Appendix 23D
Criteria Pollutant Health Impact Assessment Methodology

23D.1 Introduction

This appendix discusses the approach and methodology used to assess potential community health impacts from the criteria pollutants associated with the construction activity from the Delta Conveyance Project (project). As discussed in Chapter 23, *Air Quality and Greenhouse Gases*, potential changes health risks during operations and maintenance (O&M) are assessed qualitatively. The overall project is geographically dispersed over a broad area covering four air districts, with construction emissions spanning 12 to 14 years, depending on the alternative. The project therefore is not suitable for a screening-level community health assessment, as discussed in the Sacramento Metropolitan Air Quality Management District's (SMAQMD) *Guidance to Address the Friant Ranch Ruling for CEQA Projects* (Ramboll 2020).

This appendix provides details on a modeling methodology used to prepare a Health Impact Assessment (HIA) for construction of the project. In general, the methodology broadly follows the approach discussed in Appendix A of SMAQMD's guidance. The following key activities and methods are discussed in this appendix.

- Selection of an air quality model and air quality modeling database used in the analysis and HIA model.
- Estimating the ozone precursor and particulate matter (PM, or PM10 and PM2.5) emissions for the project.
- Processing of the project emissions for use in the selected air quality model.
- Air quality modeling of the project emissions that are used to determine the incremental ozone and PM concentrations due to the project's emissions, as these are the drivers to the principal health effects.
- Processing of the incremental ozone and PM concentrations due to the project's emissions by a health effects model to estimate the mortality, morbidity, and other health effects.

Emissions from the project include nitrogen oxides (NO_X), volatile organic compounds (VOCs), PM10, PM2.5, sulfur dioxide (SO_2), and carbon monoxide (CO). While VOCs are not criteria air pollutants, they are precursors to the formation of secondary pollutants of ozone and fine PM (typically nitrates and sulfates) in the atmosphere and so are included in the analysis. CO emissions are also included because they play a small role in the formation of ozone. Ozone and fine PM are formed in the atmosphere through a set of complex nonlinear photochemical reactions involving NO_X and VOCs in the presence of sunlight.

23D.2 Air Quality and Health Impact Assessment Models

A photochemical grid model (PGM) is the best approach available for characterizing the spatial and temporal variations and analyzing the sensitivity of ozone and secondary PM2.5 formation to their precursor emissions. The U.S. Environmental Protection Agency (EPA) modeling guidance does not recommend specific PGMs nor does California Air Resources Board (CARB), but EPA provides procedures for determining an appropriate PGM on a case-by-case basis. EPA's air quality modeling guidelines and guidance acknowledges that both the Comprehensive Air-quality Model with extensions (CAMx) and the Community Multiscale Air Quality (CMAQ) PGMs have been used extensively in past studies throughout the United States and in California. EPA uses the health effects modeling tool based on selected concentration response (C-R) functions embedded within Environmental Benefits Mapping and Analysis Program—Community Edition (BenMAP-CE) model to assess emission impacts on the incremental change in ozone and fine particulate concentrations (U.S. Environmental Protection Agency 2021).

23D.2.1 Air Quality Model Database

The development of modeling inputs for PGM modeling is resource intensive. It is almost always more effective to use an appropriate existing PGM modeling platform and doing so avoids having to develop a new emission inventory, meteorological fields, and a model performance evaluation. CARB and several air districts in California routinely develop PGM modeling databases to address ozone and PM2.5 attainment as part of their State Implementation Plans (SIPs). The HIA used a 2016 base year high-resolution 4 kilometer (km) by 4 km modeling platform developed by the Bay Area Air Quality Management District (BAAQMD). The BAAQMD modeling domain covers the entire Delta Conveyance Project study area and the potential communities affected by the project emissions (Figure 23D-1 and Table 23D-1). The BAAQMD's PGM database is tailored for California using California-specific input tools (e.g., the Emissions Factor [EMFAC] mobile source emissions model).

BAAQMD used the Weather Research and Forecasting (WRF) meteorological model (version 3.8) (Section 23D.2.2.1, *Weather Research and Forecasting (WRF)*) to develop meteorological fields for the 2016 base year. The Sparse Matrix Operator Kernel Emissions (SMOKE) emissions model (version 4.5) was used to develop a gridded emission inventory for 2012, which was projected to 2016 base year. The project PGM modeling analysis uses the same BAAQMD WRF meteorological files and SMOKE emissions files for all non-project emissions (i.e., background emissions). The same lateral boundary conditions and initial condition files are used for this project.

Future year emission inventories of non-project emission sources were developed using CARB's County-level emissions by species and source category from CARB's CEPAM (Carter 2010). These were used to project the 2016 emissions to a future year using the SMOKE (Section 23D.2.2.2, *Sparse Matrix Operator Kernel Emissions (SMOKE)*. The future year for growing the non-project emissions is based on the project construction year with the highest annual average emission rates, which is construction year 7. In a few locations, project emissions are slight greater in years beyond construction year 7, but when combined with non-project emissions, year 7 remains the analysis year with the greatest overall emissions.

