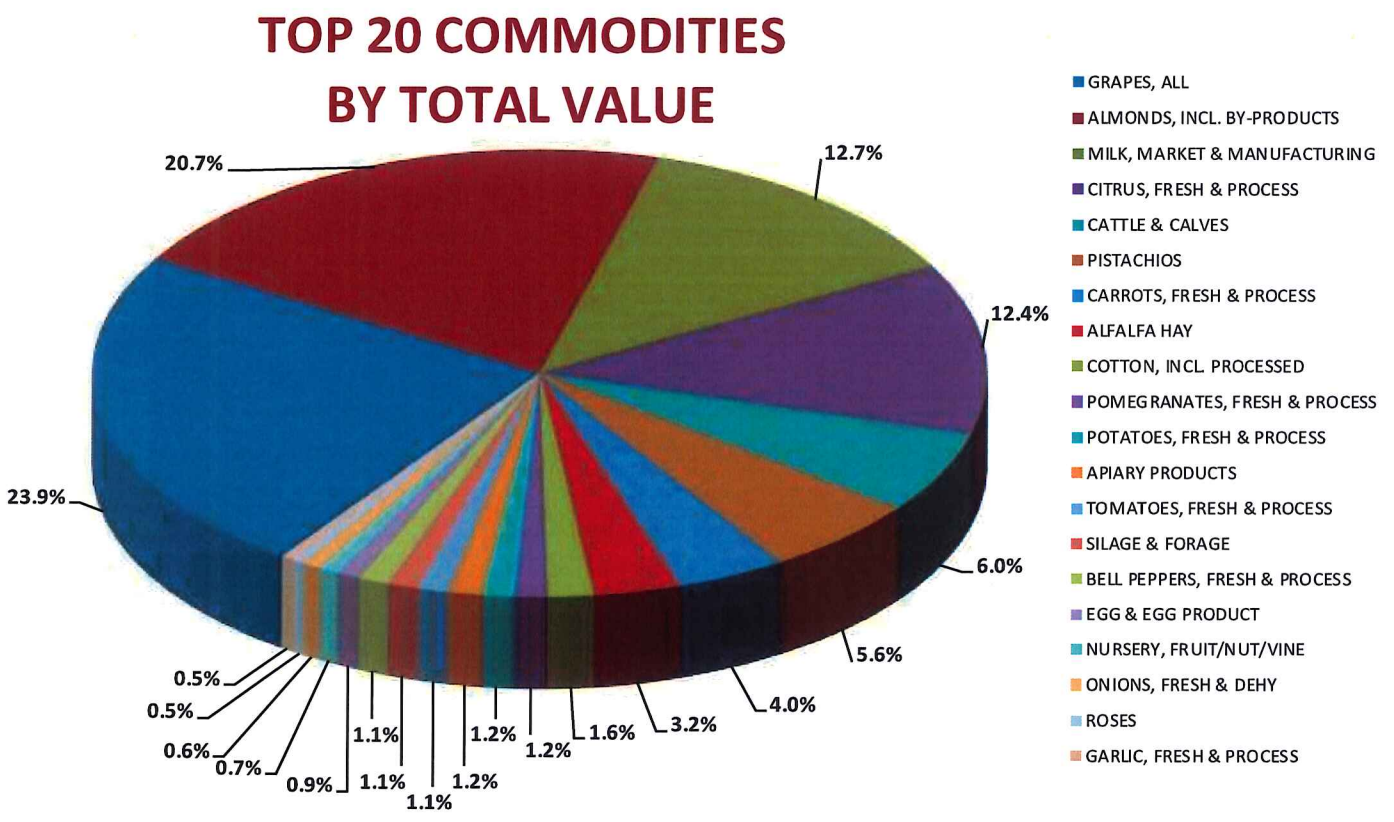
Livestock & Poultry Products - 2014

PRODUCT	YEAR	TOTAL PRODUCTION	UNIT	UNIT VALUE	TOTAL VALUE
Milk, Market	2014	40,937,000	Cwt	$ 22.30	$ 914,538,000
	2013	40,644,000	Cwt	$ 18.80	$ 764,518,000
Milk, Manufacturing	2014	24,400	Cwt	24.00	586,000
	2013	11,500	Cwt	18.30	210,000
Manure	2014	745,000	Ton	---	1,930,000
	2013	745,000	Ton	---	2,009,000
Wool	2014	675,000	Lb.	1.50	1,013,000
	2013	750,000	Lb.	1.45	1,088,000
Eggs & Egg Product	2014	---	---	---	62,689,000
	2013	---	---	---	52,055,000
Totals	**2014**	**---**	**---**	**---**	**$ 980,756,000**
	2013	**---**	**---**	**---**	**$ 819,880,000**



Apiary Products - 2014

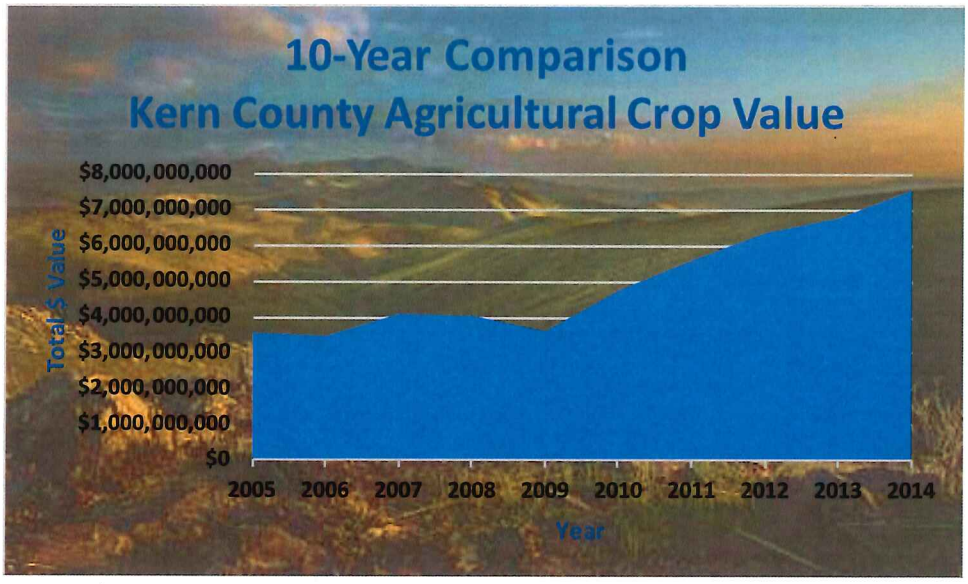
COMMODITY	YEAR	TOTAL PRODUCTION	UNIT	UNIT VALUE	TOTAL VALUE
Honey	2014	3,765,000	Lb	$ 2.03	$ 7,643,000
	2013	2,747,000	Lb	$ 2.10	$ 5,768,000
Beeswax	2014	471,000	Lb	3.50	1,647,000
	2013	343,000	Lb	3.25	1,116,000
Pollination	2014	431,000	Colony	173.00	74,447,000
	2013	332,000	Colony	153.00	50,871,000
Other Apiary Products	2014	---	---	---	---
	2013	---	---	---	---
Totals	**2014**	---	---	---	**$ 83,737,000**
	2013	---	---	---	**$ 57,755,000**





Summary - 2014

COMMODITY	YEAR	HARVESTED ACRES	RANGE	TOTAL VALUE
Fruit & Nut Crops	2014	510,308	---	$ 4,769,213,000
	2013	422,146	---	$ 4,133,389,000
Field Crops & Rangeland	2014	298,843	1,450,000	507,302,000
	2013	339,746	1,488,000	522,365,000
Vegetable Crops	2014	66,450	---	648,857,000
	2013	73,550	---	686,789,000
Nursery Crops	2014	3,356	---	93,719,690
	2013	2,087	---	111,270,590
Industrial & Wood Crops	2014	---	---	18,498,000
	2013	---	---	14,176,000
Seed Crops	2014	1,500	---	6,591,000
	2013	1,550	---	5,305,000
Livestock & Poultry	2014	---	---	443,650,000
	2013	---	---	418,926,000
Livestock & Poultry Products	2014	---	---	980,756,000
	2013	---	---	819,880,000
Apiary Products	2014	---	---	83,737,000
	2013	---	---	57,755,000
Totals	**2014**	**880,457**	**1,450,000**	**$ 7,552,323,690**
	2013	**839,079**	**1,488,000**	**$ 6,769,855,590**
Total Value without Timber	2014			$ 7,552,156,690
	2013			$ 6,769,668,590



Pest Prevention & Control - 2014

PEST EXCLUSION

INSPECTION TYPE	PREMISES VISITED	SHIPMENTS INSPECTED	PESTS A or Q
CA Overnight	192	499	0
U. S. Post Office	26	25	0
UPS	39	123	0
Federal Express	263	3,178	0
Federal Express Ground	1	3	0
Gypsy Moth	12	10	0
Florida/Southern States	5	68	0
Hawaii	14	18	0
Truck	193	288	1
Specialty Market	88	769	0
Beehives	122	9,829	0
Swap Meets	2	10	0

EXPORT TRAPPING

CROP	TRAPS DEPLOYED	COUNTRY	PEST
Apples	94	Various	Apple Maggot (Rhagoletis pomonella)

PEST DETECTION & TRAPPING

TRAP NAME	NUMBER OF TRAPS DEPLOYED
Jackson Trap	
Light Brown Apple Moth (Epiphyas postvittana)	512
Mediterranean Fruit Fly (Ceratitis capitata)	503
Melon Fruit Fly (Bactrocera curcurbitae)	255
Oriental Fruit Fly (Bactrocera dorsalis)	508
McPhail Trap	
Mexican Fruit Fly (Anastrepha ludens)	265
Delta Trap	
Gypsy Moth (Lymantria dispar)	441
Japanese Beetle Trap (Popillia japonica)	415
Trogotrap Khapra Beetle (Trogoderma granarium)	0
European Corn Borer Trap (Ostrinia nubilalis)	27
European Pine Shoot Moth Trap (Rhyacionia buoliana)	6
Glassy-winged Sharpshooter (Homalodisca coagulata)	241
Champ Trap	382
Mexican Fruit Fly (Anastrepha ludens)	
Yellow Panel Trap	
Asian Citrus Psyllid (Diaphorina citri)	2,568
Delta Trap	
European Grapevine Moth (Lobesia botrana)	3,675

Direct Marketing, Organic Farming, Exports & Pests - 2014

DIRECT MARKETING

DIRECT MARKETING PROGRAM

Direct Marketing is a system that allows Certified Producers to market their produce directly to consumers via Certified Farmers Markets. The Department of Agriculture & Measurement Standards regulates this program to insure that only certified produce is sold at Certified Farmers Markets. See a list of current Certified Farmers' Markets on Page 9 of this report.

ORGANIC FARMING

REGISTERED ORGANIC GROWER PROGRAM

Producers and growers who market their produce as "Organic" or "Organically Grown" must be certified by an accredited certifying agency and are required to register their organic fields with the state. The Department of Agriculture & Measurement Standards inspects these fields to insure compliance with applicable laws and regulations.

Registered Growers and Handlers - 52

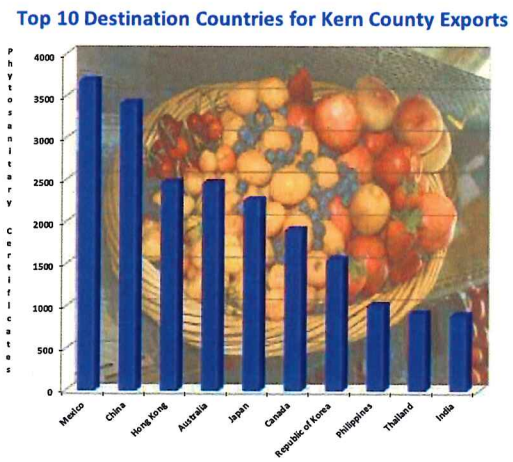
Partial listing of registered crops: Alfalfa, Apples, Broccoli, Carrots, Cotton, Lettuce, Melons (Cantaloupe, Watermelons, etc.), Olives, Onions, Oranges, Potatoes, Raisins, Safflower, Stonefruit, Table Grapes, Tomatoes, and Wheat.

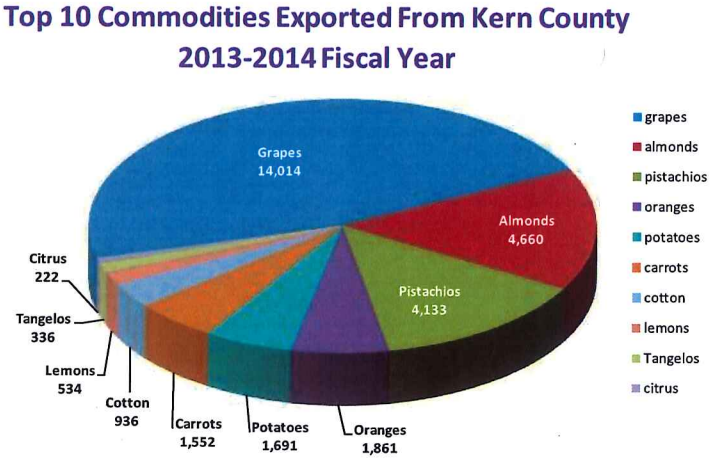
EXPORTS

Phytosanitary Certification is one of the largest programs within the Department of Agriculture. Depending on the agricultural commodity and destination country, Phytosanitary Certification may be required, which attests to the freedom from insects and diseases, by an Accredited Certifying Official (ACO).

Phytosanitary Certificates Issued	20,554

TOP 10 DESTINATION COUNTRIES & PHYTOSANITARY CERTIFICATES ISSUED (listed greatest to least):
Mexico (3,681), China (3,407), Hong Kong (2,466), Australia (2,459), Japan (2,259), Canada (1,908), Republic of Korea (1,557), Philippines (1,013), Thailand (913), and India (891)





TOP COMMODITIES EXPORTED (listed greatest to least):
Grapes, Almonds, Pistachios, Oranges, Potatoes, Carrots, Cotton, Lemon, Tangelos and Other Citrus

PEST ERADICATION

Pink Bollworm Program For Kern County, Cooperative Pink Bollworm Project

Trapping*	0	Natives Detected
Sterile Release*	0	Moths
Plowdown*	34,435	Acres

EXHIBIT AG 15

Grazing Lands

RCA Issue Brief #6 November 1995

Where are the U.S. grazing lands?
How grazing lands have changed
Why are grazing lands important?
Grazing land health
Multiple benefits of grazing lands

Did you know ...

...that nearly half of the lower 48 states is grazing land: range, pasture, hay, and grazed forest?

...that range, pasture, hay, and grazed forest land are located where they are primarily because of climate or topography and by landowners' decisions about land use?

...that properly managed grazing is one of the most energy-efficient ways of producing food and fiber?

...that grazing lands help improve water supplies for residential, commercial, agricultural, and recreational uses?

...that many wildlife species rely on grazing lands for habitat and food?

...that carbon sequestration (absorption of atmospheric carbon by soil and plants) occurs when farmers and ranchers practice good grazing land management? And that carbon sequestration is a key to mitigating climate change?

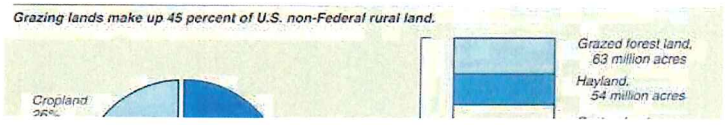
...that grazing lands could be developed by farmers and ranchers as a source of biomass energy and raw materials, which could reduce U.S. reliance on imported products?

Where are the U.S. grazing lands?