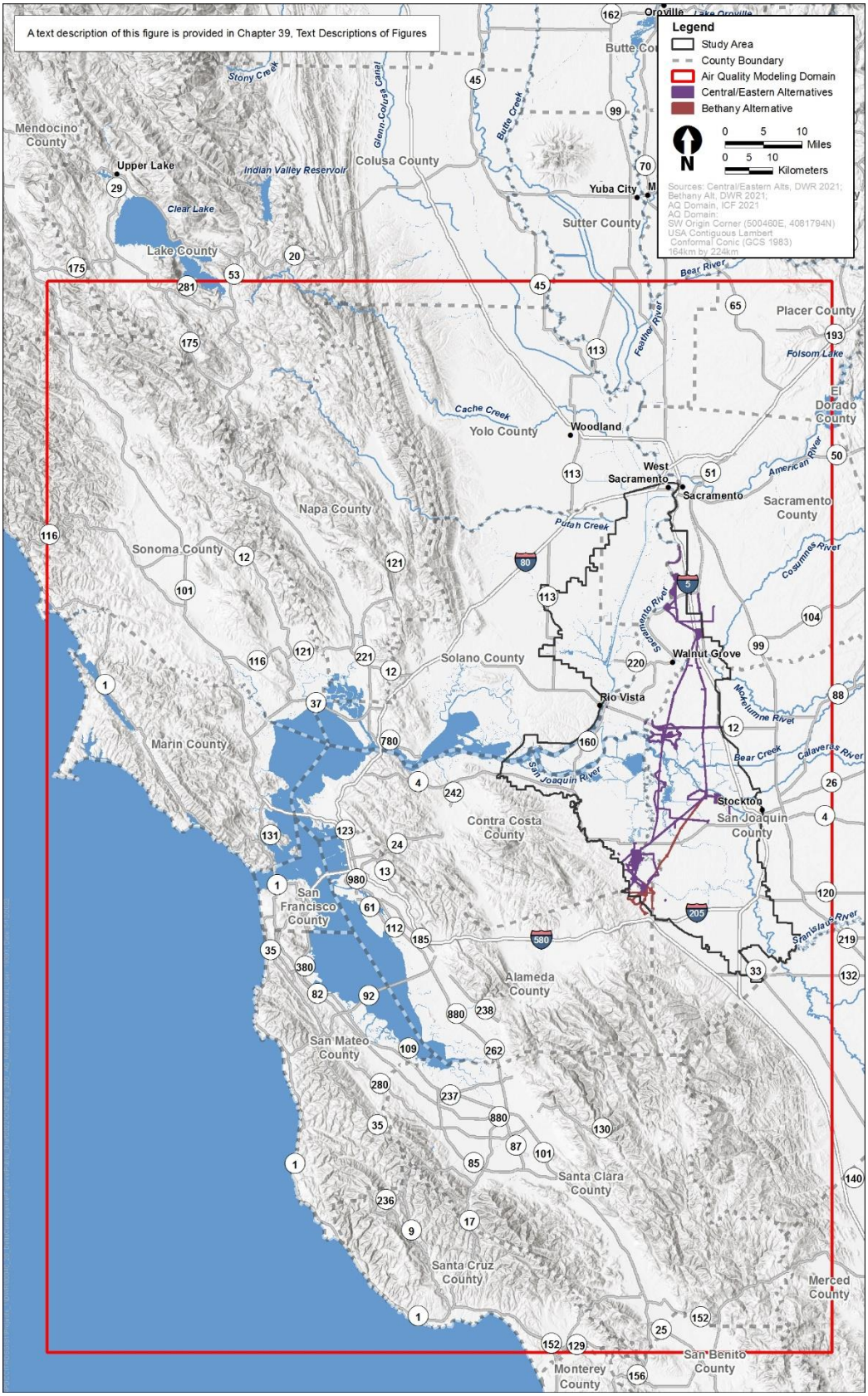


Figure 23D-1. Health Impact Assessment Air Quality Model Database Domain Relative to the Project

Table 23D-1. Definition of the 4x4-km Air Quality Model Database Domain for Photochemical Grid Modeling

Parameter	Value			
Projection	Lambert-Conformal Conic			
1st True Latitude	30 degrees N			
2nd True Latitude	60 degrees N			
Central Longitude	120.5 degrees W			
Latitude of Origin	37 degrees N			
Domain	NX	NY	X-Offset Origin (km)	Y-Offset Origin (km)
BAAQMD 4-km domain	41	56	-220	-16

km = kilometer; N = north; NX = number of grid cells in the east-west direction; NY = number of grid cells in the north-south direction; W = west.

23D.2.2 Model Selection

23D.2.2.1 Weather Research and Forecasting (WRF) Meteorological Model

The WRF model is a mesoscale numerical weather prediction system. WRF uses data assimilation techniques combining prognostic techniques with observations to provide high-resolution physically consistent meteorological fields. The WRF model has been a collaborative partnership, principally among the National Center for Atmospheric Research (NCAR), the National Oceanic and Atmospheric Administration, the National Centers for Environmental Prediction and the Forecast Systems Laboratory, the Air Force Weather Agency, the Naval Research Laboratory, the University of Oklahoma, and the Federal Aviation Administration. WRF is a publicly available weather forecast model with full documentation and has demonstrated success in simulating meteorological fields used in PGMs. The WRF model generates meteorological parameters required by the PGM, including hourly wind speed and direction, temperature, humidity, cloud cover, rain, and solar radiation. The WRF fields were developed and extensively evaluated by BAAQMD (2019). Because the model has been extensively tested and evaluated, the WRF meteorological output files were used in the PGM modeling for this assessment.

23D.2.2.2 Sparse Matrix Operator Kernel Emissions (SMOKE)

SMOKE is an emissions modeling system that generates hourly gridded speciated emission inputs of mobile, non-road, area, point, fire, and biogenic emission sources for PGMs (University of North Carolina 2018). SMOKE is principally an emission processing system whose purpose, except for mobile and biogenic sources, is to provide an efficient tool for converting an existing base emissions inventory data that is typically at the county or point-source level into the hourly gridded speciated emission files using spatial allocation surrogates for input into the PGM. Because of the model's flexibility and linkages to the PGM model, SMOKE was used to fully develop the gridded speciated emissions needed for the PGM input.

23D.2.2.3 Photochemical Grid Model (PGM)

PGMs simulate air concentrations using emissions from all sources, including all anthropogenic and biogenic sources. All sources are needed because of the nonlinear chemistry that occurs in the formation of ozone and fine particulate matter. As discussed earlier, there are two models widely available and tested extensively for photochemical modeling: CAMx and CMAQ. CAMx was selected because of greater flexibility available in developing inputs to the PGM. CAMx is a state-of-science multiscale PGM capable of addressing ozone, PM, acid deposition at urban and local scale typically for period of a year. CAMx is a publicly available open-source computer modeling system for the integrated assessment of gaseous and particulate air pollution. CAMx is designed to (1) simulate air quality, (2) treat a wide variety of inert and chemically active pollutants including ozone, and inorganic and organic PM2.5 and PM10, (3) provide source-receptor analyses and (4) is computationally efficient and easy to use. The current version of CAMx (7.11), which was released in January 2021, was used in the analysis. The model has been widely used in California by multiple air districts, in assessing both ozone and secondary PM impacts.

There are several approaches that can be used to determine the incremental contribution of emissions from the project to ozone and PM concentrations. Source apportionment methods can be used to alleviate the problem of determining relatively small differences between two model runs but comes at significantly increased computation burden. Construction emissions generated by the project are relatively small compared to the county total emissions; however, they tend to be clustered at a few locations making a clear signal when looking at differences between alternatives. Because emission differences were large enough between alternatives and the base case, analysts used the Brute Force Method in the HIA (discussed further below).

23D.2.3 Base Year Inputs and Model Configuration

CAMx requires gridded, hourly emissions inputs, meteorological inputs, land-use data, photolysis rates, ozone column data, initial and boundary conditions to drive the simulation. This section summarizes the procedures used in developing the meteorological, emissions, and air quality inputs used in assessing the impacts from the Project.

The 2016 modeling databases were developed by the BAAQMD for the CMAQ. The CMAQ annual 2016 modeling database and a full set of hourly l 2016 WRF meteorological model output files were obtained from the BAAQMD. The following subsections discuss how the data was processed.

23D.2.3.1 Meteorological Inputs

The WRF meteorological model output data was processed to provide inputs for the CAMx. The WRFCAMx processor utility maps WRF meteorological fields to the format required by CAMx. It also calculates turbulent vertical exchange coefficients (K_z) that define the rate and depth of vertical mixing in CAMx.

The general steps in the WRFCAMx processing include:

- Reading in meteorological model output files.
- Extracting meteorological data for the air quality modeling domain.
- Interpolates meteorological variables from WRF grid “cross” points to CAMx grid cell centers.
- Computing K_z.

- Output the meteorological fields in the formats used by CAMx.