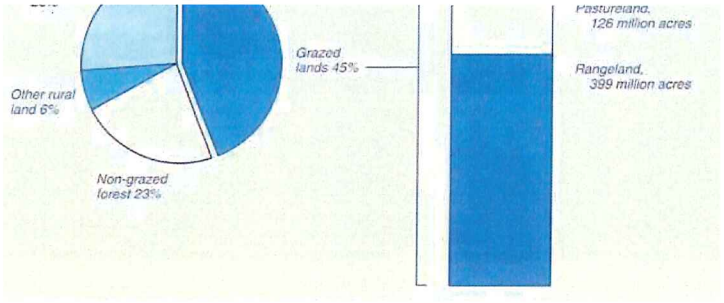
Grazing lands exist in every state, but the amounts and kinds of land and the uses, products, and values from grazing lands vary from state to state. Examples of grazing land include--

annual grasslands of California;
hot deserts in the southwestern states and cold deserts in the Great Basin;
shrub-grasslands throughout the western states;
prairie grasslands of the Great Plains and Corn Belt;
humid grasslands of the eastern United States and Hawaii;
tundra rangelands of Alaska;
improved pasture and hay lands throughout the Intermountain West, Northern Great Plains, Great Lakes, Northeast, and South;
wetlands and riparian areas in every state; and
grazed forests in all states adjacent to and east of the Mississippi River and in the mountain states of the West.

Although some pasture and hay lands are managed as a monoculture, others--particularly rangelands--are complex mixes of species that offer increased plant, animal, and landscape diversity. Many eastern forests used for timber production are also grazed, particularly if the forest land type is suitable for livestock grazing and other forage, such as pasture or hay, is available.



How grazing lands have changed



During the first half of this century, most agricultural operations included both cropland and grazing land. Cattle, sheep, and goats often grazed land that could not or should not have been cultivated or otherwise used intensively. New technology and new marketing opportunities in the 1970's, however, encouraged farmers to plow lands that had not been previously cultivated. The result, in many places, was increased erosion on lands that formerly had been protected by grasses, legumes, and shrubs.

Although some runoff and erosion are natural, accelerated erosion on degraded land reduces the land's production potential and causes offsite damage from sedimentation in streams, rivers, lakes, and reservoirs. Accelerated erosion is a concern not only where grazing lands have been plowed, but also on lands that are grazed improperly. Improper grazing can lead to other detrimental environmental impacts. Twenty-five percent of the Nation's grazing lands need some form of conservation treatment to reduce erosion.

Why are grazing lands important?

Energy savings

Grazing animals eat plants that cannot be digested by humans and many other animals, and have the advantage of producing food and fiber with little expenditure of fossil fuel energy. On properly managed grazing land--including pasture-land and hayland--only 1 calorie of fossil-fuel energy is needed to produce up to 2 calories of food and fiber energy. Many crops require from 5 to 10 calories of fossil-fuel energy for every calorie of food or fiber produced. Improving the efficiency of grazing land production can increase landowners' income, improve environmental quality, and help reduce the Nation's dependence on imported fossil fuel.

Food, medicine, and other products

Grazing by domestic livestock has been the primary use of grazing lands since European settlement and remains one of the most important uses today. Meat, milk, leather, wool, and mohair are well-known products from grazing animals. Less well known are pharmaceuticals produced from nonfood parts of the animals; natural fertilizers from animal bones, blood, and manure; and new and unique uses of familiar products--such as using wool, which readily absorbs oil, to remove spilled oil from soils, streams, lakes, and oceans.

Water storage and release

Vast quantities of rain and snow fall on the Nation's grazing lands. On healthy grazing lands, much of the water infiltrates into the soil and is used for plant growth, is stored in underground aquifers, or flows through the soil, providing water for streamflow, riparian areas, wetlands, and lakes, and sub- sequent use by people and wildlife.

Water quality

Modern grazing land management is one of the most important ways that farmers and ranchers can reduce erosion and water pollution and diversify income. For example, natural drainage areas on farms and the riparian areas adjacent to streams can be planted to grazing land plants. These forage plants capture runoff and sediment from the fields and protect water quality. Where sufficient plant material is left in grassed waterways or stream buffer zones for soil and water conservation purposes, a significant amount of the plant material can be grazed or mechanically harvested. There may also be outdoor recreation income options available--hiking, camping, horseback riding, hunting, and fishing.



Wildlife

Hunting and fishing are important recreational activities, and when many people think of wildlife they think of game species--deer, elk, grouse, or trout. But all wildlife have intrinsic value and are part of the ecological functioning of grazing lands. Everyone enjoys the unexpected view of a white-tailed deer on a pasture or grazed forest in the eastern United States, of an antelope in the Northern Great Plains or the Great Basin, of a pheasant in a grassed waterway in the Corn Belt, of a hawk in the desert Southwest, and of a mule deer on rangelands in any of the western states. People enjoy watching and listening to songbirds, and hearing--maybe seeing--a fish jump in a stream or pond. These experiences are made more enjoyable by the spectacular scenery that is often associated with grazing lands--the mountains of the West, the stark desert landscape of the Southwest, the prairie vistas of the Great Plains, and the green grass of pastures contrasted with the fall color of trees in the East.

Waste utilization

As concentrated animal production facilities--poultry and swine farms, beef feedlots, and confinement dairies--have become more common in a few geographical areas, and cities have begun to run out of landfill space, grazing lands have become attractive and appropriate locations on which to spread organic products and recycle the nutrients they contain. Spreading poultry litter on pasture land in the southern and eastern United States has allowed landowners to improve forage production and develop a more successful beef industry.

When properly applied, manure and other organic by-products can enhance the productivity and soil quality of grazing lands by increasing soil organic-matter content, improving soil moisture-holding capacity, and supplying valuable nutrients. If such by-products are applied to degraded land, or if they are applied in excess of the land's capacity to absorb them, the organic matter and nutrients from them can wash into streams, lakes, and estuaries, causing serious water quality degradation.

Carbon sequestration

Grazing land soils in the Great Plains contain over 40 tons of carbon per acre, while cultivated soils contain only about 26, on average. Carbon dioxide and other greenhouse gases may be increasing in the earth's atmosphere and changing the earth's climate. The grasses, legumes, and shrubs on grazing lands remove carbon dioxide from the air through photo- synthesis and store it in the soil when roots die and decompose. This process promotes the long-term sequestration of carbon as soil organic matter. Cultivated lands planted to grassland plants as part of the Conservation Reserve Program were found to have added an average of 1,000 pounds of carbon per acre per year during the first 5 years after planting. This means that the CRP alone is removing 18 million tons of carbon from the atmosphere each year. This gain in sequestration of atmospheric carbon will continue until the soil reaches its equilibrium level of carbon.

Biomass

Grazing land plants can be harvested as sources for biomass energy or as feed stocks for industrial materials. There is a growing interest in using plant materials for energy because of the United States' dependence on foreign oil and concern about climate change associated with the release of fossil carbon into the atmosphere. Using homegrown plant material for energy would reduce to some extent the amount of oil that is imported. Burning plants for energy releases carbon dioxide into the air, but this carbon is offset by the carbon removed from the atmosphere through photosynthesis. Biomass carbon is, therefore, a renewable and sustainable resource.

Grazing land health

Good grazing land management often leads to a more productive mix of plants. Also, soils are less compacted and more protected from the erosive forces of wind or water, and the self-regenerative capacity of the land is improved. Collectively, this improvement is considered a gain in grazing land health. Loss of grazing land health means that some options for current and future uses of the land have been temporarily or perhaps permanently lost.

What causes loss of grazing land health? The most common reason is overgrazing by domestic and wild animals. Fortunately, grazing lands can be maintained in a healthy state with grazing, and properly managed grazing can enhance ecosystem health. Sheep grazing, for instance, can reduce the dominance of leafy spurge and other noxious weeds on rangelands and thereby promote greater biodiversity. In many parts of the country, livestock--cattle, sheep, and goats--graze in shrub- and forest-dominated ecosystems to remove and prevent the buildup of highly flammable material and reduce the likelihood of wildfire.

Multiple benefits of grazing lands

Healthy grazing lands provide benefits other than feed for domestic animals. They are important habitats for a variety of large and small mammals, birds, and insects. Water runoff on healthy grazing land is slow, so more water infiltrates into the soil, providing cleaner, more abundant water for fish, wildlife, and human use. The plant cover on more than 600 million acres of grazing land sequesters millions of tons of carbon, thus reducing atmospheric carbon dioxide. Many grazing lands are among the Nation's most picturesque landscapes.

Although grazing lands are our biggest agricultural reserve, most of them are not suitable for crops. Nevertheless, some 180 million acres of non-Federal grazing lands--more than one-fourth of all privately owned grazing lands--are in soil capability classes I through III and therefore could be used to produce crops in the future if needed.



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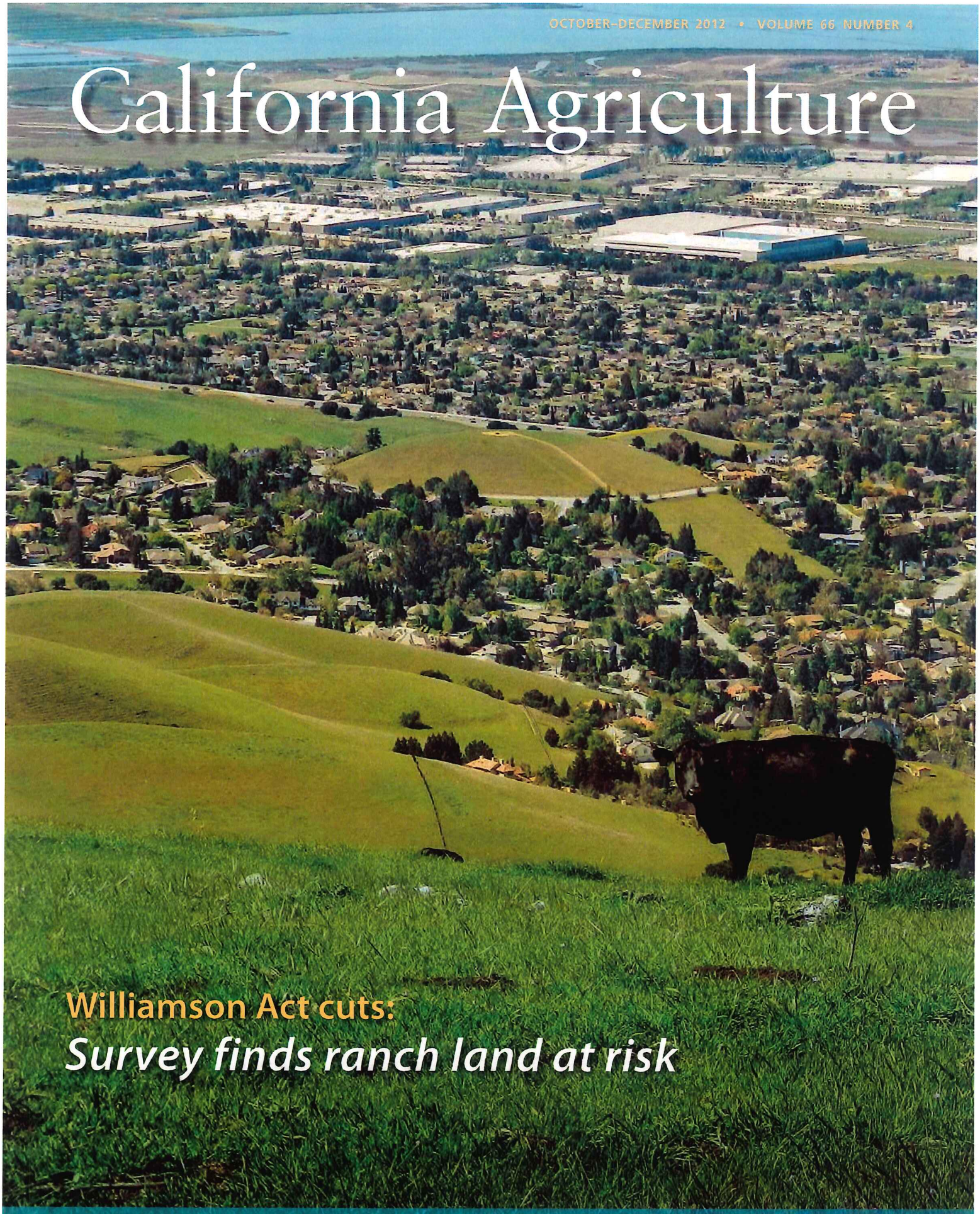
EXHIBIT AG 16

OCTOBER–DECEMBER 2012 • VOLUME 66 NUMBER 4

California Agriculture



Williamson Act cuts:
Survey finds ranch land at risk

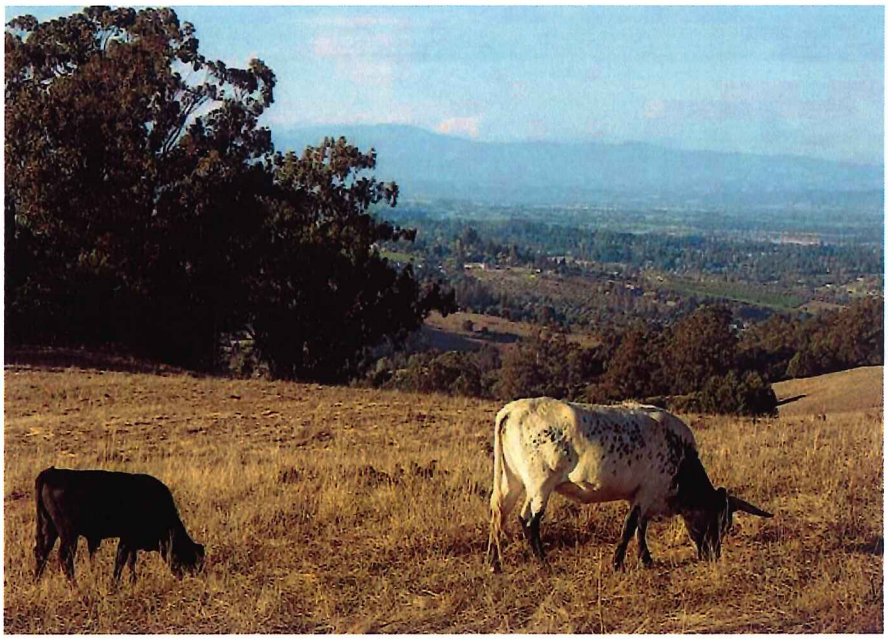
University of California | Peer-reviewed Research and News in Agricultural, Natural and Human Resources

RESEARCH ARTICLE

Analysis reveals potential rangeland impacts if Williamson Act eliminated

by William C. Wetzel, Iara L. Lacher, Daniel S. Swezey, Sarah E. Moffitt *and* Dale T. Manning

California budget cuts have resulted in dramatic reductions in state funding for the Williamson Act, a land protection program that reduces property taxes for the owners of 15 million acres of California farms and rangeland. With state reimbursements to counties eliminated, the decision to continue Williamson Act contracts lies with individual counties. We investigated the consequences of eliminating the Williamson Act, using a geospatial analysis and a mail questionnaire asking ranchers for plans under a hypothetical elimination scenario. The geospatial analysis revealed that 72% of rangeland parcels enrolled in Williamson Act contracts contained habitat important for statewide conservation goals. Presented with the elimination scenario, survey respondents reported an intention to sell 20% of their total 496,889 acres. The tendency of survey participants to respond that they would sell land was highest among full-time ranchers with low household incomes and without off-ranch employment. A majority (76%) of the ranchers who reported that they would sell land predicted that the buyers would develop it for nonagricultural uses, suggesting substantial changes to California's landscape in a future without the Williamson Act.



Sarah E. Moffitt

The Williamson Act reduces property taxes for private owners of California farmland and rangeland. In a survey, ranchers were asked what their plans would be for their land if the tax benefit were eliminated. *Above*, cattle graze near Santa Rosa.

Ranching provides broad social, economic and environmental benefits to the state of California (Huntsinger and Hopkinson 1996; Knight et al. 1994, 2002). Properly managed rangeland can conserve important ecosystem services, including the delivery of fresh water and maintenance of habitats vital for native flora and fauna (Barry and Huntsinger 2002; Marty 2004). California ranching has faced an increasingly volatile economic climate in recent years (Andersen et al. 2002). The rate of rangeland development in California for nonagricultural uses exceeds the landscape conversion rate for both forest and croplands, and this accelerating development is predicted to continue for rangelands surrounding California's Central Valley (CDF-FRAP 2010). This development pressure threatens both the ranching industry and the native species that depend on rangeland for survival.

The economic success of ranching in California is intertwined with the California Land Conservation Act of 1965 (known as the Williamson Act), one of the nation's oldest agricultural conservation programs. The goal of the Williamson Act is to preserve agricultural and open space lands by encouraging landowners to stay in agricultural production through reduced property tax rates. Under the Williamson Act, landowners voluntarily commit to maintaining their land in agricultural production under a local county contract for a minimum of 10 years. In return, landowners receive a reduction in their annual property taxes. Under the original program, contract-holding counties received annual subvention payments from the state in proportion to their enrollment and to the productivity of the enrolled lands. These funds helped compensate for the tax revenue losses counties faced due to their participation in the program. Since 1965, thousands of California ranchers and 53 of the 58 counties in California have enrolled in the Williamson Act program.

Beginning in budget year 2008-2009, California drastically reduced subvention reimbursements to counties as part of a plan to phase out the program. In 2009-2010, California Governor Arnold Schwarzenegger cut state subvention funding to $1,000, essentially eliminating state support. In 2008, before subvention payments were cut, state reimbursements to counties ranged from $5.2 million in

Online: http://californiaagriculture.ucanr.edu/landingpage.cfm?article=ca.v066n04p131&fulltext=yes
DOI: 10.3733/ca.v066n04p131

heavily agricultural counties (e.g., Fresno, Kern, Tulare) to less than $12,000 in more urbanized counties (e.g., Orange, San Bernardino). In 2010, in response to subvention payment loss, Imperial County ended its participation in the program, nonrenewing (allowing contracts to expire) contracts countywide. Under mounting budget deficits, a number of counties placed a moratorium on new contracts because of uncertainty surrounding the future of subvention payments (Sokolow 2010).

Assembly Bill 1265 (passed in 2011) offers counties the option to continue Williamson Act contracts while giving them an opportunity to recoup some lost tax revenues. Under AB 1265, a county can shorten Williamson Act contracts by 10% and increase the assessed value of land by 10% of the difference between Proposition 13 values and the Williamson Act assessed value. This option becomes available if state subvention payments fall below half of a county's actual foregone general fund property tax revenue. This increased property tax revenue is allocated exclusively to counties; for many counties this is projected to compensate for lost state subvention payments. If landowners agree to enter into the shorter contracts, counties would presumably be encouraged to stay in the program because they avoid losing property tax revenue. Because the state has not approved funding for future subvention payments, the decision to continue the program under this new structure has fallen into the hands of individual counties.

Williamson Act savings may make a critical difference in turning a profit versus taking a loss for the majority of California ranchers.

Using a mail survey and landscape analysis, we explored the economic and ecological impacts if counties decided to eliminate Williamson Act contracts.

Survey design and delivery

In 2010, we collaborated with the California Cattlemen's Association (CCA), a ranching membership association, to randomly survey 702 CCA members from 33 counties of California's Central Valley and surrounding foothills. We used stratified random sampling to select 62% of the region's CCA members. We chose these counties because they overlapped with a California Rangeland Conservation Coalition study of sensitive rangeland habitats (CRCC 2007b). In a few cases, respondents owned additional land in counties not included in the CRCC study. We used the Dillman (2000) method for mail questionnaires to ask ranchers about their Williamson Act contracts, ranching operation finances, attitudes toward the Williamson Act and future ranching plans. The questions forming the core of our analysis asked ranchers for their plans in the hypothetical event that their Williamson Act–sponsored tax reductions were eliminated. Additional demographic, fiscal and geographic information was also collected.

Survey responses to hypothetical scenarios are typically subject to biases (List and Gallet 2001). In our survey, respondents had a potential financial interest in maintaining Williamson Act funding and thus may have perceived an incentive to report exaggerated consequences of contract elimination. We deal with this potential bias by interpreting results as relative vulnerabilities instead of as exact predictions of future behavior and land use. Comparisons of relative vulnerabilities are justified because ranchers in all socioeconomic categories benefit from their Williamson Act contracts and all may have perceived an incentive to respond in ways that protect the Williamson Act. Where we discuss absolute sizes of reported impacts, we interpret them as upper limits for rancher responses to the loss of Williamson Act contracts.

We received responses from 52% of the 702 ranching businesses randomly selected for our survey. Of the 364 returned surveys, 294 (84%) reported ownership of rangeland in California and 57 (16%) responded that they exclusively leased land for their livestock operations. Of the landowners, 244 (83%) indicated that they held Williamson Act contracts. Not all 244 respondents answered every question, so sample sizes varied by question.

We used an exploratory data analysis approach to summarize relationships in the survey responses. Our approach involved graphing response and independent variables followed by a visual assessment of any relationships conforming to particular hypotheses. The strength of this approach is that it is robust to nonlinearity and outliers because it makes few

Sarah E. Moffitt



Under a hypothetical elimination scenario for Williamson Act contracts, ranchers predicted that about three-quarters of the land sold in response would be commercially developed. Conversely, 80% said that their heirs would continue grazing the land if the contracts continued.

assumptions about shapes of curves and distributions of data (Bolker 2008).

Landscape analysis

We used ArcGIS software to calculate the percentage of nonprime Williamson Act contract parcels in the 33 counties that overlapped with sensitive habitat on the CRCC's biological prioritization map (CRCC 2007b), which identifies areas of privately owned rangeland that "have high biodiversity value and require conservation action in the next 2 to 10 years" (CRCC 2007a). We chose nonprime parcels because they are primarily rangeland. The Williamson Act defines prime and nonprime land based on per-acre production value.

We based the analysis on the percentage of parcel overlap instead of area of overlap because a large portion of publicly available county data contained insufficient acreage data. We obtained the Williamson Act parcel data from county websites. San Benito and San Joaquin counties did not have prime/nonprime designations in their publicly available Williamson Act parcel data. For these two counties, we used data on the distribution of grazing land from California's Farmland Monitoring and Mapping Program (FMMP) to deduce the Williamson Act categories of unlabeled Williamson Act parcels. This was done by extracting parcels within the county that were also designated as grazing land by the FMMP. Therefore, for these counties we assume grazing Williamson Act land is also nonprime Williamson Act land.

Importance of property tax reductions

Opinions and perceptions. The majority of ranchers (91% of 237) reported that the Williamson Act was "very important" or "extremely important" for the "long-term viability of their cattle and rangeland operations" and for "ranching in California as a whole" (96% of 240); the rest said it was "slightly," "somewhat," or "not at all" important for their ranch and ranching in California as a whole. Enrolled ranchers estimated a $10,000 median annual property tax reduction through their participation in Williamson Act contracts (with a range from $1,000 to $120,000), which fits with county estimates of rancher savings over their Proposition 13 property taxes (e.g., in 2003 Yolo County estimated a per-acre savings of $6 to $15; Sokolow and Bennett 2004).

The proportion of ranchers who reported that the Williamson Act was important for the long-term viability of their rangeland operations decreased with increasing household income level. Those who identified as part-time ranchers, or as ranchers who were additionally employed off-ranch, also placed reduced overall importance on the Williamson Act. Opinions regarding the importance of the Williamson Act did not vary by ranch acreage, years spent ranching, estimated land values, estimated ranch profit, rancher age or previous land sale history. The result that Williamson Act importance varies with household income but not with ranch profit is also true for vulnerability to selling.

Profits and savings. Seventy-three percent of respondents reported that in 2009 they earned less than $10,000 in annual profit from their ranching businesses (fig. 1) and 71% reported that their annual profit was equal to or less than their Williamson Act savings. Ninety-three percent of ranchers earning less than $10,000 in annual profit reported that their Williamson Act savings exceeded their profit in 2009. These results indicate that Williamson Act savings may make a critical difference in turning a profit versus taking a loss for the majority of California ranchers.

Propensity to sell land

On average, ranchers said they would sell 29% ± 3.2% (mean ± standard error) of their owned rangeland under the hypothetical scenario of Williamson Act contract elimination. Ranchers tended to plan to sell all or none of their ranch with relatively few planning to sell parts of

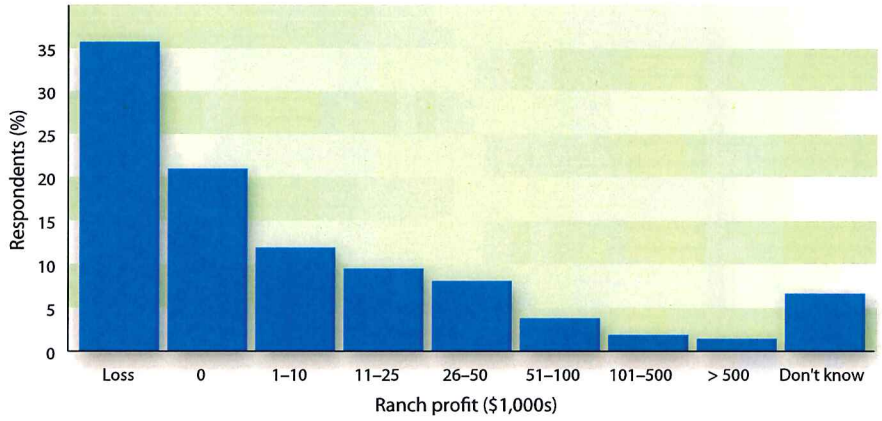


Fig. 1. Ranching operation profits reported by survey respondents who had land enrolled in Williamson Act program, 2009 (n = 196).

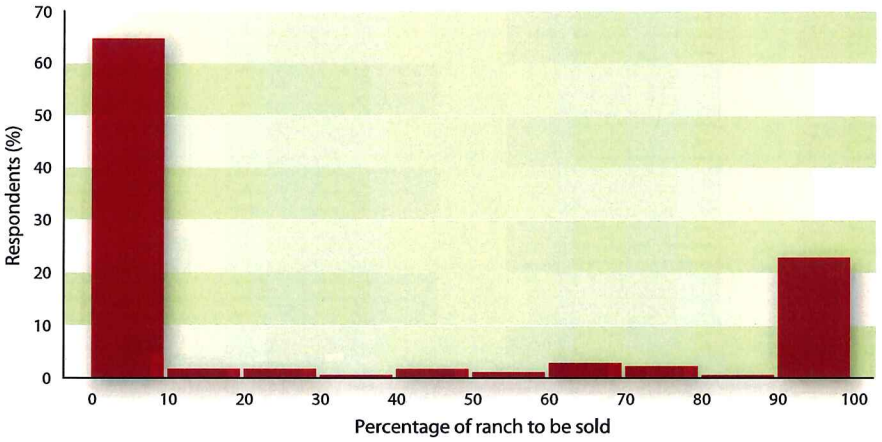


Fig. 2. Rancher estimates of percentage of rangeland they would attempt to sell given elimination of Williamson Act contracts (n = 175). Answers are binned into 10% increments.

ranches (fig. 2). Only 18% of respondents reported that they would sell a portion of their ranch, whereas 19% planned to sell all and 63% planned to sell none. Respondents intended to sell a total of 99,137 acres, or 20% of the total owned acreage reported.

These numbers give an indication of rancher-stated intentions, not the true amount of land that would be sold. We interpret them as upper bounds on the true values for two reasons. First, not all intentions to sell land translate into land sales; it can often be difficult to find buyers. Second, this is a hypothetical scenario and responses on reported intent to sell could be exaggerated.

Williamson Act parcel vulnerability

We used two metrics to assess a ranch's vulnerability in the Williamson Act contract elimination scenario: the estimated probability of selling a ranch (on a scale from 1 to 5), and the estimated percentage of ranch acreage respondents would intend to sell. The choice of metric did not change the conclusions of the analysis, so we present results only for the estimated percentage of ranch acreage intended to be sold. The vulnerability metrics varied most strongly with household income, off-ranch employment and additional operational income from ranch sources other than livestock production (e.g., tourism, hunting, firewood operations). There was no clear relationship between vulnerability and other rancher or ranch enterprise characteristics (analysis not shown), including years spent ranching, estimated land sale price, ranch distance from town and history of nearby development, among many others. Our results may exaggerate the absolute value of vulnerability, but only the relative value of vulnerability matters for these comparisons.

Household income and ranch profit. There was a strong negative relationship between household income and ranch vulnerability (fig. 3) but no relationship between ranch profit and vulnerability. Respondents with off-ranch employment or identifying as part-time ranchers tended to have higher household incomes. Ranchers with diversified ranch activities other than cattle production also intended to sell less land (23% of total land owned) on average compared to ranchers whose sole ranch income came from cattle production (33% of total land owned). In contrast, there was no relationship between ranch profit and vulnerability. The one exception to this trend was that none of the ranches earning over $100,000 in profits intended to sell any land in the Williamson Act termination scenario.

Future land use. Predictions made by ranchers regarding the future use of their land showed a potential for loss of open space and rangeland in California if Williamson Act tax reductions ended. Ranchers predicted that 76% of the land sold in response to Act elimination would likely be developed commercially for nonagricultural, nonopen space uses including housing developments (fig. 4). Only 15% of these same ranchers listed continued grazing as a likely future land use after sale. In contrast, the majority of respondents (78%) reported that their heirs would continue grazing their land if Williamson Act contracts continued. Fewer than 2% reported that heirs would develop their rangeland for urban or suburban use. While these numbers do not directly translate to an estimate of the total acreage that would be developed, they do suggest that land passed to heirs might have a greater chance of escaping development than land put up for sale in the event of Williamson Act elimination. Commercial development is only one of several possible outcomes for land sold by ranchers, but the fact that this was the most commonly predicted outcome is alarming.

Trends in ranch vulnerability. Household income played the strongest role in determining the probability that a rancher would intend to sell land, with higher income groups intending to sell less land

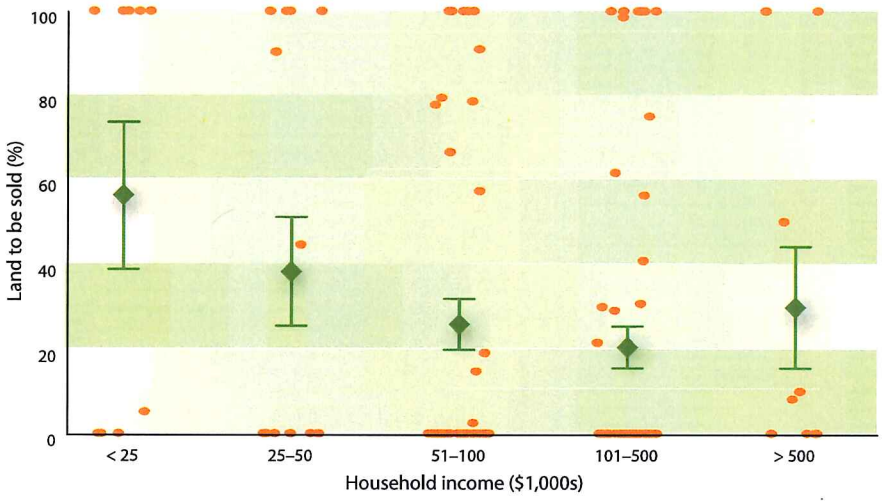


Fig. 3. Percentage of owned ranchland that respondents in different household income categories reported they would attempt to sell given elimination of the Williamson Act (n = 134). Green diamonds are the average percentage of ranchland to be sold; green lines show one standard error above and below the mean; orange points show actual data points spread out horizontally within each household income category.