The meteorology remains the same in both the base year and future year. The WRF model employs a terrain-following coordinate system normalized by pressure, using multiple heights (50) from the surface to 50 millibars (approximately 18 km above ground level). This was reduced to 28 vertical layers for the CAMx simulations. Below 1,500 meters, the CAMx layers match the WRF vertical structure, while some of the upper-level meteorological model layers above 1,500 meters are collapsed in the preparing meteorological inputs for CAMx to reduce computational time. This is a common practice in air quality modeling, as pollutant levels in layers aloft are relatively low and do not significantly affect concentrations at the surface at these regional scales.

23D.2.3.2 Initial and Boundary Conditions Data

Lateral and initial boundary conditions were provided from the larger outer domain used by the BAAQMD in their modeling analysis. That domain covers the San Francisco Bay Area, San Joaquin Valley, and Sacramento Valley, as well as portions of the Pacific Ocean and the Sierra Nevada. That outer domain was initialized, and its boundary conditions were updated every 6 hours using outputs from a global air quality model (MOZART), available from the NCAR. The MOZART Version 4 model is a global photochemical model developed by NOAA, NCAR, Geophysical Fluid Dynamics Laboratory and others. Seven days of spin-up was used to minimize the effects of the initial conditions.

23D.2.3.3 Photolysis Rates

Additional data needed for the modeling include ozone column data. The CAMxO3MAP program reads the ozone mapping and profile suite ozone column e data (as provided by BAAQMD) and interpolates to fill gaps and generates gridded daily ozone column input data for use in CAMx radiative transfer module to calculate photolysis rates.

23D.2.3.4 CAMx Configurations

Table 23D-2 provides the CAMx configuration used for the project modeling.

Table 23D-2. CAMx Model Configurations

Science Options	CAMx	Comment
Model Code	CAMx V7.1 – Jan 2021	
Horizontal Grid	4-km one-way	
1 km grid	41 columns x 56 rows	
Vertical Grid	28 vertical layers up to ~ 18 km	Collapsed from 50 WRF layers to 28
Initial Conditions	Extracted from the 4-km grid initial conditions used by BAAQMD	7-day spin-up
Boundary Conditions	Extracted from the BAAQMD 4-km outer grid	
Photolysis Rates	Photolysis Rate Look-up table	Based on ozone column data from NOAA's Ozone Mapping and Profiler Suite available daily. (National Oceanic and Atmospheric Administration Center for Satellite Applications and Research 2019)

Science Options	CAMx	Comment
Aerosol-phase chemistry	ISORROPIA (inorganic aerosol) SOAP v2.2 (organic aerosol)	
Gas Phase Chemistry	SAPRC07	SAPRC 2007 chemical mechanism
Meteorological Processor	WRFCAMX 5.1	Outputs processed as NetCDF files
Horizontal Diffusion	K-theory, eddy diffusion algorithm	
Vertical Diffusion	K-theory	Lower limit dependent on land cover
Gas Phase Chemistry Solver	Euler Backward Iterative Fast Solver	
Vertical Advection	Eulerian continuity equation	
Horizontal Advection scheme	Piecewise Parabolic Method	

BAAQMD = Bay Area Air Quality Management District; km = kilometer; NOAA = National Oceanic and Atmospheric Administration.

23D.2.4 Emissions Processing

23D.2.4.1 No-Project Emissions

The BAAQMD's 2016 CMAQ 2-D and in-line point emissions files were converted to CAMx merged low-level and point-source emission files using the CMAQ2CAMx interface program. Emissions were escalated to the highest project emission year using county pollutant source category-growth factors derived from CEPAM. Both growth factors and control factors were applied. Emissions of criteria pollutant precursors were speciated for the SAPRC07 (Carter 1994, 2010) photochemistry mechanism using SOAP2.2 (organic) and ISORROPIA (inorganic) aerosol chemical mechanisms. The speciation profiles are compatible with the SAPRC07TC chemical and aerosol mechanism for PM2.5 and are consistent with the emissions used in the BAAQMD's modeling system. SMOKE processing resolves the annual emissions to a monthly, day-of-week and hour-of-day timescale for photochemical modeling. These allocations are determined from the particular source category, specified by the Emission Inventory Code (EIC). Monthly, weekly, and diurnal profiles are cross-referenced to EIC in the SMOKE processing to provide the appropriate temporal resolution.

23D.2.4.2 Project Emissions

The maximum annual emissions of criteria pollutants and their precursors from project construction were used in the analysis. Construction emissions of NO_X, VOC, and PM2.5 were included as well as CO and SO_2. For PGM modeling, the project emissions must be converted into the hourly gridded speciated emission inputs in the format used by the PGM. This was accomplished using the SMOKE modeling system, as discussed below.

23D.2.4.3 SMOKE Emissions Modeling of Project Emissions

The first step in the SMOKE emissions processing is to convert the project emission inventory into a flat file format for input to SMOKE. Each emissions process (e.g., off-road equipment) is assigned an appropriate EIC that is then used to cross-reference to that particular source sector's chemical speciation and temporal allocation profile (U.S. Environmental Protection Agency n.d.; California Air

Resources Board 2021). Approximately 1,500 unique EIC codes are used in the analysis depending upon pollutant. Chemical speciation was performed using the SAPRC07 chemical mechanism. Temporal allocation takes the emissions and distributes them to month of year, day of week and hour of day using typical temporal profiles for each source sector as defined by the EIC.

As part of the analysis, the project source emissions are spatially allocated to appropriate geographic locations (i.e., 4x4-km grid cells). The emissions were allocated to modeling grid cells using gridding surrogates for non-project emissions. For project emissions they were allocated — based on the known location where the construction-related emission will occur in the appropriate grid cell(s). For mobile source emissions associated with transport of the material to the project site, the surrogate distributions were developed using the EPA's Spatial Allocation Tool, which combines geographical information system (GIS)-based data (shapefiles) and modeling domain definitions to generate the appropriate gridded surrogate data set. In SMOKE, the project sources are assigned specific surrogates for gridding by cross-referencing the EICs. All onsite project emissions were distributed in the modeling grid cell(s) where the project was located.

The final step in the emissions processing was to merge the project gridded emissions with other regional components through the gridded merge program (MRGUAM) for CAMx.

23D.2.5 Quality Assurance/Control

Standard quality assurance/quality control (QA/QC) of the SMOKE processed emissions was conducted as part of the review process. The steps undertaken in this process followed the approach recommended in EPA's (2007) modeling guidance. SMOKE includes quality assurance (QA) and reporting features to keep track of the adjustments at each processing stage and ensure data integrity. The SMOKE log files were reviewed for error messages to ensure that appropriate source profiles were used in the analysis. All error records reported during processing were reviewed and all discrepancies resolved. This ensures that source categories are correctly characterized. A key step in the QA/QC process is to compare SMOKE input and output emissions to make sure no emissions are dropped or added during the processing. Summary tables of emissions were reviewed to compare input inventory totals against model-ready output totals to ensure consistency. Spatial plots were generated to visually verify correct spatial allocation of emissions.

23D.3 CAMx Modeling

The PGM modeling was conducted for the future year emissions scenario with the objective of determining the contribution of the project's emissions to ozone and PM concentrations. To determine source contribution, the Brute Force Method was used by taking the differences between alternatives and the base case. A Base Case simulation was developed using the future year emissions from all sources other than the project. Another simulation was run with the project emissions (Alternative Case). Each simulation generated separate hourly average concentration files:

- Base Case model output of hourly gridded total surface layer concentrations.
- Alternative Case output of hourly gridded total surface layer concentrations.