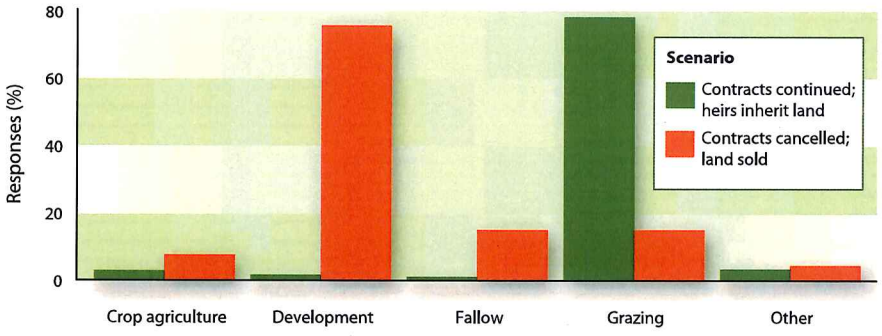


Fig. 4. Rancher predictions for future use of their land under ownership of heirs if Williamson Act contracts continued, and if they were eliminated and the land was sold.

than low-income ranchers. Interestingly, 5% of ranchers earning $100,000 or more in annual household income reported that they did not know their ranching operational profit from 2009. This finding suggests that among wealthier owners, ranching profits play a small role in land sale decisions. The 5.6% of respondents who reported annual household incomes of less than $25,000 and profits less than $10,000 were the group with the greatest vulnerability. Diversification away from sole dependence on conventional ranching activities is an emergent trend in the economic landscape of California ranching (Rilla et al. 2011). Survey respondents who were part-time ranchers, had off-ranch employment or earned ranch income from sources other than cattle (e.g., agritourism) reported far lower ranch vulnerabilities. That ranch diversification decreases economic vulnerability should be an important lesson for ranchers and conservationists in California.

Development pressure. Most ranchers who intended to sell land in the Williamson Act elimination scenario indicated that they believed it would be developed for nonagricultural use. This trend suggests that many ranchers perceive significant development pressures in the areas surrounding their parcels. The location of rangeland parcels will determine the scale of property tax increases in the absence of the Williamson Act savings and obviously influence the degree of development pressure and the land's resale value. If development across California follows previous models for the Mojave Desert regions, land located close to cities and other development is more likely to develop first (Gomben et al. 2012) and thus may see a larger increase in property taxes without the Williamson Act. Land sale by economically vulnerable ranch households may be more likely in these areas.

Heirs. A major finding of our study was that a majority of ranchers believed their heirs would continue to commercially graze their properties when land is passed to them (fig. 4). This suggests that if the Williamson Act remains in place, ranching communities and rangeland in California may be protected in the near future, and that the Williamson Act is meeting its goal of preserving agricultural communities and ranching landscapes in California.

Conservation value of nonprime parcels

Out of 102,384 nonprime Williamson Act parcels within the CRCC study region, 43,639 were located within CRCC "critical" habitat, and 29,672 were located within CRCC "important" habitat (fig. 5). Thus, 43% of nonprime Williamson Act parcels in our study area were classified as CRCC "critical," with an additional 29% classified as "important." A future without the Williamson Act in place may see increasing development and conversion of rangeland that is critical or important for conservation, putting ecologically valuable habitats at risk.

The large majority of nonprime Williamson Act parcels in our study area were located in the foothills encircling the Central Valley. CRCC habitats designated as either critical or important were scattered throughout the lower elevations of the foothills, with a patchy distribution spanning multiple habitat types generally dominated by oak savannas and grasslands (CRCC 2007b; LandFire 2010). These grassland habitats are home to native plants and animals and threatened vernal pool ecosystems and associated organisms, at least some of which benefit from moderate grazing (CRCC 2007b; Marty 2004).

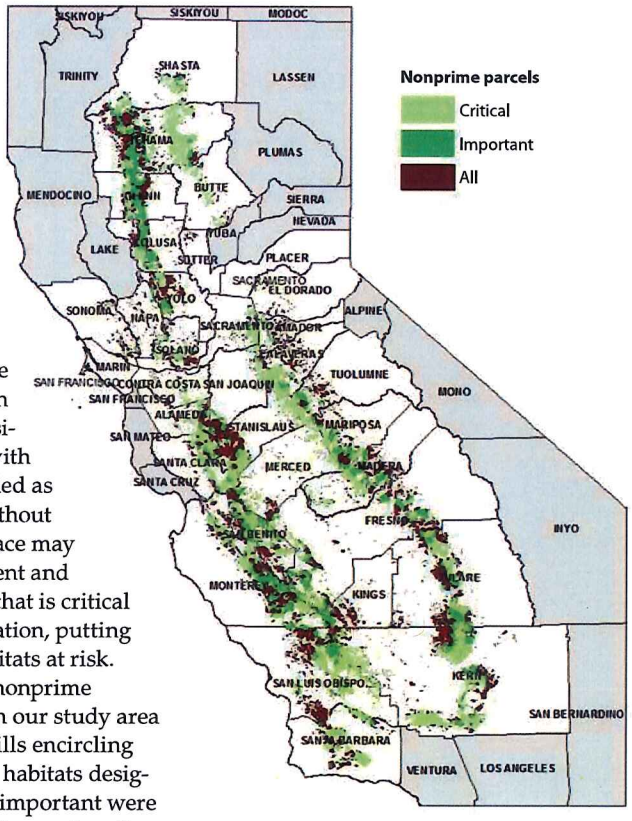


Fig. 5. Conservation designation of all nonprime Williamson Act parcels within California Rangeland Conservation Coalition (CRCC) study area, showing high overlap between nonprime Williamson Act parcels and CRCC conservation habitat (CRCC 2007b).

An important land management tool

The Williamson Act has served as a land management tool for close to half a century by encouraging the conservation of agricultural lands, open spaces and rural communities throughout the state. Under the current state budget crisis, AB 1265 means that counties now must decide if they want to continue honoring Williamson Act contracts through the shortening of contract duration and the reduction of tax benefits to landowners. Many counties will likely continue with the modified version of the Williamson Act because the benefits are popular with property owners and the increase in revenue can compensate for the loss of state subvention payments. Some counties with major budget shortfalls, like Fresno, have already gone down the road of reducing benefits to landowners. Beyond politics, a fundamental question is what will happen to rangeland and ranching in California if counties begin to eliminate Williamson Act contracts (fig. 6).

Results of this study show that ranchers perceive the Williamson Act to be a critical component of their ranching businesses. Ranching is a low-profit venture nationally (Gosnell and Travis 2005). Our study confirms this for California: 71% of Williamson Act–enrolled ranchers reported a net annual profit equal to or less than their Williamson Act property tax savings in 2009. Williamson Act tax reductions make the difference between profit and loss for the majority of California ranchers in the Central Valley and surrounding foothills. Ranchers with high annual household incomes, typically earned from off-ranch employment, seemed less likely to be influenced by a decrease in profits or changing property

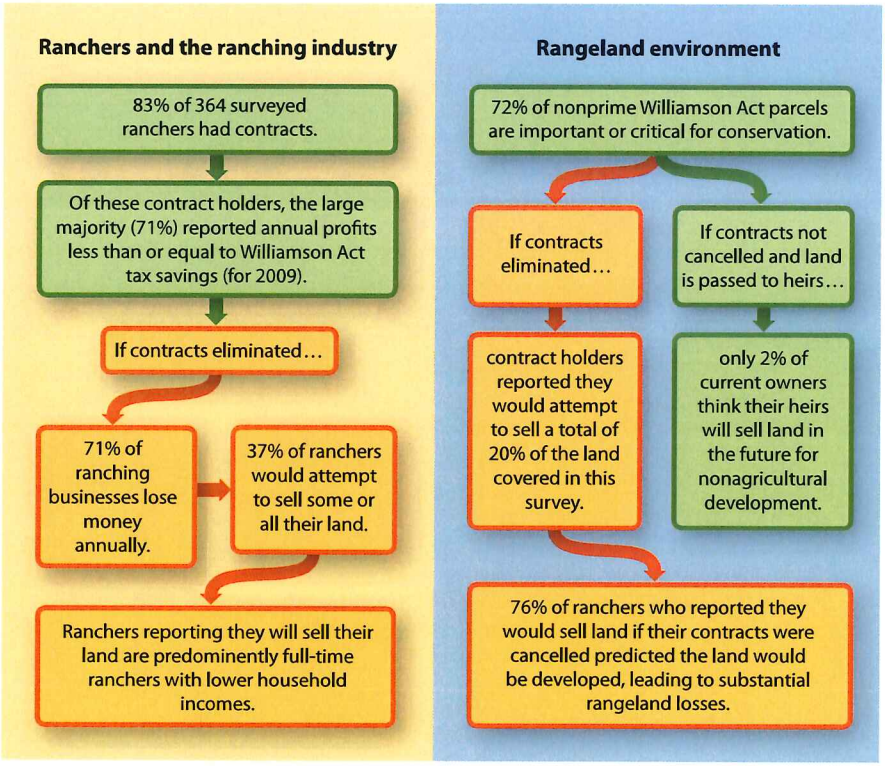


Fig. 6. Possible consequences of eliminating Williamson Act contracts and property tax savings for ranching landowners.

tax burden. On the other hand, full-time ranchers with low annual household incomes frequently reported that they intended to sell land if they had to pay full property taxes in the absence of the Williamson Act. Our results indicate that the Williamson Act program buffers low-income, full-time ranchers from fiscal insolvency. The likelihood that ranchers who lose their Williamson Act contracts would attempt to sell land increases among our survey population as household income decreases.

Nonrenewal of Williamson Act contracts could make large areas of rangeland throughout the state vulnerable to sale, and ranchers indicated that these lands would likely be commercially developed. These lands have important conservation value and host numerous rare and endangered plant and animal species (CRCC 2007b). New conservation grazing and sustainable rangeland management practices (Brunson and Huntsinger 2008) hold significant promise as tools for integrating ecological conservation with agricultural production and preserving the integrity and beauty of the California landscape. Careful consideration of how policymakers can protect rangeland and its diverse habitats is of utmost importance in the years to come.

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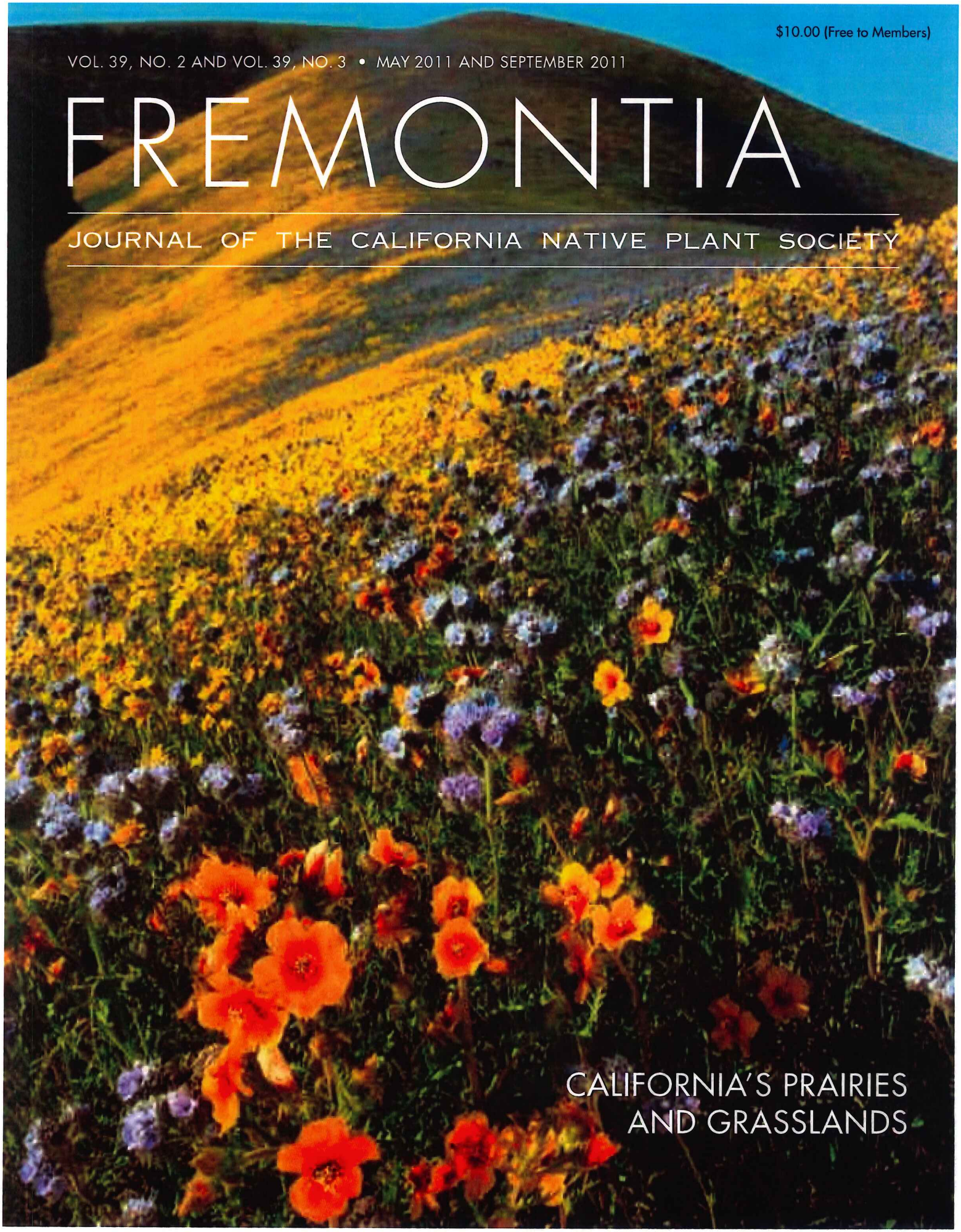


CALIFORNIA'S PRAIRIES AND GRASSLANDS



Cattle grazing is used to control invasive species and reduce fire fuel loads at Mission Peak Regional Preserve in Fremont managed by the East Bay Regional Parks District. Photograph courtesy of Sheila Barry, University of California Cooperative Extension.

CONSERVING AND MANAGING PRAIRIE, GRASSLAND, AND VERNAL POOL LANDSCAPES THROUGH COLLABORATION

by Pelayo Alvarez

About 250 years ago the Spaniards arrived in California in an event that forever changed landscapes in the state. They brought with them things from the old world that were important for their survival, including livestock and a long list of plant species that thrived in California's Mediterranean climate. Some of those non-native species provide the basis for what is now a vibrant agricultural multibillion dollar industry.

Other plant species, such as yellow star thistle, were accidentally introduced and became invasive, wreaking havoc in both natural and agricultural systems, reducing production, fragmenting habitats, and altering competitive interactions among plant species and other important ecosystem processes. The scale and rapidity of the vegetation conversion was unprecedented and brought about additional management challenges to the already complex system that comprises California grasslands. Today only one percent of remaining grasslands are native. Despite that catastrophic vegetation conversion, California grasslands remain one of the most biodiverse systems in the world.

ECOLOGICAL VALUE OF GRASSLANDS

There are over 11 million acres of grasslands within and encircling the Central Valley and the interior Coast Range, many of which are privately owned and managed as rangelands for livestock production. Grasslands in California provide multiple ecosystem services—the benefits that human societies obtain from nature—including wildlife habitat, watershed protection, open space, and climate change mitigation.

California grasslands support a wide variety of wildlife species including freshwater fish, birds, invertebrates, and mammals (Hunting 2003). There are 75 species associated with California grasslands, including 10 vertebrates, 14 invertebrates, and 51 plants that are listed as threatened or endangered under the Endangered Species Act (Jantz et al. 2007).

California valley grasslands arguably provide the most important



In serpentine soils, grazed sites (right) provided better habitat for the endangered Bay Checkerspot butterfly than ungrazed ones (left). Photograph courtesy of Dr. Stuart Weiss, Creekside Center for Earth Observation.

wintering habitat for raptors in North America (Pandolfino 2006). California Bird Species of Special Concern (Shuford and Gardali 2008) which use these habitats extensively include Mountain Plover, Burrowing Owl, Loggerhead Shrike, Grasshopper Sparrow, and Tricolored Blackbird.

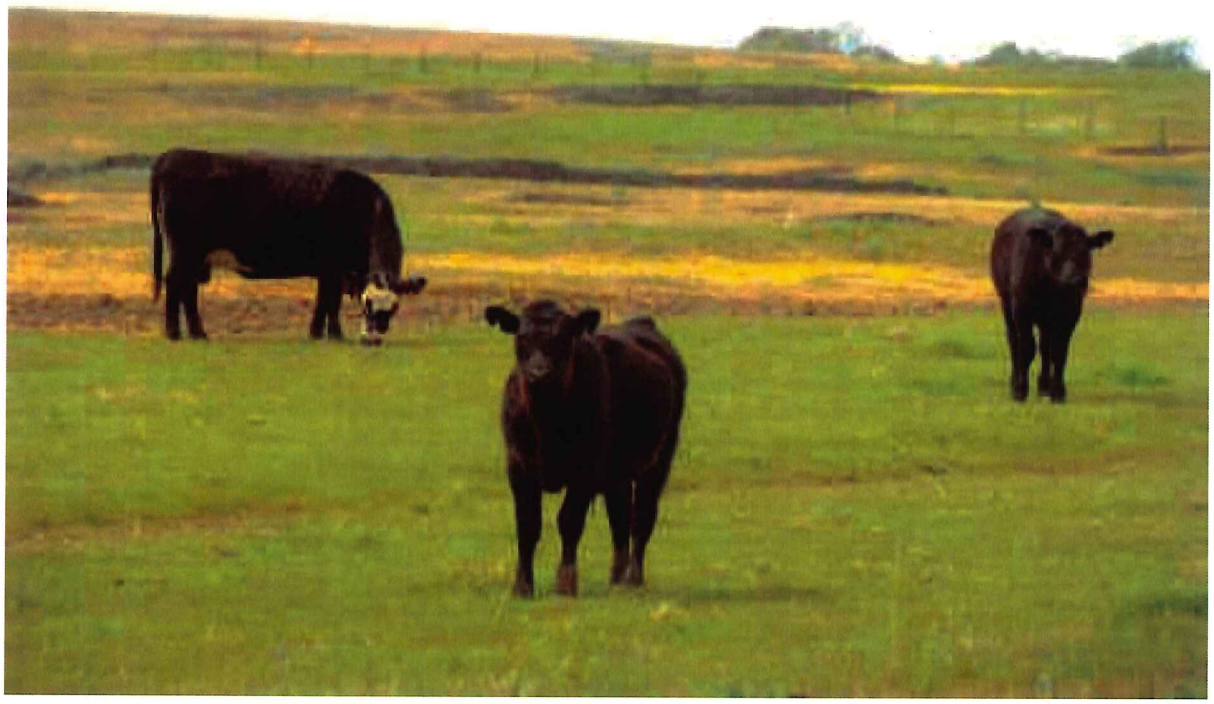
Grasslands also provide important habitat for pollinators that are essential for pollinating California's agricultural crops. The value of pollinator services from wild pollinators to California agriculture has been estimated at between $937 million and $2.4 billion per year (Chaplin-Kramer et al. 2011).

Despite their ecological value, California grasslands do not enjoy the same protection that other areas do. In the 1980s and 1990s the perception among land managers and the conservation community regarding grazing and other ranching activities was very negative. Land managers in California quickly removed grazing from land that was historically grazed in an attempt to restore it to a natural state. After a few years and in the absence of disturbance, the non-native annual grasses and other invasive plant species created an impenetrable thatch that further suppressed native plants. However, a few forward thinking land managers began rethinking the previously held views on the role of grazing when they saw that, on a number of private ranches, the wildflowers were still thriving in upland areas and vernal pools.

A NEW PERSPECTIVE ON GRAZING

The concept that grazing could be beneficial in the management of California grasslands was not news to the California Native Plant Society. An article in the January 1992 issue of *Fremontia* describes how grazing could be used to favor native bunch grasses (Edwards 1992). But it was not until years later that research done in California started to provide scientific evidence that

Cattle grazing vernal pools at North Table Mountain Ecological Preserve, managed by the California Department of Fish and Game. Photograph by Tracy Schohr.



properly managed grazing could be an important tool for increasing the conservation value of grasslands and associated habitats in California.

Research conducted by Jaymee Marty, an ecologist with the Nature Conservancy, and collaborators suggested that cattle grazing could be an essential management tool in maintaining biodiversity in vernal pool ecosystems (Marty 2005). Cattle consume the more palatable non-native annual grasses that invade vernal pools, allowing native plants and the species that depend on them to thrive. In addition, by reducing evapotransporation from the non-native annual grasses, cattle grazing increases the inundation period of the pools by as much as 50 days. This allows vernal pool endemic invertebrate species to complete their life cycle (Pyke and Marty 2005).



Dark blue shows rangelands of highest conservation value and level of threat of conversion. Source: California Rangeland Conservation Coalition, 2007.

Similar beneficial effects of grazing have been found on serpentine sites south of San Francisco Bay (Weiss 1999). These sites support many rare plant and wildlife species, including the endangered Bay checkerspot butterfly. Studies conducted by Dr. Stuart Weiss, chief scientist at the Creekside Center for Earth Observation, showed beneficial effects of grazing on butterfly habitat in south San Jose where non-native annual grasses were outcompeting the dwarf plaintain, a plant that the checkerspot butterfly caterpillar feeds on. In this ecosystem, cattle selectively graze the non-native grasses over the native forbs, favoring the dwarf plaintain and allowing the butterfly to thrive (Weiss 1999).

More recent research published in the December issue of the *Journal of Wildlife Management* (Germano et al. 2011) summarizes ten years of data on the effects of grazing and invasive grasses on desert vertebrates in California. The study concluded that grazing can be used to control exotic non-native grasses and be beneficial to vertebrate species that rely on open habitats, such as the blunt-nosed leopard lizards, giant kangaroo rats, short-nosed kangaroo rats, and San Joaquin antelope squirrels, among others.

Today grazing is recognized as a cost-effective and natural tool for managing vegetation and enhancing wildlife habitat and other ecosystem services. It is also a tool that is being used by several land management agencies in California that rely on local ranchers to be able to meet their conservation goals.

Other activities associated with ranching are also beneficial from a conservation standpoint. Ranch stock ponds play an increasingly important role in providing habitat for amphibians. In the Bay Area, stock ponds on ranchlands provide up to 50% of the remaining habitat for the threatened California tiger salamander (United States Fish and Wildlife Service 2006).

Other ecosystem services from rangelands are increasingly being recognized, including open space, watershed protection, and climate change mitigation and cultural services. Among the cultural values we should recognize are recreation, open space, and the knowledge ranchers have accumulated over generations on how to manage these lands.

Although views on the ecological importance of grasslands and the role of ranching are gradually changing, ranchers still face numerous challenges to stay in business. Profit margins are extremely low, making conversion to other uses (vineyards, orchards) a tempting proposition to ranchers that are land rich and cash poor. Younger generations may not be interested in ranching, and land prices make it difficult for them to start their own operations. Little by little the infrastructure that once supported ranching has slowly been dismantled, making ranching in some areas a marginal activity.

A recent rangeland vulnerability assessment by the Nature Conservancy found that every year 20,000 acres of rangeland in California are converted to intensive agriculture and urbanization (Nature Conservancy, unpublished data). The loss and fragmentation of these habitats

CALIFORNIA RANGELAND TRUST

California Rangeland Trust formed following a round table discussion among innovative ranchers who understood the need for a land trust dedicated to preserving not only the land, but also the stewardship and the iconic California ranching heritage that the ranchers provide. Since its founding in 1998, the Rangeland Trust has grown substantially, and to-date has protected in perpetuity over 250,000 acres of rangeland.

Rangeland Trust works to preserve grasslands through voluntary conservation easements. A conservation easement can be purchased or donated, and is an agreement between the landowner and the land trust that the land will remain as is, undeveloped forever. Funding is applied from state and federal programs, and more often these days comes from private foundations and individuals who believe that the Rangeland Trust is protecting both the heritage and the future of ranching in California. Currently, the Rangeland Trust has 120 families on its waiting list that hold nearly 500,000 combined acres of grassland.

In California, there are 34.1 million acres of grassland that provide sanctuary and habitat for the state's diverse wildlife and plant species. Of those, 22 million acres are privately owned, and all are cared for and stewarded by California ranchers.

Through the use of rotational grazing and land management practices by ranchers, rangelands provide habitat and homes for 95% of the state's endangered and threatened species. Grazing and grasslands are also key factors in the spectacular wildflowers that bloom in the spring. Many of the native flowers would be overtaken by invasive species without the use of grazing as a natural management tool.

Urban development and sprawl are major challenges for California's open spaces, and they will continue to put pressure on grasslands and the resources they provide, including clean air, clean water, and species habitat. Between 1984 and 2006 over 400,000 acres of California grasslands—the equivalent of more than 303,000 football fields—were lost to development. With the California population still on the rise, development pressures will continue to be relentless.

Conservation easements held by land trusts are an extremely viable alternative to combat the pressures of development. Through conservation easements, ranchers can receive tax benefits and funding to ensure the future of their ranches. Many ranchers use conservation easements to ensure that the ranch stays in the family and remains economically viable. Estate taxes often leave heirs with significant debt and few options to pay the inheritance tax. At times the family is forced to subdivide and sell the ranch for development. However, a conservation easement provides a way to pay inheritance taxes and takes development options out of the equation, lowering both land taxes and the estate taxes.

The hard work and long hours put forth by land trusts in California are key in preserving the state's open spaces and resources. Conservation easements provide rangelands a preferred advantage over development options. However, with the economic downturn and state budget cuts, funds to preserve rangelands are shrinking. As funds become scarcer, land trusts like Rangeland Trust will be relying more heavily on donations from those who believe in their mission.

For the foreseeable future, ranchers and the Rangeland Trust will be facing some tough challenges. However, numerous opportunities still exist to preserve grasslands and the resources they provide for future generations of Californians. The fact that the Rangeland Trust has a half-million acres waiting to be protected through conservation easements is a hopeful sign.

—Sahara Saude

reduces their ability to provide ecosystem services and erodes the socioeconomic framework of rural communities.

The accumulation of scientific evidence on the use of grazing as a management tool and concerns over grassland conversion has created an unprecedented alliance. The US Fish and Wildlife Service took the lead in bringing together ranchers, environmentalists, and regulatory and non-regulatory agencies, after repeatedly hearing from the environmental community about the loss of grassland habitats and species, and from the ranching community about the impact that regulations were having on their ability to stay in business.

BIRTH OF THE RANGELAND COALITION

A barbeque in Sunol, CA provided the backdrop for the first meeting of a group of 12 organizations who had the courage and vision to set aside their differences and focus on potential solutions to protect California rangelands. Among them

were representatives from the California Native Plant Society. "We did not know if we were going to a barbeque or to be barbequed," said Carol Witham, "but it was clear that there was some common ground to work with."

The new coalition was called the California Rangeland Conservation Coalition,[1] and founding organizations crafted a document, the Rangeland Resolution, that outlines the principles by which Coalition signatories work together. A focus map was created (see page 51) that prioritized area in the Central Valley and inner Coast Ranges where important species and habitats needed to be protected. It included 500 rare plant species in grasslands, blue oak woodlands, and vernal pool habitats.

Today the Coalition has grown to more than 100 organizations, including government agencies, researchers, environmental organizations, and others who work together to protect and enhance the economic and ecological values of grasslands in the Central Valley of California. Overall the Coalition tries to promote collaboration and improve communications among all the people and organizations who have an interest in these areas.

Science was essential in breaking the barriers between the various Coalition partners, and that made possible the creation of this broad umbrella organization. Science remains central to its ongoing work, which promotes multidisciplinary scientific collaborations and facilitates interactions between the research community, ranchers, and land managers.

Outreach efforts are focused on raising awareness of the importance of California grasslands and the need to work with private landowners for their protection. The Coalition organizes a yearly conference, maintains a website (http://www.carangeland.org), and hosts several field trips, workshops, and presentations on a variety of topics such as grassland ecology and management, existing conservation programs available to ranchers, and emerging markets for ecosystem services such as carbon sequestration and water quality markets.

In the policy arena, the Coalition supports public policies that maintain essential infrastructure and technical capacities of government agencies, and at the same time improve the business and regulatory environment for ranchers. For instance, it supports policy tools that are important to ranchers such as the Williamson Act—which provides tax incentives to agricultural producers in California—and the estate tax.

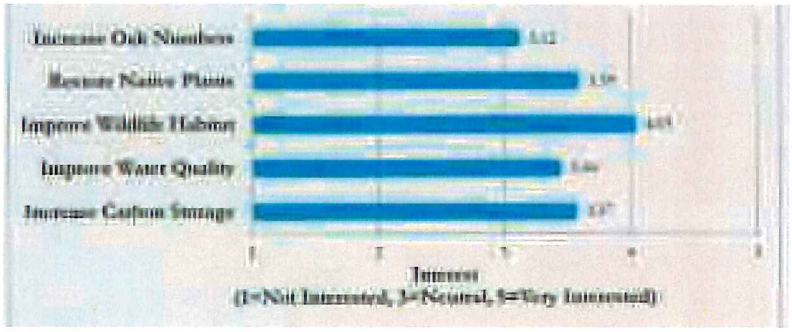
It also seeks common ground among its signatories to increase funding for grassland conservation in California. In addition, the Coalition works to promote collaboration among several government agencies in order to increase awareness of the ecological importance of privately owned grasslands, coordinate permits for conservation projects on private lands, and improve communications with the ranching community.

RECOGNIZING SHARED VALUES

Defenders of Wildlife, a national environmental organization with a strong California presence, early on became one of the most active members of the Coalition. "We realized that we needed to work with ranchers in order to be successful at protecting the native species and habitats that are important to our mission," explained Kim Delfino, director of the California Office of Defenders of Wildlife. "It's not always easy for an environmental group to partner with ranchers. Sometimes we have mistrust and preconceived ideas, but after talking with these folks, I've come to realize that we share a love of the landscape."

Today Defenders of Wildlife, in collaboration with other Coalition signatories, conducts research on identifying and quantifying the public benefits of protecting California grasslands. A recent survey of ranchers in the Central Valley showed that ranchers are indeed interested in protecting ecosystem ser-

FIGURE 2. RANCHER INTEREST IN SELECTED ECOSYSTEM SERVICE RELATED ACTIVITES.