The Base Case and Alternative Case gridded hourly concentration output files were post-processed to generate annual (365 days) gridded files for:

- Daily average total PM2.5 concentrations.
- Maximum daily 8-hour (MDA8) ozone concentrations.

The gridded average daily PM2.5 and MDA8 ozone concentrations were used as input to BenMAP-CE model to determine the incremental health effects due to the project criteria pollutant emissions.

The following three Alternative Case runs were completed.

- Alternative 2a—largest activity for the central conveyance alignment
- Alternative 4a—largest activity for the eastern conveyance alignment
- Alternative 5—Bethany Reservoir alignment

23D.4 Preparation of BenMAP Inputs

This section discusses the method to translate potential health impacts from the PM and ozone concentrations predicted by CAMx. The health impact estimates are developed through the application of BenMAP v.1.5. Developed by EPA and Abt Associates, BenMAP a tool used to estimate human health and economic impacts from changes in air quality. BenMAP outputs include PM- and ozone-related health impacts including premature mortality, hospital admissions, and emergency room visits.

BenMAP uses the following framework to relate changes in ambient air pollution to estimated health impacts (U.S. Environmental Protection Agency 2021):

> Health Effect = Air Quality Change x Response Function x Exposed Population x Baseline Health Incidence

The inputs needed to calculate the health impacts in BenMAP include:

- **Air Quality Change.** The difference between the starting air pollution level (the base) and the air pollution level after some change, in this case, construction emissions from the Delta Conveyance Project.
- **Concentration Response (C-R) or Δy.** An estimate of the percentage change in an adverse health effect due to unit change in ambient air pollution. The health functions are obtained from epidemiological studies.
- **Exposed Population.** The number of people affected by the air quality changes from grid cell to grid cell. Population for each grid cell is based on U.S. 2010 block group level census data as the U.S. Census Bureau has not yet released age information from the 2020 census needed for the age-specific concentration response (C-R) functions as discussed below. Block group population and age group data was mapped to 4-km grid cells using ArcGIS. BenMAP has population projections from 2010 out to 2050. The projected maximum construction year 7 was used as the projected population year for the assessment.
- **Baseline Health Incidence.** An estimate of the average number of people who die or suffer an adverse health effect such as hospital admissions or emergency room visits, in each population over a given period. BenMAP contains county-level mortality and morbidity rates.

EPA reviews and selects the C-R functions to determine health impacts. C-R functions are equations that relate the change in the number of adverse health effect incidences in a population to a change

in pollutant concentration experienced by that population. Typically, epidemiological studies are used to estimate the relationship between a pollutant and a health endpoint. Most common C-R functions are represented in log-linear form.

$$\Delta y = y_0 \times \left(1 - e^{-\beta \times (Air - threshold)}\right)$$

where:

- Δy = Change in the mortality rate of the study area population corresponding to a particular change in air concentration (deaths/person/year).
- y_0 = Baseline incidence rates (deaths/person/year or illnesses/person/year).
- β = Coefficient based on the relative risk associated with a concentration ($1/[\mu g/m^3]$).
- Air = Ambient air concentration ($\mu g/m^3$).
- threshold = Ambient air concentration below which no health impacts are expected to occur ($\mu g/m^3$).

The same log-linear equation form can be used for estimating any of the various mortality or morbidity rates, but the parameters and rates will differ among health endpoints as well as among epidemiological studies and models, study areas, and time periods. Therefore, to assess the incremental change in a health endpoint incidence requires specification of y_0, β, air, and a threshold. The y_0 variable is specific to the study area. The y_0 variable is obtained from national, state, or local data on annual numbers of deaths or illnesses for the study area and time period of interest.

For the health impact function, BenMAP provides multiple C-R based on different epidemiological studies for a given health endpoint. Ideally the C-R would be specific to the area being evaluated, but this is generally not possible. The selection of endpoint and the C-R are also dependent on the availability of baseline health incidence data. Potential health endpoints and associated C-R considered in the project analysis include all-cause mortality, emergency room visits, acute myocardial infarction, and hospital admissions. Each C-R is based on a certain age range for the given health endpoint depending on the underlying epidemiological study on which it is based. In this study we used the default C-R functions with zero for the thresholds for the health impacts, as shown in Table 23D-3 for PM2.5 and Table 23D-4 for ozone.

Table 23D-3. Health Impact Functions Used to Estimate PM2.5-Related Health Effects

Endpoint	Age Range
Mortality, all cause [a]	0–2 months
Mortality, all cause [a]	30–99
Mortality, all cause [a]	65–99
Acute myocardial infarction, nonfatal [b]	18–99
Hospital admissions, cardiovascular [b]	65–99
Incidence, asthma [a]	0–4
Incidence, asthma [a]	5–17
Hospital admissions, respiratory [b]	0–18
Hospital admissions, respiratory [b]	65–99

Source: U.S. Environmental Protection Agency 2021.

[a] Annual.

[b] 24-hour mean.

Table 23D-4. Health Impact Functions Used to Estimate Ozone-Related Health Effects

Endpoint	Age Range
Mortality, respiratory [a]	0–99
Mortality, respiratory [a]	30–99
Emergency room visits, asthma [a, c, d]	0–99
Hospital admissions, respiratory [a, e, f]	65–99

Source: U.S. Environmental Protection Agency 2021.
[a] Metric is daily maximum 8-hour ozone.
[b] Metric is daily maximum 8-hour ozone; ozone season.
[c] Child model; metric is daily maximum 8-hour ozone; 3-day lag; May–September.
[d] Adult model; metric is daily maximum 8-hour ozone; 4-day lag; May–September.
[e] Metric is daily maximum 8-hour ozone; Summer, 1985–1994 (penalized splines).
[f] Metric is daily maximum 8-hour ozone; Summer, 1985–1994 (natural splines).

In addition to reporting results for a zero threshold, analysts determined the relative confidence in the threshold for the PM2.5 used in the health studies. This benchmark approach (also referred to as the Lowest Reported Level [LRL] analysis) has been used in several EPA (2018) regulatory impact analyses and EPA's (2011) *Policy Assessment for Particulate Matter* by reporting the estimated PM2.5-related premature deaths according to alternative concentration cutpoints. The LRL analysis, for example, determines the portion of population exposed to annual mean PM2.5 levels at or above different concentration levels, which provides insight into the level of uncertainty in the estimated PM2.5 mortality benefits. These concentration benchmarks should not be viewed as concentration thresholds below which not to quantify health impacts, but rather, the impact reflecting the full range of air quality concentrations associated with the emissions changes being evaluated. For this analysis, the results were reported for two cohorts both for mortality, all cause (Turner et al. 2016), which has an annual LRL of 1.4 $\mu g/m^3$, and (Di et al. 2017), which has an LRL of 0.2 $\mu g/m^3$.

23D.5 Limitations and Uncertainty

The following discussion summarizes the main uncertainties associated with the PGM and the HIA. The methodology used in this analysis ensures that the uncertainty tends toward a conservative outcome.