Ranchers in the Central Valley were asked to rate their interest in providing ecosystem services (Cheatum et al. 2011). Respondents expressed an interest in "improving wildlife habitat" and "restoring native plants."

[1] The California Rangeland Conservation Coalition is an alliance of environmental organizations, government agencies, and the ranching community whose mission is to bring together ranchers, environmentalists, and government entities to conserve and enhance the ecological values and economic viability of California's working rangelands.



In the absence of disturbance such as grazing, invasive plant species dominate vernal pools, thus reducing biodiversity. Photograph courtesy of Dr. Jaymee Marty, The Nature Conservancy.

vices such as wildlife habitat and water quality, and increasing native species (see Figure 2), provided that there are incentives available. Relying on the ranchers' desire to become more involved in conservation, Defenders is now working on the development of payments for ecosystem services programs that will give ranchers the opportunity to stay on the land while providing all the environmental benefits that California grasslands produce.

Other environmental organizations have also come to recognize the importance of California grasslands and are now working with the ranching community. By providing incentives that keep ranchers on the land, we will be better able to protect grasslands and their species.

California grasslands and coastal prairies produce many benefits to Californians. The protection of California's prairies and grasslands requires complex solutions and is integrally linked to the ability of ranchers to continue being good stewards of the land. Fostering collaborations that cross boundaries and engage private landowners, this broad coalition is working towards the protection of these beautiful landscapes. Constantly threatened by the worst in human nature, California grasslands might very well be saved by the best of it.

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California Agriculture

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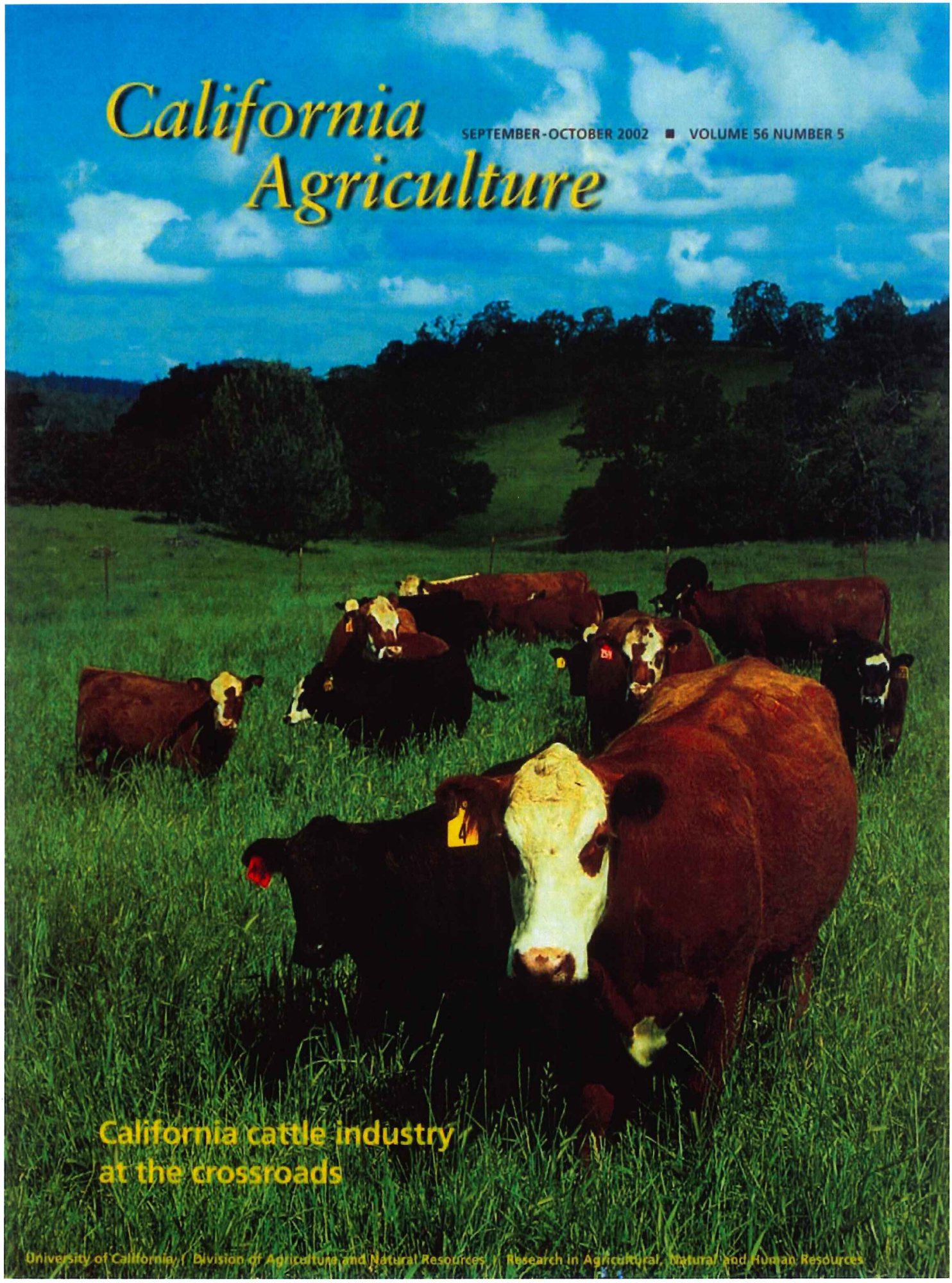


California cattle industry at the crossroads

University of California | Division of Agriculture and Natural Resources | Research in Agricultural, Natural and Human Resources

California's cattle and beef industry at the crossroads

Matt A. Andersen
Steven C. Blank
Tiffany LaMendola
Richard J. Sexton

Beef cattle remain one of California's most important agricultural products, ranking fifth in 2001 at $1.35 billion in value of production, behind dairy, grapes, nursery products and lettuce. However, technological change, coupled with declining consumption of red meats during the 1970s and 1980s, triggered a wave of mergers and acquisitions in the beef-processing sector. To evaluate how such trends are affecting the industry in California, we undertook a survey during 2000 and 2001 and obtained responses from ranchers in 40 counties. Our results confirm that the industry appears to be at a crossroads, for a variety of reasons. Cow-calf ranching operations now predominate, and a significant percentage of cattle leave the state for feeding and slaughter. Auction yards, a principal marketing outlet for most of the survey respondents, require a large volume of activity in order to operate efficiently. As aging ranchers exit the business, this important exchange mechanism is threatened, possibly contributing to the industry's further decline. Most ranchers reported having five or fewer potential buyers for their cattle.



California Beef Council

While cattle and beef are California's fifth most valuable agricultural product, the industry is struggling due to technological change and consolidation. Cattle are rounded up at a California ranch.

The cattle and beef sectors in the United States have evolved in rapid and fundamental ways. The "boxed-beef" technology introduced in the 1960s and concurrent advances in shipping technology have enabled carcasses to be processed into individual cuts, packed and shipped nationally or internationally from the same plant where slaughter took place. This capital-intensive technology resulted in expanded economies of scale. Technological change, coupled with declining consumption of red meat during the 1970s and 1980s, triggered a wave of mergers and acquisitions in the beef-processing sector. In 1977, the four leading beef packers were estimated to hold 30% of total U.S. slaughter capacity; by 1999 that share had risen to 82%. Analysts generally agree that this technological change, coupled with the increase in packer concentration, has increased efficiency in the processing sector (Morrison-Paul 2000). However, benefits to producers from enhanced efficiency can be dissipated or eliminated if packers are able to exercise market power as a result of industry consolidation (USDA 1996; Azzam and Schroeter 1997).

Rapid change has also occurred in the marketing arrangements between cattle producers and beef processors. In particular, there is evidence of tighter vertical control, such as packer-fed cattle, producer-packer forward contracts, and marketing agreements between producers and packers wherein cattle are priced according to a predetermined formula. All of these arrangements are lumped under the term "captive supplies" because the cattle are tied *ex ante* to a particular processor, and not sold on the open market.

Empirical evidence from various markets suggests a negative correlation between the use of captive supplies in a region and the cash-market price (Ward 2002). Accordingly, various producer groups, government regulators and academics have expressed concern about the evolution of these marketing arrangements, especially in light of rising packer concentration and reduced selling opportunities for producers. A ban on packer feeding was debated but not included in the Farm Bill that recently passed, and is now being debated by Congress as a stand-alone piece of legislation.

Most of the aforementioned investigation has focused on the major cattle-

producing states in the Midwest, and comparatively little attention has been paid to California's cattle industry. However, beef cattle and calves remain one of California's most important agricultural products, ranking fifth (behind dairy, grapes, nursery products and lettuce) in 2001 value of production at $1.35 billion. Cattle and calves were the leading agricultural commodity, based on value of production, for nine California counties: Calaveras, Imperial, Mariposa, Nevada, Plumas, Shasta, Sierra, Trinity and Tuolumne. They are second in importance in six others: Amador, Inyo, Marin, Modoc, Placer and San Bernardino.

Because of its importance to California's agricultural economy and the comparative neglect it has received in the multitude of studies conducted on the U.S. cattle and beef industry (Ward 2002), we undertook an investigation of the status of those industries in California. The main goal was to document the evolution of production and marketing and to obtain a perspective on the impacts of increasing packer concentration and vertical coordination on the California industry.

Cattle production and processing

California's greatest concentrations of cattle are in the Central Valley counties of Fresno, Kern, Merced, Stanislaus and Tulare, and the arid southern region comprised by Imperial, Riverside and San Bernardino counties (fig. 1). Although cattle production is a leading agricultural industry for such northern counties as Modoc, Plumas, Shasta, Sierra and Trinity, production in those counties pales relative to the Central Valley and southern counties.

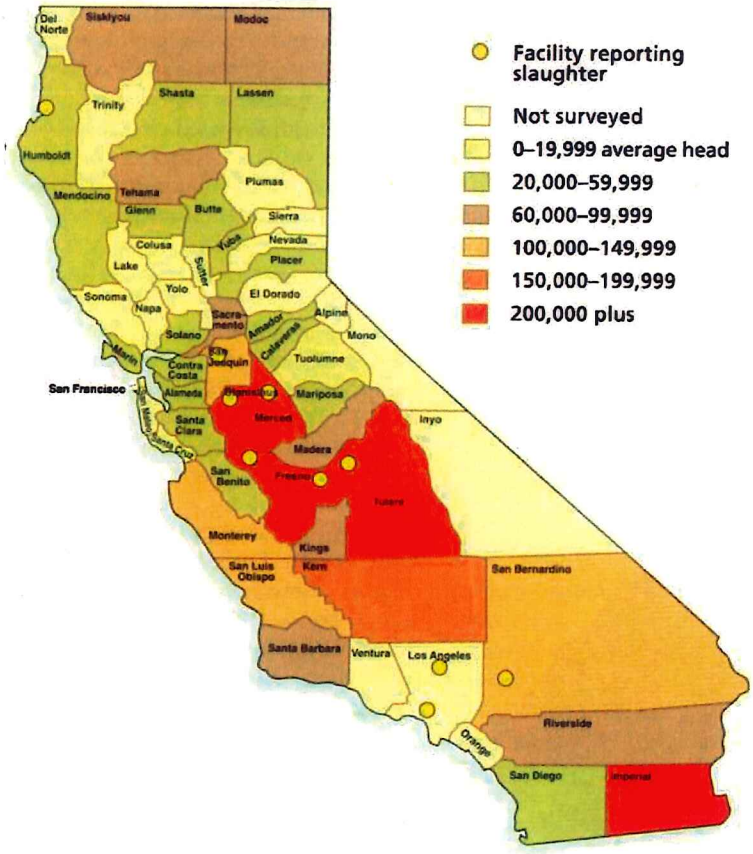


Fig. 1. Cattle and calves, average inventory levels by county, 1982–1997, and locations of facilities reporting slaughter of cattle and calves, 1997. Sources: California Census of Agriculture; USDA Grain Inspection, Packers and Stockyards Administration.

The major growth has occurred in the Central Valley and desert-south regions, with an additional pocket of growth in North Coast counties such as Del Norte, Humbolt, Mendocino and Trinity (fig. 2). Not surprisingly, cattle production has declined in the counties that represent the major urban growth corridors within the state, particularly the central- and south-coast regions.

In 1997, 10 facilities in California reported slaughter of cattle and calves to the U.S. Department of Agriculture (USDA)(fig. 1). Only three of those process significant numbers of cattle: an IBP plant in Fresno, Harris Ranch in Coalinga and Shamrock Meats in Los Angeles. The others are small specialty operations that do not contribute importantly to the state's processing capacity. By way of contrast, 52 facilities reported slaughter of cattle and calves to USDA in 1972. Due to the rapid decline in its slaughter capacity, California is now a significant net exporter of live cattle for slaughter, with cattle being shipped to plants in locations ranging from Washington to Utah and Colorado. Long-distance shipping of cattle is costly, due both to the transportation costs and stress on the animals, so the necessity of such travel reduces the profitability of cattle production in California.

Producer survey

Only a limited amount of information specific to California cattle production can be gleaned from the standard statistical sources, so we undertook a survey of cattle producers in the state during 2000 and 2001. To facilitate the survey, we cooperated with county-level UC Cooperative Extension livestock advisors. The county personnel contributed to development of the survey and distributed the survey forms, either in-person, at trade shows or through the mail. To further encourage compliance, we kept the survey form short, one double-sided page with 12 categorical or short-answer questions, focusing primarily upon marketing issues.

In total, we received 280 completed surveys. We obtained responses from

TABLE 1. Number of cattle marketed annually by type for survey respondents

	1–50	51–150	151–300	300+	Total
Calves	109	61	36	25	231
Cull cows/bulls	181	25	4	6	216
Yearlings	82	41	20	25	168
Fed cattle	26	7	2	17	52
Total responses	398	134	62	73	

ranchers in 40 of California's 58 counties. Counties with the most respondents were Shasta (66), Stanislaus (58), Merced (58) and Calaveras (34). (A single respondent might operate, and hence be counted, in multiple counties.) We focused the survey on three regions of the state to see if there are geographic differences in industry structure and marketing opportunities. The north region was centered in Lassen, Shasta and Tehama counties. The central region focused on Stanislaus and surrounding counties, while the coastal region included counties ranging from Humboldt to Monterey. In general, our survey results indicate that average ranches in the north and central regions are virtually identical in size, herd composition and marketing strategies. Ranches in the coastal region, on average, are much smaller and more often part-time operations.

Land ownership. The vast majority of respondents (246) owned some of their own ranch land and also rented additional land in either the summer or winter. In particular, 178 rented summer land and 167 rented winter land from private parties, while 38 reported renting summer land and 12 reported renting winter land from the U.S. Bureau of Land Management or Forest Service.

Ranching experience. The average years of experience in ranching among the survey respondents was 34.9, meaning that ranching has been a lifetime operation for most and that, collectively, they represent a well-seasoned group. Most of the operations are family oriented, so the fact that many operators appear to be nearing retirement age raises questions about continuity of the operations if sons/daughters choose not to carry on the family business.

Cattle sold. We used categories of 1 to 50, 51 to 150, 151 to 300, and more than 300 to inquire about the number of cattle marketed annually by type (table 1). Ranchers in the north, central and coastal regions are primarily cow-calf operators, who specialize in raising and marketing young cattle and cull cows or bulls. In particular, relatively few engage in feedlot operations. Only 16% of respondents in the north, 20% in the central and 8% in the coastal region marketed fed cattle.

The largest category of response for all types of cattle was the 1 to 50 animal category. Such operations represent part-time businesses. In the central and north regions, calves and yearlings are the primary focus, and large operations make up a significant part of the industry. For example, in the central region, 11% of ranches sell more than 300 calves per year, and 12% of ranches sell more than 300 yearlings annually. These operations are clearly full-time business with sizeable assets invested.

Sales mechanisms. We also asked respondents to indicate the selling

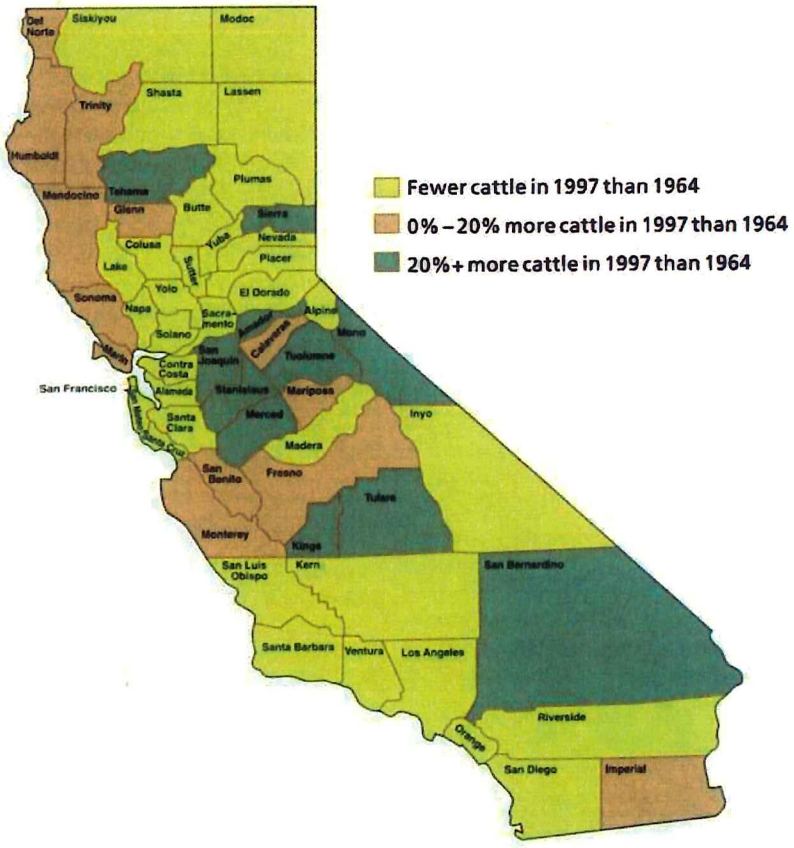
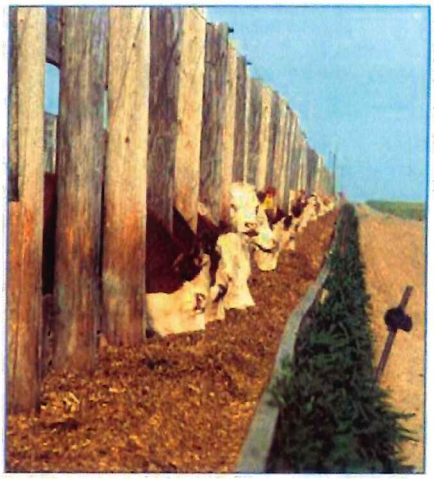


Fig. 2. Cattle and calves (excluding milk cows), percentage change in inventory levels, 1964–1997. Source: California Census of Agriculture.



Brian Prechtel-USDA/ARS

In a survey covering nearly 300 ranches in 40 counties, the authors found that only 29% of the state's cattle destined for feedlots remained in California, with the rest shipped to the U.S. Northwest, Midwest and Southwest.

mechanism they utilized to market their cattle. The predominant marketing mechanism among the respondents in all regions was the traditional, privately operated auction sale yard, which 240 reported utilizing for at least some sales. Sixty-one ranchers also indicated using an auction operated by a cattle association. One hundred five respondents reported direct sales to local buyers, with 52 reporting direct sales to regional or national buyers. Interestingly, the much-touted "high-tech" selling mechanisms, such as video and electronic auctions, were used infrequently by the respondents — 27 reported using a video auction (none from the coastal region) and only one person reported using an electronic auction.

An important point in considering the marketing tools utilized by California ranchers is that substantial economies of scale exist with respect to some selling mechanisms, including various forms of direct sales and video or electronic auctions. The standard trucks used to haul cattle accommodate, for example, upwards of 50 yearling calves. Ranchers who cannot provide at least this much volume in a sales transaction are at a competitive disadvantage. Private or cattle-association auction yards represent the primary sales outlet for these small-scale producers because buyers can rather easily aggregate small lots from various sellers to attain truck capacity. For example, among the respondents to our survey, 93 marketed more than 150 cattle annually in at least one of the four categories indicated in table 1. Among this group of larger producers, 35 (37.6%) reported sales to regional or national buyers, whereas only 17 (10.2%) of the 167 with sales of 150 cattle or less in any category were able to attract the interest of these buyers. Due to the rising concentration in the industry, it is important for ranchers to be able to access the widest pool of potential buyers possible.

Other marketing tools. Our respondents were reluctant to use futures and/or options contracts, with only 6% reporting use of these marketing tools (none from the coast). Similarly, the much discussed and disputed captive-supply mechanisms were little in evidence among our respondents, with only 8.6% reporting using either forward contracts or marketing agreements. The limited use of these marketing tools is due in part to the fact that California ranchers in most cases are not selling cattle directly to packers, where these mechanisms have been used most widely, and also due to the small scale of many respondents' operations.

Cattle destinations. Most likely due to the limited processing capacity in the state, a large portion of California production nowadays consists of young cattle, which are then sold for fattening elsewhere. This conclusion is supported by responses to a question about the cattle's destination after leaving the producers' ranch. A total of 135 respondents indicated that cattle were headed for further development on grassland, while 205 indicated that cattle were destined for a feedlot. Only 58 reported making sales directly to a packinghouse. (Totals sum to more than the number of survey responses because ranchers may have multiple destinations for their cattle.)

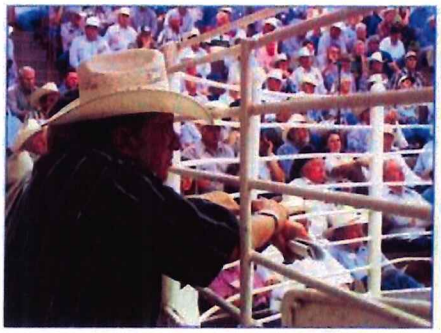
Among the cattle destined for further development on rangeland, 53% were reported to remain in California, with Northwestern states (Idaho, Oregon and Washington) representing the second-most reported destination. Among the cattle destined for feedlots, only 29% remained in California, with 19%, 16% and 12% destined for feedlots in the Northwest, Midwest (Kansas, Nebraska) and Southwest (Arizona, Nevada, New Mexico, Texas), respectively. Nearly 62% of cattle destined for packinghouses remained in California, based upon survey responses.

Potential buyers. Finally, because of the consolidation among firms in the beef sector, we asked about the number of potential buyers available to cattle producers in a given selling environment. The respondents indicated either one, two, three to five, or more than five potential buyers. The modal response (with a total of 115) was three to five buyers. Ninety-eight ranchers (more often from the central region) reported more than five buyers, with 29 reporting only one or two possible buyers. A firm consensus has not emerged among economists as to the number of0 buyers needed to create a competitive selling environment. Most, however, would agree that five or fewer buyers represent an oligopsony market setting, where buyer market power is a potential concern.

Future of California beef industry

While cattle production remains one of California's most important agricultural industries, it is now at a crossroads, for a variety of reasons. As

Photos: Kevin Devine/Shasta Livestock





Concerned about economic trends that are leaving them with a shrinking percentage of the beef dollar, cattle ranchers gathered at the Shasta Livestock Auction in Cottonwood in June to discuss futures contracts, packer concentration and improved cooperation among producers. *Left,* Duane Martin of Clements, Calif., helped organize the meeting. *Right,* Ellington Peek of Shasta Livestock looks on as Ron Anderson moderates.

noted, many operators of these predominantly family-run businesses are nearing retirement age, with uncertain prospects for continuity of the family operations. Moreover, the state's industry now consists predominantly of cow-calf ranching operations, with a significant share of cattle leaving the state for feeding and slaughter. A key factor in explaining the paucity of feeding operations in the state is California's status as a net importer of feed grains such as corn. This status was reinforced through the 1990s when significant acreage in California moved from annual crops such as corn and wheat to perennial tree and vine crops (Blank 2000). Feed grains for cattle are now grown in California primarily as a rotation crop. In practical terms, it is cheaper to incur the one-time expense of hauling the steer to the feed than to continuously haul the feed to the steer.

Because of the expense and risk of shipping fattened cattle long distances, it is economical to locate processing facilities in close proximity to feedlots, helping to explain the exodus of packing facilities from California. The transaction costs associated with out-of-state shipment inevitably place California at a competitive disadvantage relative to states (such as Colorado, Kansas, Nebraska and Texas) and regions (such as the Midwest and Southwest) that combine substantial capacity in production, feeding and processing. Moreover, the lack of local selling alternatives may place California producers in a disadvantageous competitive position in dealings with out-of-state buyers.

The rangeland utilized for cattle production in California often has few alternative uses, except other grazing operations. This fact may explain the resiliency of this segment of the cattle-beef chain, despite the generally poor economic climate for cattle production in recent years, and the mid-1990s in particular, when weak demand and the high-production phase of the cattle cycle caused most producers to lose money. Nonetheless, the long-run viability of these operations requires a stream of revenues that is at least sufficient to compensate for all costs, including opportunity costs for owned land and operator labor. Achieving such revenues will be a challenge if the state continues to operate with cost disadvantages relative to competing states. The auction yards, which provide the principal marketing outlet for most of the survey respondents, require a large volume of activity in order to operate efficiently. If some ranchers exit the business, their departure will impose external costs on those who remain by threatening the vitality of these exchange mechanisms. In turn, if spot-market exchanges wane, ranchers will be compelled to expand or consolidate to attain the selling economies needed to participate in direct sales or other high-tech selling mechanisms.

Furthermore, feedlots and packing plants are not popular enterprises in a populous and environmentally conscious state like California due to odor and waste-disposal issues. However, these operations provide favorable marketing outlets for California's ranch operators and, hence, affect the vitality of the entire cattle-beef sector. The political challenges in gaining approval for such facilities notwithstanding, the economics of these operations favor locating them in regions with extensive feed-grain production, so California is at a cost disadvantage. For a variety of reasons, there is little chance that these operations will expand in California and they may well continue to decline. California cattle ranchers must continue to search for marketing innovations that will enable them to compete effectively in a challenging environment.

M.A. Andersen is Graduate Student, S.C. Blank is Cooperative Extension Specialist, and R.J. Sexton is Professor, Department of Agricultural and Resource Economics, UC Davis; and T. LaMendola is Director of Economic Research, Western United Dairymen. Blank is Member and Sexton is Director, Giannini Foundation of Agricultural Economics. *We gratefully acknowledge the contributions to this project by Larry Forero, Franz Rolofson, Jim Farley, Marc Horney and Glen Nader, UC Cooperative Extension livestock advisors.*

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Carl F. Twisselman II
Martha M. Twisselman
Temblor Ranch
9501 Lokern Road
McKittrick, Calif. 93251
June 27, 2018

RECEIVED
JUL 03 2018
Kern County Planning &
Natural Resources D

Lorelei Oviatt, Director
Kern County Planning Commission
2700 M. Street St. 100
Bakersfield, Calif. 93301

comments on EIR for Oil exploration and production

Dear Ms. Lorelei:

I operate a cattle grazing operation on the Westside of Kern County and my family has been here grazing cattle for 150 years. We lease the grazing rights on a lot of land from oil companies, which is a very important part of our operation. We also own mineral rights on some of the land and hope to have oil and gas development on those rights at some time in the future. Oil and gas development has almost no impact on grazing land in this area, as the oil companies own most of the land that they develop, and when operating on someone else's land, their facilities take up very little space. In my case, the existence of the oil companies actually increases available grazing land, as they allow me to graze the land that is not under production.

Land on the westside is of very low productive value, it takes 40 acres to produce enough feed for one cow for one year. When drilling a well, the oil company uses about one acre of land, within three years after completion, most of that one acre begins to produce grass again.

Any loss of grazing land from oil and gas production in Kern County would be insignificant and would not impact the environment in any way. I would like to see the deletion of any requirement for mitigation for loss of grazing land due to oil and gas production.

The taxes from oil production are the life-blood of every governmental agency that provides services on this side of the valley, and certainly plays an important role in income to Kern County. There are already too many restrictions and added costs on oil production, I ask you not to add any more.

As to whether or not paving a dirt road reduces air emission particulates, there is no question that it does. Anyone who says it does not must have never driven on a dirt road in Kern County. Whomever argues against that most likely wants the mitigation money rather than cleaner air.

Sincerely,

Carl F. Twisselman II

phone 661-762-7528 cell 661-747-4379 email carlt2@hughes.net

Office Memorandum

KERN COUNTY

To: Planning Department
Cindi Hoover

Date: June 4, 2018

From: Public Works Department
Floodplain Management Section
Kevin Hamilton, by Brian Blase

Phone: (661) 862-5098
Email: BlaseB@kerncounty.com

Subject: Notice of Preparation of a Draft Environmental Impact Report
Approved Amendments to Title 19 – KC Zoning Ordinance (2015C)

From the information supplied, we have no comments or recommendations regarding the above project.

COUNTY OF KERN
PUBLIC WORKS DEPARTMENT
Office Memorandum

To: Lorelei Oviatt, Director
Planning and Natural Resources Department
Attn: Cindi L Hoover, Planner I

June 20, 2018

From: Warren D. Maxwell, Development Review Engineer
Building and Development Division

Subject: 7-5.3 Notice of Preparation of a Draft Supplemental Environmental Impact Report for Approved Amendments to Title 19 – Kern County Zoning Ordinance (2015C) Focused on Oils and Gas Permitting.

This Department has reviewed subject project and has no comment.

Thank you for the opportunity to comment on this project, if you have any questions or comments please contact Paul Candelaria at this Department.

NORTH of the RIVER
NOR
recreation & park district
JOIN THE FUN!

June 27, 2018

Ms. Lorelei H. Oviatt AICP
Kern County Planning and
Natural Resources Department
2700 M Street, Suite 100
Bakersfield, California 93301

SUBJECT: Notice of Preparation of a Draft Supplemental Environmental Impact Report

Dear Ms. Oviatt:

The above referenced Supplemental Environmental Impact Report for approved amendments to Title 19-Kern County Zoning Ordinance (2015C) focused on oil and gas local permitting will have no impact to North of the River Recreation and Park District's services or facilities.

Thank you for the opportunity to review this project.

Sincerely,

Stephanie Sanders, PLA, ASLA
Landscape Architect & Park Planner

SMS:bc

Lorelei H. Oviatt, AICP, Director
2700 "M" Street, Suite 100
Bakersfield, CA 93301-2323
Phone: (661) 862-8600
Fax: (661) 862-8601 TTY Relay 1-800-735-2929
Email: planning@co.kern.ca.us
Web Address: http://pcd.kerndsa.com/

PLANNING AND NATURAL RESOURCES DEPARTMENT

Planning
Community Development
Administrative Operations

NOTICE OF PREPARATION

DATE: May 31, 2018

TO: See Attached Mailing List

FROM: Kern County Planning and
Natural Resources Department
Attn: Lorelei H. Oviatt AICP
2700 "M" Street, Suite 100
Bakersfield, CA 93301 (661) 862-8866
Loreleio@kerncounty.com

RE: NOTICE OF PREPARATION OF A DRAFT SUPPLEMENTAL ENVIRONMENTAL IMPACT REPORT

The Kern County Planning and Natural Resources Department, as Lead Agency (pursuant to California Environmental Quality Act [CEQA] Guidelines Section 15050 *et seq.*) has determined that preparation of a draft Supplemental Environmental Impact Report (SEIR) (pursuant to CEQA Guidelines Section 15162) is necessary for the project identified below. The Planning and Natural Resources Department solicits the views of your agency as to the scope and content of the environmental information which is germane to your agency's statutory responsibilities about the proposed project. Your agency will need to use the SEIR prepared by our agency when considering your permit or other approval of projects.