23D.5.1 Emission Estimates

Uncertainties exist in estimating emissions from construction equipment. Since the maximum annual emissions at a given project site are modeled concurrently with the maximum emissions for the other sites, emission estimates are conservatively estimated. Furthermore, the underlying equipment activity levels are conservatively estimated based on the number of hours of needed operation, thereby likely overestimating the total emissions that will likely occur.

23D.5.2 CAMx Modeling

In addition to the uncertainty associated with emission estimates, uncertainty exists regarding the pollutant concentrations estimated by CAMx. CAMx, and other PGMs, estimate the complex and dynamic chemical (nonlinear chemistry) and physical processes (deposition, turbulent mixing,

advection) occurring in the atmosphere through the mathematical representation of these processes. Uncertainty is also introduced into CAMx through model inputs (e.g., emissions, boundary conditions, meteorological characterizations). In addition, model formulation (e.g., chemical mechanism, advection scheme) and simplifications in characterizing physical processes, as well as approximations (grid cell size, time step, numerical approximation), introduce uncertainty.

23D.5.3 Health Impact Analysis

The health impact inherits the uncertainties of the modeled concentrations from the PGM. There are also uncertainties in the health assessment itself. The BenMAP-CE model relies on epidemiological studies and health impact functions that develop statistical relationships between outdoor air pollution exposures and human health effects. These studies report correlations between health effects and outdoor air exposure to PM2.5 and ozone, not a direct link. There is also the assumption that the health effects seen at large concentration differences can be linearly scaled down to small concentration differences, even though there is a potential threshold below which health effects may not occur. Another limitation is that the model does not include time spent indoors, which often results in lower exposure to outdoor air depending on the indoor environment and exchange rate.

BenMAP only uses the spatial distribution of population based on the 2010 census primarily because future estimates are highly dependent on many factors that could influence population spatial changes, land-use, migration, fertility, and future life expectancy. Certain health impact functions available in BenMAP are applicable only to specific age groups (e.g., BenMAP evaluates asthma incidence for those aged 5–17). Populations that are outside of the age ranges are excluded from the analysis. This may result in an underestimate of changes in health effects with changes in population.

Predictions of baseline health incidence for future years are not widely available for non-mortality health effects. This means that default morbidity health incidence data from 2021 or earlier are used in the analysis of future year health effects. This may result in an overestimate or underestimate of changes in health effects. BenMAP does not include health impact functions specific to the modeled region. We have used default BenMAP health impact functions from peer-reviewed studies that focus on national data or regional U.S. locations. Using these functions in this study may result in an overestimate or underestimate of changes in actual local health effects.

23D.6 Additional County-Specific Analysis

Results from the HIA presented in Chapter 23 are representative of pollutant concentrations and potential community health risks over the entire model domain (Figure 23D-1). The analysis isolated the results for the specific counties in which the physical project footprint will be constructed—Sacramento, San Joaquin, Contra Costa, and Alameda (Alternative 5 only). The county-specific results are presented in Tables 23D-5 through 23D-14.

Table 23D-5. Conservative Estimate of Health Effect Incidence during Construction of Alternative 2a in Sacramento County

Health Endpoint	Age Range [a]	Annual Incidence per Year: Future Ambient [b]	Annual Incidence per Year: Project Contribution [c]	Project Increase over Future Ambient (%) [d]
PM2.5 Emissions, Respiratory				
Incidence, asthma	0–4	2,639	0.62	0.0235%
Incidence, asthma	5–17	2,193	0.54	0.0247%
Hospital admissions, respiratory	0–18	2,206	0.03	0.0015%
Hospital admissions, respiratory	65–99	4,257	0.01	0.0001%
PM2.5 Emissions, Cardiovascular				
Hospital admissions, cardiovascular	65–99	18,621	0.06	0.0003%
Acute myocardial infarction, nonfatal	18–99	4,291	0.08–0.53 [e]	0.0018%–0.0122% [e]
PM2.5 Emissions, Mortality				
Mortality, all cause	0–2 months	95	<0.01	0.0030%
Mortality, all cause	30–99	13,511	0.39	0.0029%
Mortality, all Cause	65–99	11,524	0.40	0.0034%
ROG and NO_X Emissions, (ozone health effects) Respiratory				
Hospital admissions, respiratory	65–99	3,261	0.01	0.0003%
Emergency room visits, asthma	0–99	4,213	0.16	0.0039%
ROG and NO_X Emissions, (ozone health effects) Mortality				
Mortality, respiratory	0–99	611	<0.01	0.0007%
Mortality, respiratory	30–99	1,451	0.09	0.0061%

NO_X = nitrogen oxides; PM2.5 = particulate matter that is 2.5 microns in diameter and smaller; ROG = reactive organic gases.

[a] Individuals may be affected at other ages, but the age ranges shown are the ones used by EPA in their health assessments and are consistent with epidemiological study that is the basis of the health function.

[b] The future ambient health incidence is the average annual number of people that suffer from a health consequence in absence of project construction over the entire modeled county area.

[c] The project contribution is the average annual number of additional people that may suffer from a health consequence over the entire modeled county area due to the highest annual unmitigated project construction emissions. The project contribution during all other years of construction would be lower than the values presented in this table.

[d] Project contribution divided by future ambient.

[e] As a means of recognizing the strengths of the study used by EPA while also incorporating the newer evidence found in the four single and multi-city studies, the table present a range of acute myocardial infarction estimates. The upper end of the range is calculated using the study underpinning EPA's health assessment while the lower end of the range is the result of an equal-weights pooling of four newer studies.

Table 23D-6. Conservative Estimate of Health Effect Incidence during Construction of Alternative 2a in San Joaquin County

Health Endpoint	Age Range [a]	Annual Incidence per Year: Future Ambient [b]	Annual Incidence per Year: Project Contribution [c]	Project Increase over Future Ambient (%) [d]
PM2.5 Emissions, Respiratory				
Incidence, asthma	0–4	1,505	0.64	0.0423%
Incidence, asthma	5–17	1,218	0.51	0.0416%
Hospital admissions, respiratory	0–18	1,033	0.03	0.0026%
Hospital admissions, respiratory	65–99	3,373	0.01	0.0002%
PM2.5 Emissions, Cardiovascular				
Hospital admissions, cardiovascular	65–99	7,449	0.05	0.0006%
Acute myocardial infarction, nonfatal	18–99	1,550	0.05–0.37 [e]	0.0035%–0.0237% [e]
PM2.5 Emissions, Mortality				
Mortality, all cause	0–2 months	58	<0.01	0.0055%
Mortality, all cause	30–99	6,144	0.36	0.0058%
Mortality, all Cause	65–99	5,075	0.36	0.0070%
ROG and NO_X Emissions, (ozone health effects) Respiratory				
Hospital admissions, respiratory	65–99	2,061	0.02	0.0009%
Emergency room visits, asthma	0–99	2,477	0.46	0.0186%
ROG and NO_X Emissions, (ozone health effects) Mortality				
Mortality, respiratory	0–99	292	0.01	0.0025%
Mortality, respiratory	30–99	693	0.16	0.0229%

NO_X = nitrogen oxides; PM2.5 = particulate matter that is 2.5 microns in diameter and smaller; ROG = reactive organic gases.

[a] Individuals may be affected at other ages, but the age ranges shown are the ones used by EPA in their health assessments and are consistent with epidemiological study that is the basis of the health function.

[b] The future ambient health incidence is the average annual number of people that suffer from a health consequence in absence of project construction over the entire modeled county area.

[c] The project contribution is the average annual number of additional people that may suffer from a health consequence over the entire modeled county area due to the highest annual unmitigated project construction emissions. The project contribution during all other years of construction would be lower than the values presented in this table.

[d] Project contribution divided by future ambient.

[e] As a means of recognizing the strengths of the study used by EPA while also incorporating the newer evidence found in the four single and multi-city studies, the table present a range of acute myocardial infarction estimates. The upper end of the range is calculated using the study underpinning EPA's health assessment while the lower end of the range is the result of an equal-weights pooling of four newer studies.

Table 23D-7. Conservative Estimate of Health Effect Incidence during Construction of Alternative 2a in Contra Costa County

Health Endpoint	Age Range [a]	Annual Incidence per Year: Future Ambient [b]	Annual Incidence per Year: Project Contribution [c]	Project Increase over Future Ambient (%) [d]
PM2.5 Emissions, Respiratory				
Incidence, asthma	0–4	1,879	0.14	0.0074%
Incidence, asthma	5–17	1,587	0.12	0.0074%
Hospital admissions, respiratory	0–18	710	<0.01	0.0005%
Hospital admissions, respiratory	65–99	5,085	<0.01	<0.0001%
PM2.5 Emissions, Cardiovascular				
Hospital admissions, cardiovascular	65–99	12,875	0.01	0.0001%
Acute myocardial infarction, nonfatal	18–99	2,318	0.01–0.08 [e]	0.0005%–0.0033% [e]
PM2.5 Emissions, Mortality				
Mortality, all cause	0–2 months	54	<0.01	0.0010%
Mortality, all cause	30–99	11,333	0.09	0.0008%
Mortality, all Cause	65–99	10,106	0.09	0.0009%
ROG and NO_X Emissions, (ozone health effects) Respiratory				
Hospital admissions, respiratory	65–99	3,455	0.01	0.0002%
Emergency room visits, asthma	0–99	3,755	0.15	0.0040%
ROG and NO_X Emissions, (ozone health effects) Mortality				
Mortality, respiratory	0–99	509	<0.01	0.0004%
Mortality, respiratory	30–99	1,209	0.05	0.0039%

NO_X = nitrogen oxides; PM2.5 = particulate matter that is 2.5 microns in diameter and smaller; ROG = reactive organic gases.

[a] Individuals may be affected at other ages, but the age ranges shown are the ones used by EPA in their health assessments and are consistent with epidemiological study that is the basis of the health function.

[b] The future ambient health incidence is the average annual number of people that suffer from a health consequence in absence of project construction over the entire modeled county area.

[c] The project contribution is the average annual number of additional people that may suffer from a health consequence over the entire modeled county area due to the highest annual unmitigated project construction emissions. The project contribution during all other years of construction would be lower than the values presented in this table.

[d] Project contribution divided by future ambient.

[e] As a means of recognizing the strengths of the study used by EPA while also incorporating the newer evidence found in the four single and multi-city studies, the table present a range of acute myocardial infarction estimates. The upper end of the range is calculated using the study underpinning EPA's health assessment while the lower end of the range is the result of an equal-weights pooling of four newer studies.

Table 23D-8. Conservative Estimate of Health Effect Incidence during Construction of Alternative 4a in Sacramento County

Health Endpoint	Age Range [a]	Annual Incidence per Year: Future Ambient [b]	Annual Incidence per Year: Project Contribution [c]	Project Increase over Future Ambient (%) [d]
PM2.5 Emissions, Respiratory				
Incidence, asthma	0–4	2,639	0.61	0.0231%
Incidence, asthma	5–17	2,193	0.53	0.0243%
Hospital admissions, respiratory	0–18	2,206	0.03	0.0015%
Hospital admissions, respiratory	65–99	4,257	0.01	0.0001%
PM2.5 Emissions, Cardiovascular				
Hospital admissions, cardiovascular	65–99	18,621	0.06	0.0003%
Acute myocardial infarction, nonfatal	18–99	4,291	0.08–0.52 [e]	0.0018%–0.0120% [e]
PM2.5 Emissions, Mortality				
Mortality, all cause	0–2 months	95	<0.01	0.0029%
Mortality, all cause	30–99	13,511	0.38	0.0028%
Mortality, all Cause	65–99	11,524	0.39	0.0034%
ROG and NO_X Emissions, (ozone health effects) Respiratory				
Hospital admissions, respiratory	65–99	3,261	0.01	0.0003%
Emergency room visits, asthma	0–99	4,213	0.16	0.0039%
ROG and NO_X Emissions, (ozone health effects) Mortality				
Mortality, respiratory	0–99	611	<0.01	0.0007%
Mortality, respiratory	30–99	1,451	0.09	0.0061%

NO_X = nitrogen oxides; PM2.5 = particulate matter that is 2.5 microns in diameter and smaller; ROG = reactive organic gases.

[a] Individuals may be affected at other ages, but the age ranges shown are the ones used by EPA in their health assessments and are consistent with epidemiological study that is the basis of the health function.

[b] The future ambient health incidence is the average annual number of people that suffer from a health consequence in absence of project construction over the entire modeled county area.

[c] The project contribution is the average annual number of additional people that may suffer from a health consequence over the entire modeled county area due to the highest annual unmitigated project construction emissions. The project contribution during all other years of construction would be lower than the values presented in this table.

[d] Project contribution divided by future ambient.

[e] As a means of recognizing the strengths of the study used by EPA while also incorporating the newer evidence found in the four single and multi-city studies, the table present a range of acute myocardial infarction estimates. The upper end of the range is calculated using the study underpinning EPA's health assessment while the lower end of the range is the result of an equal-weights pooling of four newer studies.

Table 23D-9. Conservative Estimate of Health Effect Incidence during Construction of Alternative 4a in San Joaquin County

Health Endpoint	Age Range [a]	Annual Incidence per Year: Future Ambient [b]	Annual Incidence per Year: Project Contribution [c]	Project Increase over Future Ambient (%) [d]
PM2.5 Emissions, Respiratory				
Incidence, asthma	0–4	1,505	0.61	0.0403%
Incidence, asthma	5–17	1,218	0.48	0.0397%
Hospital admissions, respiratory	0–18	1,033	0.03	0.0025%
Hospital admissions, respiratory	65–99	3,373	0.01	0.0002%
PM2.5 Emissions, Cardiovascular				
Hospital admissions, cardiovascular	65–99	7,449	0.05	0.0006%
Acute myocardial infarction, nonfatal	18–99	1,550	0.05–0.35 [e]	0.0033%–0.0226% [e]
PM2.5 Emissions, Mortality				
Mortality, all cause	0–2 months	58	<0.01	0.0052%
Mortality, all cause	30–99	6,144	0.34	0.0055%
Mortality, all Cause	65–99	5,075	0.34	0.0067%
ROG and NO_X Emissions, (ozone health effects) Respiratory				
Hospital admissions, respiratory	65–99	2,061	0.02	0.0009%
Emergency room visits, asthma	0–99	2,477	0.46	0.0186%
ROG and NO_X Emissions, (ozone health effects) Mortality				
Mortality, respiratory	0–99	292	0.01	0.0025%
Mortality, respiratory	30–99	693	0.16	0.0229%

NO_X = nitrogen oxides; PM2.5 = particulate matter that is 2.5 microns in diameter and smaller; ROG = reactive organic gases.