Due to the limits mandated by State law, your response must be received by **July 2, 2018 at 5:00 pm.** In addition, comments can be submitted at a scoping meeting to conducted by the Department :

SCOPING MEETING : June 15, 2018 - Friday at 1:30 p.m
Kern County Planning and Natural Resources Department
2700 M Street Room 1 A
Bakersfield California 93301

PROJECT TITLE: Supplemental Environmental Impact Report for Approved Amendments to Title 19 – Kern County Zoning Ordinance (2015 C) Focused on Oil and Gas Local Permitting.

PROJECT LOCATION: The project boundary encompasses approximately 3,700 square miles (approximately 2.3 million acres) and generally includes the San Joaquin Valley Floor portion of Kern County, up to an elevation of 2,000 feet. The boundary includes: west side – the San Luis Obispo County line; north side- the Kings and Tulare county lines, east side – the 2,000-foot elevation contours, squared off to the nearest section line; and south side – the northern boundary of the Los Padres National Forest..

PROJECT DESCRIPTION: The action consists of the preparation of a Supplemental Environmental Impact Report (SEIR) for approved amendments to Title 19 of the Kern County Zoning Ordinance (2015C) (Ordinance) focused on Oil and Gas local permitting for text amendments to various chapters, which include site development standards and permitting procedures for oil and gas exploration, extraction, operations, and production activities in unincorporated Kern County. The County certified a final Environmental Impact Report (EIR), and approved the amendments to the Ordinance, on November 9, 2015.

Several parties filed lawsuits challenging the adequacy of the certified EIR, and the cases were consolidated before Judge Eric Bradshaw of the Kern County Superior Court (*Vaquero Energy, Inc. et al. v. County of Kern et al.*, *King & Gardiner Farms LLC v. County of Kern et al.*, and *Committee for a Better Arvin et al. v. County of Kern et al.*, Kern County Superior Court Case No. BCV-15-101645, consolidated with Case Nos. BCV-15-101666 and BCV-15-101679). On April 20, 2018, the Court issued a judgment (Judgment) that upheld the EIR in its entirety except for requiring supplemental analysis under the California Environmental Quality Act (CEQA) for two issues: (i) impacts to rangeland/grazing land, and (ii) impacts from road paving as a potential future means of mitigation to reduce designated air emissions. The Judgment did not vacate any portion of the Ordinance or the EIR. Pursuant to the Judgment, the Court issued a writ of mandate (Writ) to the County that states:

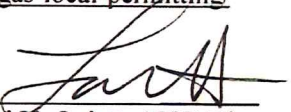
> (a) Within 45 days from service of the writ of mandate, County shall transmit to the San Joaquin Valley Air Pollution Control District copies of this court's Ruling, this judgment, and the related peremptory writ of mandate.
>
> (b) Consistent with the Ruling and the procedures set forth in CEQA and CEQA Guidelines, County shall prepare such analysis as is necessary to address the EIR's deficient analysis of the Project's (i) environmental impacts to rangeland/grazing land, and (ii) environmental impacts from road paving as an air emissions mitigation measure ("Supplemental Analysis"). In the event the Supplemental Analysis determines that any such environmental impacts are potentially significant, the Supplemental Analysis shall identify feasible mitigation measures and/or alternatives to mitigate or avoid such impacts consistent with CEQA's requirements, unless County makes findings of infeasibility and overriding considerations as provided by CEQA.
>
> (c) Upon completion of the Supplemental Analysis described in Part 2(b) above, County shall: (i) reconsider its approval of the Project and its Statement of Overriding Considerations adopted in connection with that project, in light of any new information in the Supplemental Analysis, and (ii) take any and all further action that may be necessary to bring the approval of the project and the related findings and mitigation monitoring and reporting program into compliance with CEQA.

Consistent with the Writ, the County will prepare a draft Supplemental Environmental Impact Report (SEIR), pursuant to CEQA Guidelines Section 15162, to address potential environmental impacts to rangeland/grazing land. Cattle and sheep grazing have historically occurred, and are expected to continue within the project area, including at locations affected by future oil and gas operations under the amended Ordinance. As required by the Court, the SEIR will address the project's potential environmental impacts to grazing/rangelands and identify feasible mitigation measures and/or alternatives to mitigate or avoid impacts determined to be potentially significant. Consistent with

CEQA, the County may also make findings of infeasibility and overriding considerations for any such impacts. The certified EIR provided a comprehensive analysis of all probable environmental effects of the project, and the Judgment upheld the EIR in its entirety except for the two narrow issues discussed above. The Vaquero Judgment did not vacate any portion of the Ordinance or the EIR.

On May 16, 2018, the County transmitted a copy of the Judgment to the San Joaquin Valley Air Pollution Control District (District), as directed by the Court. As discussed in the transmittal letter to the District (see Attachment A), road paving was identified in the County's staff report and in the EIR as an example of a potential future means of mitigation to offset criteria emissions that could potentially be undertaken by a permit applicant under Mitigation Measure (MM) 4.3-8 in the adopted EIR and Mitigation Monitoring and Reporting Program (MMRP) for the project. Road paving is not an approved air quality mitigation measure in the EIR or the Ordinance. Appendix M-3 of the EIR includes a draft Emission Reduction Agreement (ERA) (which was executed by the County District in August 2016) that sets forth the required procedures for considering road paving and any other potential direct emission reduction activities by applicant (air emission offset) as an alternative to paying some portion of air quality mitigation fees. Pursuant to the ERA, road paving could have been accepted as an air emission offset if and only if in the future both the District and the County accepted a future applicant request for an approved protocol for quantifying the emission reduction benefits of road paving. The County's attached transmittal letter to the District confirmed that any project applicant request for recognition of emission reduction offsets for road paving will require future discretionary approvals by the County and District, will further trigger the need for additional environmental review and compliance with CEQA, and that the County has declined to approve of road paving as a potential future applicant air emission offset. Any future road paving request must first be submitted to the County, which will coordinate with the District and complete the CEQA process, inclusive of public notice and outreach, prior to making a determination as to whether or under what conditions road paving would be eligible as a direct applicant emission reduction activity at the conclusion of the required CEQA process. Since road paving is not authorized as an air emission offset in either the Ordinance or EIR, and no changes to the Ordinance or EIR are required by the Judgment, the SEIR will not address potentially significant impacts of road paving.

Documents can be viewed online at : https://kernplanning.com/final-environmental-impact-report-revisions-kern-county-zoning-ordinance-2015-c-focused-oil-gas-local-permitting/

Signature: 

Name: Lorelei H. Oviatt, AICP Director

Appendix E

AECOM Imagine it. Delivered.

AECOM
300 Lakeside Drive, Suite 400
Oakland, CA, 94612
aecom.com

To:
Lorelei H. Oviatt, AICP
Kern County Planning and Natural Resources

Date:
August 7, 2018

From:
Dina Robertson, Steve Leach, and Galen Peracca

Subject: Current Condition of Grazing Lands in the Southern San Joaquin Valley, Kern County CA

Introduction

This memorandum (memo) describes the current condition and factors affecting grazing lands in the southern San Joaquin Valley of California, with a focus on the structure and composition of vegetation within "Tier 1" areas, as described in the Kern County Oil and Gas Environmental Impact Report (EIR) (Kern County 2015). As defined in the Oil and Gas EIR, Tier 1 areas are portions of Kern County in which oil and gas production is the primary land use. These areas are found on the valley floor of the southern San Joaquin Valley as well as the adjacent terraces and hills. The discussion of changing vegetation conditions presented below is informed by published land use histories and technical literature.

Pre-European Vegetation

Alkaline soils of the valley floor were originally dominated by bunchgrasses, such as *Sporobolus airiodes,* that are tolerant of high salinity (Minnich 2008). At slightly higher elevations adjacent to the valley floor, alluvial terraces and hills supported grasslands and alkali desert scrub (Kern County 2015; URS 2004). Within the Tier 1 area alkali desert scrub species originally included desert saltbush (*Atriplex polycarpa*), fourwing saltbush (*A. canescens*) and spiny saltbush (*A. spinifera*) (Spiegal 2015). Grasslands on non-alkaline soils above the valley floor were originally dominated by annual forbs, with scattered perennial grasses in specialized sites with enhanced water availability (Minnich 2008, Mooney and Zavaleta 2016, Spiegal 2015). Many of the small mammals in the valley evolved in these open vegetation types that had substantial bare ground.

Changes to Grazing Lands Following European Settlement

Livestock grazing during the Mexican Era consisted of large numbers of domestic livestock, usually cattle or sheep, grazing large expanses of land. On the valley floor the primary forage for cattle included saltgrass (*Distichlis spicata*) and *Atriplex* shrubs, and in the drier, upland areas forage likely consisted of annual grasses, forbs and *Atriplex* shrubs. Due to low rainfall and the vegetation composition of the valley floor and adjacent areas, forage productivity of these lands is relatively low with the highest productivity during the late winter-early spring (depending on rainfall amounts), and declining productivity in the late spring, summer and fall.

There is some dispute about the initial effects of livestock grazing on the pre-European landscape of California. Even before livestock were introduced to the southern San Joaquin Valley, early Spanish explorers who scouted inland areas during early expeditions of California in the 1770's noted the

widespread presence of certain European plant species. One such recorded species is the now ubiquitous filaree (*Erodium cicutarium)* (Minnich 2008). Establishment of filaree and other European plant species may be attributed to their rapid early season growth, drought tolerance, high seed production and earlier seed establishment rather than to the introduction of domestic livestock (D'Antonio et. al 2007).

Grazing practices in the southern San Joaquin Valley changed in the 1850s to meet increased demand for beef during the California gold rush period. The southern San Joaquin Valley was actively grazed year-round instead of seasonally, and stocking rates increased dramatically, and stayed high, until the end of the gold rush. These grazing practices were unsustainable in the southern San Joaquin Valley due to the low productivity and seasonal nature of forage growth. California experienced a five-year flood-drought sequence from 1860 through1865 that led to the collapse of open-range cattle grazing in the state (Minnich 2008). The overstocking of the range combined with the drought presented ideal conditions for European annual plant species that arrived during gold rush period to spread throughout the valley.

From the late 1800's through the early 20th Century, nonnative annual grasses, in particular the bromes (*Bromus tectorum, B. madritensis ssp. mardritenses, B. tectorum, B. hordeacous*), rapidly expanded their range and achieved co-dominant status in California inland grasslands (Minnich 2008). Other species that concurrently expanded rapidly in California grasslands include oats (*Avena* sp.), mustard (*Brassica* sp.), bur clover (*Medicago polymorpha)* and common fescue (*Festuca myuros*) (Minnich 2008). Grazing lands in the southern San Joaquin Valley are currently dominated by non-native annual grasses and alkali desert scrub with an understory of red brome (*B. madritensis*). The predominance of nonnative grasses (in particular, the nonnative bromes) produces a higher concentration of dry biomass (thatch) that increases the frequency and intensity of wildland fires compared to native shrub-dominated vegetation.

The increase in non-native annual species corresponds with a decline in some wildlife species including special status species (National Research Council, 1995). Many of the ground-dwelling special status species in the southern San Joaquin Valley require habitats that include bare ground or very short vegetation heights. Examples include special-status wildlife species such as blunt-nosed leopard lizard, Tipton kangaroo rat and giant kangaroo rat. Germano et al (2010) documented an inverse relationship between increased herbaceous vegetation and populations of ground-dwelling special status species. For example, open habitats allow species like the blunt-nosed leopard lizard to effectively escape predators; however, in dense grasslands this species is easily captured (Germano et al., 2001). Similarly, Fresno and Tipton kangaroo rats appear intolerant of dense grass cover (Williams and Germano, 1992). Kangaroo rats generally prefer open habitats that allow them to travel unimpeded (Goldingay et al., 1997).

Conclusion

The following anthropogenic changes have had a notable effect on the species composition and productivity of grazing lands in the Tier 1 areas and adjacent portions of the southern San Joaquin Valley:

- The increased accumulation of fuels (e.g. thatch) associated with introduced annual herbaceous species has increased the fire frequency in shrub dominated communities and reduced the cover of native annual species (grasses and forbs).
- The San Joaquin Valley receives as much as 10 kg nitrogen per hectare per year, which is one of the highest levels of atmospheric nitrogen deposition in the state (Viers et al., 2012). Nitrogen deposition is believed to increase the competitive advantage of nonnative grasses in some ecosystems.

- Recently introduced, aggressive nonnative invasive plants, such as medusahead (*Elymus caput-medusae*), jointed goat grass (*Aegilops cylindrica*) and yellow star thistle (*Centauria solsitsialis*) continue to invade valley grasslands and pose a risk to livestock grazing, as all three species have the potential to create monocultures in areas they colonize that exclude native and nonnative forage species.
- Increased vegetation cover potentially degrades the suitability of natural habitats utilized by wildlife, including special status species such as the blunt-nosed leopard lizard and some kangaroo rats. Many of the ground-dwelling special status species in the Valley require bare ground or shorter vegetation heights typical of pre-European shrub-dominated vegetation types.

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Appendix F

WSPA
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Suzanne Noble
Director, Production Operations

Date: June 27, 2018

To: Kern County Planning Department

From: Suzanne Noble

RE: **Grazing Lease Information for Draft Supplemental Environmental Impact Report – Kern County Oil and Gas Zoning Ordinance**

At the County's request, for purposes of preparing the Draft Supplemental Environmental Impact Report for Revisions to the Oil and Gas Zoning Ordinance 2015(C) focused on Oil and Gas Local Permitting, we are providing the following information on livestock grazing leases on lands owned by oil and gas operators.

We reviewed information on acres leased for livestock grazing by nine operators. Seven of the operators lease a total of 108,090 acres in Kern County for grazing. The seven operators providing acreage data include the County's largest three oil and gas operators by volume of annual production. The average number of acres leased per operator is 15,441 acres, ranging from 640 to 37,000 acres. Two other operators (not included in the average) do not lease land for grazing.

In addition, we reviewed sample grazing leases provided by four operators to identify typical lease provisions. A typical grazing lease contains the following provisions:

1. Parties.
2. Leased land description.
3. Lease term.
4. Rent.
5. Lessee will maintain leased premises, including fences, water tanks and other improvements, in good condition.
6. Lessee may construct specified improvements, e.g., fences; or lessee may construct improvements with lessor approval.
7. Lessee will remove improvements at lease termination, unless lessor consents to improvements remaining.
8. Lessee will provide water for livestock.
9. Grazing must be conducted in a prudent manner and not interfere with lessor's operations.

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10. Lessee will take reasonable steps to control erosion, fire hazards and weeds. Some but not all leases require compliance with U.S. Department of Interior, Bureau of Land Management's *Central California Standards for Rangeland Health and Guidelines for Livestock Grazing Management*, attached to this memo for reference.
11. Lessor retains right of access and right to explore, drill and produce minerals, construct roads, pipelines, etc.
12. Insurance and indemnity provisions.
13. Procedural provisions including assignment, notice, governing law, etc.

If you have any questions, please contact me at 661-319-6340.

Sincerely,

Suzanne Noble

Appendix G