[a] Individuals may be affected at other ages, but the age ranges shown are the ones used by EPA in their health assessments and are consistent with epidemiological study that is the basis of the health function.

[b] The future ambient health incidence is the average annual number of people that suffer from a health consequence in absence of project construction over the entire modeled county area.

[c] The project contribution is the average annual number of additional people that may suffer from a health consequence over the entire modeled county area due to the highest annual unmitigated project construction emissions. The project contribution during all other years of construction would be lower than the values presented in this table.

[d] Project contribution divided by future ambient.

[e] As a means of recognizing the strengths of the study used by EPA while also incorporating the newer evidence found in the four single and multi-city studies, the table present a range of acute myocardial infarction estimates. The upper end of the range is calculated using the study underpinning EPA's health assessment while the lower end of the range is the result of an equal-weights pooling of four newer studies.

Table 23D-10. Conservative Estimate of Health Effect Incidence during Construction of Alternative 4a in Contra Costa County

Health Endpoint	Age Range [a]	Annual Incidence per Year: Future Ambient [b]	Annual Incidence per Year: Project Contribution [c]	Project Increase over Future Ambient (%) [d]
PM2.5 Emissions, Respiratory				
Incidence, asthma	0–4	1,879	0.13	0.0070%
Incidence, asthma	5–17	1,587	0.11	0.0070%
Hospital admissions, respiratory	0–18	710	<0.01	0.0004%
Hospital admissions, respiratory	65–99	5,085	<0.01	<0.0001%
PM2.5 Emissions, Cardiovascular				
Hospital admissions, cardiovascular	65–99	12,875	0.01	0.0001%
Acute myocardial infarction, nonfatal	18–99	2,318	0.01–0.07 [e]	0.005%–0.0031% [e]
PM2.5 Emissions, Mortality				
Mortality, all cause	0–2 months	54	<0.01	0.0009%
Mortality, all cause	30–99	11,333	0.08	0.0007%
Mortality, all Cause	65–99	10,106	0.09	0.0009%
ROG and NO_X Emissions, (ozone health effects) Respiratory				
Hospital admissions, respiratory	65–99	3,455	0.01	0.0002%
Emergency room visits, asthma	0–99	3,755	0.15	0.0039%
ROG and NO_X Emissions, (ozone health effects) Mortality				
Mortality, respiratory	0–99	509	<0.01	0.0004%
Mortality, respiratory	30–99	1,209	0.05	0.0038%

NO_X = nitrogen oxides; PM2.5 = particulate matter that is 2.5 microns in diameter and smaller; ROG = reactive organic gases.

[a] Individuals may be affected at other ages, but the age ranges shown are the ones used by EPA in their health assessments and are consistent with epidemiological study that is the basis of the health function.

[b] The future ambient health incidence is the average annual number of people that suffer from a health consequence in absence of project construction over the entire modeled county area.

[c] The project contribution is the average annual number of additional people that may suffer from a health consequence over the entire modeled county area due to the highest annual unmitigated project construction emissions. The project contribution during all other years of construction would be lower than the values presented in this table.

[d] Project contribution divided by future ambient.

[e] As a means of recognizing the strengths of the study used by EPA while also incorporating the newer evidence found in the four single and multi-city studies, the table present a range of acute myocardial infarction estimates. The upper end of the range is calculated using the study underpinning EPA's health assessment while the lower end of the range is the result of an equal-weights pooling of four newer studies.

Table 23D-11. Conservative Estimate of Health Effect Incidence during Construction of Alternative 5 in Sacramento County

Health Endpoint	Age Range [a]	Annual Incidence per Year: Future Ambient [b]	Annual Incidence per Year: Project Contribution [c]	Project Increase over Future Ambient (%) [d]
PM2.5 Emissions, Respiratory				
Incidence, asthma	0–4	2,639	0.49	0.0185%
Incidence, asthma	5–17	2,193	0.43	0.0195%
Hospital admissions, respiratory	0–18	2,206	0.03	0.0012%
Hospital admissions, respiratory	65–99	4,257	<0.01	0.0001%
PM2.5 Emissions, Cardiovascular				
Hospital admissions, cardiovascular	65–99	18,621	0.05	0.0003%
Acute myocardial infarction, nonfatal	18–99	4,291	0.06–0.41 [e]	0.0014%–0.0097% [e]
PM2.5 Emissions, Mortality				
Mortality, all cause	0–2 months	95	<0.01	0.0023%
Mortality, all cause	30–99	13,511	0.31	0.0023%
Mortality, all Cause	65–99	11,524	0.31	0.0027%
ROG and NO_X Emissions, (ozone health effects) Respiratory				
Hospital admissions, respiratory	65–99	3,261	0.01	0.0002%
Emergency room visits, asthma	0–99	4,213	0.13	0.0032%
ROG and NO_X Emissions, (ozone health effects) Mortality				
Mortality, respiratory	0–99	611	<0.01	0.0005%
Mortality, respiratory	30–99	1,451	0.07	0.0050%

NO_X = nitrogen oxides; PM2.5 = particulate matter that is 2.5 microns in diameter and smaller; ROG = reactive organic gases.

[a] Individuals may be affected at other ages, but the age ranges shown are the ones used by EPA in their health assessments and are consistent with epidemiological study that is the basis of the health function.

[b] The future ambient health incidence is the average annual number of people that suffer from a health consequence in absence of project construction over the entire modeled county area.

[c] The project contribution is the average annual number of additional people that may suffer from a health consequence over the entire modeled county area due to the highest annual unmitigated project construction emissions. The project contribution during all other years of construction would be lower than the values presented in this table.

[d] Project contribution divided by future ambient.

[e] As a means of recognizing the strengths of the study used by EPA while also incorporating the newer evidence found in the four single and multi-city studies, the table present a range of acute myocardial infarction estimates. The upper end of the range is calculated using the study underpinning EPA's health assessment while the lower end of the range is the result of an equal-weights pooling of four newer studies.

Table 23D-12. Conservative Estimate of Health Effect Incidence during Construction of Alternative 5 in San Joaquin County

Health Endpoint	Age Range [a]	Annual Incidence per Year: Future Ambient [b]	Annual Incidence per Year: Project Contribution [c]	Project Increase over Future Ambient (%) [d]
PM2.5 Emissions, Respiratory				
Incidence, asthma	0–4	1,505	0.57	0.0375%
Incidence, asthma	5–17	1,218	0.45	0.0369%
Hospital admissions, respiratory	0–18	1,033	0.02	0.0023%
Hospital admissions, respiratory	65–99	3,373	0.01	0.0002%
PM2.5 Emissions, Cardiovascular				
Hospital admissions, cardiovascular	65–99	7,449	0.04	0.0006%
Acute myocardial infarction, nonfatal	18–99	1,550	0.05 - 0.33 [e]	0.0031% - 0.0211% [e]
PM2.5 Emissions, Mortality				
Mortality, all cause	0–2 months	58	<0.01	0.0048%
Mortality, all cause	30–99	6,144	0.32	0.0052%
Mortality, all Cause	65–99	5,075	0.32	0.0063%
ROG and NO_X Emissions, (ozone health effects) Respiratory				
Hospital admissions, respiratory	65–99	2,061	0.01	0.0007%
Emergency room visits, asthma	0–99	2,477	0.34	0.0136%
ROG and NO_X Emissions, (ozone health effects) Mortality				
Mortality, respiratory	0–99	292	0.01	0.0018%
Mortality, respiratory	30–99	693	0.12	0.0168%

NO_X = nitrogen oxides; PM2.5 = particulate matter that is 2.5 microns in diameter and smaller; ROG = reactive organic gases.

[a] Individuals may be affected at other ages, but the age ranges shown are the ones used by EPA in their health assessments and are consistent with epidemiological study that is the basis of the health function.

[b] The future ambient health incidence is the average annual number of people that suffer from a health consequence in absence of project construction over the entire modeled county area.

[c] The project contribution is the average annual number of additional people that may suffer from a health consequence over the entire modeled county area due to the highest annual unmitigated project construction emissions. The project contribution during all other years of construction would be lower than the values presented in this table.

[d] Project contribution divided by future ambient.

[e] As a means of recognizing the strengths of the study used by EPA while also incorporating the newer evidence found in the four single and multi-city studies, the table present a range of acute myocardial infarction estimates. The upper end of the range is calculated using the study underpinning EPA's health assessment while the lower end of the range is the result of an equal-weights pooling of four newer studies.

Table 23D-13. Conservative Estimate of Health Effect Incidence during Construction of Alternative 5 in Contra Costa County

Health Endpoint	Age Range [a]	Annual Incidence per Year: Future Ambient [b]	Annual Incidence per Year: Project Contribution [c]	Project Increase over Future Ambient (%) [d]
PM2.5 Emissions, Respiratory				
Incidence, asthma	0–4	1,879	0.09	0.0048%
Incidence, asthma	5–17	1,587	0.08	0.0048%
Hospital admissions, respiratory	0–18	710	<0.01	0.0003%
Hospital admissions, respiratory	65–99	5,085	<0.01	<0.0001%
PM2.5 Emissions, Cardiovascular				
Hospital admissions, cardiovascular	65–99	12,875	0.01	0.0001%
Acute myocardial infarction, nonfatal	18–99	2,318	0.01–0.05 [e]	0.0003%–0.0022% [e]
PM2.5 Emissions, Mortality				
Mortality, all cause	0–2 months	54	<0.01	0.0006%
Mortality, all cause	30–99	11,333	0.06	0.0005%
Mortality, all Cause	65–99	10,106	0.06	0.0006%
ROG and NO_X Emissions, (ozone health effects) Respiratory				
Hospital admissions, respiratory	65–99	3,455	<0.01	<0.0001%
Emergency room visits, asthma	0–99	3,755	0.01	0.0002%
ROG and NO_X Emissions, (ozone health effects) Mortality				
Mortality, respiratory	0–99	509	<0.01	<0.0001%
Mortality, respiratory	30–99	1,209	<0.01	0.0001%

NO_X = nitrogen oxides; PM2.5 = particulate matter that is 2.5 microns in diameter and smaller; ROG = reactive organic gases.

[a] Individuals may be affected at other ages, but the age ranges shown are the ones used by EPA in their health assessments and are consistent with epidemiological study that is the basis of the health function.

[b] The future ambient health incidence is the average annual number of people that suffer from a health consequence in absence of project construction over the entire modeled county area.

[c] The project contribution is the average annual number of additional people that may suffer from a health consequence over the entire modeled county area due to the highest annual unmitigated project construction emissions. The project contribution during all other years of construction would be lower than the values presented in this table.

[d] Project contribution divided by future ambient.

[e] As a means of recognizing the strengths of the study used by EPA while also incorporating the newer evidence found in the four single and multi-city studies, the table present a range of acute myocardial infarction estimates. The upper end of the range is calculated using the study underpinning EPA's health assessment while the lower end of the range is the result of an equal-weights pooling of four newer studies.

Table 23D-14. Conservative Estimate of Health Effect Incidence during Construction of Alternative 5 in Alameda County

Health Endpoint	Age Range [a]	Annual Incidence per Year: Future Ambient [b]	Annual Incidence per Year: Project Contribution [c]	Project Increase over Future Ambient (%) [d]
PM2.5 Emissions, Respiratory				
Incidence, asthma	0–4	2,458	0.04	0.0018%
Incidence, asthma	5–17	2,002	0.04	0.0018%
Hospital admissions, respiratory	0–18	3,235	<0.01	0.0001%
Hospital admissions, respiratory	65–99	5,252	<0.01	<0.0001%
PM2.5 Emissions, Cardiovascular				
Hospital admissions, cardiovascular	65–99	14,235	<0.01	<0.0001%
Acute myocardial infarction, nonfatal	18–99	2,782	<0.01–0.03 [e]	0.0001%–0.0009% [e]
PM2.5 Emissions, Mortality				
Mortality, all cause	0–2 months	70	<0.01	0.0002%
Mortality, all cause	30–99	11,921	0.03	0.0002%
Mortality, all Cause	65–99	10,109	0.03	0.0003%
ROG and NO_X Emissions, (ozone health effects) Respiratory				
Hospital admissions, respiratory	65–99	3,711	<0.01	<0.0001%
Emergency room visits, asthma	0–99	4,878	<0.01	0.0001%
ROG and NO_X Emissions, (ozone health effects) Mortality				
Mortality, respiratory	0–99	522	<0.01	<0.0001%
Mortality, respiratory	30–99	1,240	<0.01	0.0003%

NO_X = nitrogen oxides; PM2.5 = particulate matter that is 2.5 microns in diameter and smaller; ROG = reactive organic gases.

[a] Individuals may be affected at other ages, but the age ranges shown are the ones used by EPA in their health assessments and are consistent with epidemiological study that is the basis of the health function.

[b] The future ambient health incidence is the average annual number of people that suffer from a health consequence in absence of project construction over the entire modeled county area.

[c] The project contribution is the average annual number of additional people that may suffer from a health consequence over the entire modeled county area due to the highest annual unmitigated project construction emissions. The project contribution during all other years of construction would be lower than the values presented in this table.

[d] Project contribution divided by future ambient.

[e] As a means of recognizing the strengths of the study used by EPA while also incorporating the newer evidence found in the four single and multi-city studies, the table present a range of acute myocardial infarction estimates. The upper end of the range is calculated using the study underpinning EPA's health assessment while the lower end of the range is the result of an equal-weights pooling of four newer studies.

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