Appendix G

HEALTH ANALYSES: CONTROL MEASURE FOR OCEAN-GOING VESSELS AT BERTH

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HEALTH ANALYSES: CONTROL MEASURE FOR OCEAN-GOING VESSELS AT BERTH

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I. OVERVIEW

California Air Resources Board (CARB) staff conducted health analyses to evaluate the health impacts of emissions from ocean-going vessels operating at berth. These health analyses examine present and future health impacts with adopted regulations in place (Existing Regulation),[1] as well as the health benefits that would be achieved with the implementation of the (Proposed Regulation). This document presents two separate analyses, a health risk assessment (HRA) and a particulate matter (PM) mortality and illness analysis. Each quantifies different health effects and each is equally important.

The HRA evaluates localized health impacts from diesel particulate matter (DPM) exposure for people living near large and small ports and marine terminals. Exposure to DPM has both cancer and noncancer chronic health impacts. The HRA uses air quality modeling to estimate the concentration of DPM at specific locations near the ports; estimates DPM exposure to people living in those communities; and estimates the health impacts that would be expected to result from that exposure. The HRA further projects how those impacts would change with implementation of the Proposed Regulation.

The PM mortality and illness analysis evaluates regional health impacts and focuses on PM2.5 either directly emitted from vessel engines and boilers or formed in the atmosphere from emissions of nitrogen oxides (NOx). Exposure to these pollutants can result in health outcomes that include premature death from cardiopulmonary disease, hospital admissions, and emergency room visits. This analysis uses the HRA modeling results, air quality monitoring data, emissions inventory data, and county-specific statistics on health outcomes attributable to emissions from ocean-going vessels operating at berth.

CARB staff released a preliminary health analyses document for public review on November 5, 2018.[2] The preliminary health analyses were based on an earlier regulatory concept that differs from the Proposed Regulation. These differences resulted in changes to the emissions inventory, thereby impacting the results of these health analyses. In addition, revisions and refinements to the methodology for the regional PM mortality and illness analysis resulted in different health impacts as compared to the preliminary health analyses. Information on the current methodology for the regional mortality and illness analysis can be found at https://www.arb.ca.gov/resources/documents/carbs-methodology-estimating-health-effects-air-pollution.

[1] Airborne Toxic Control Measure for Auxiliary Diesel Engines Operated on Ocean-Going Vessels At-Berth in a California Port

[2] California Air Resources Board Staff Preliminary Health Analyses: Control Measure For Ocean-Going Vessels At Berth And At Anchor, Public Review Draft, November 5, 2018

A. Approaches Used in the Health Analyses

The approaches used in each of these health analyses are outlined below:

Health Risk Assessment

- Select California ports and marine terminals to evaluate.
- Develop a DPM emissions inventory based on implementation dates for the Proposed Regulation that reflect the anticipated amount of DPM released annually from at berth emissions.
- Conduct air dispersion modeling to estimate the ground-level concentrations of DPM that result from these emissions.

Estimate the potential health impacts from exposure to the modeled concentrations.

Mortality and Illness Analysis

- Develop a PM2.5 and NOx emissions inventory based on implementation dates for the Proposed Regulation that reflect the anticipated amount of each pollutant released annually from at berth emissions.
- Estimate statewide PM2.5 noncancer mortality and illness impacts associated with exposure to primary PM2.5 (DPM and boiler PM) and secondary PM2.5 from NOx emissions.

B. Years Evaluated in the Health Analyses

For the health analyses, CARB staff evaluated specific years based on the implementation schedule of the Proposed Regulation. For the HRA, staff evaluated 2020 (when the Existing Regulation is fully implemented), 2021, 2023, 2025, 2027, 2029, and 2031. Although 2023 and 2031 are not implementation years in the Proposed Regulation, they are provided for informational purposes because they are key attainment deadlines for the South Coast Air Basin under the State Implementation Plan (SIP). For the PM2.5 mortality and illness analysis, staff evaluated the health benefits over a 12-year period from 2021 to 2032.

Table 1 summarizes the implementation schedule of the Proposed Regulation. In 2021, vessel types currently included in the Existing Regulation (container, reefer, and cruise vessels) will become subject to requirements in the Proposed Regulation. In 2025, the roll-on roll-off (ro-ro) carrier vessels will become subject to the requirements in the Proposed Regulation. For tanker vessels, implementation begins in 2027 at the Port of Los Angeles (POLA) and the Port of Long Beach (POLB), and 2029 for all other regulated tanker terminals statewide. More information on the Proposed Regulation can be found in Chapter III – Summary of the Proposed Regulation.

Table 1. Proposed Regulation Implementation Schedule

Vessel Category	2021[1]	2025	2027	2029
Container/Reefer	✓			
Cruise	✓			
Ro-Ro		✓		
Tankers			✓ POLA & POLB Terminals	✓ Remaining Statewide Terminals

1. Vessels not covered under the Existing Regulation will be subject to requirements in 2023.

C. Applicability of DPM Health Values for Marine Auxiliary Engines

Ocean-going vessel auxiliary engines operating at berth use various diesel fuel types (e.g., marine gas oil (MGO), marine diesel oil (MDO), or marine heavy fuel oil (HFO)). CARB staff, in consultation with the Office of Environmental Health Hazard Assessment (OEHHA), has concluded that PM emissions from ocean-going vessel diesel (compression ignition) engines operating on MGO, MDO, or HFO constitute DPM emissions. As such, the cancer potency factor (CPF) and chronic reference exposure level (REL) for DPM are applicable to exhaust emissions from ocean-going vessel diesel engines using MGO, MDO, or HFO. The reasoning used to support these conclusions is summarized below.

- MGO and MDO are distillate fuels with most fuel properties nearly identical to diesel fuel.
- The fuel specifications for MGO and MDO are very similar to the diesel fuel specification that existed prior to 1993.
- HFO is a blended petroleum product containing the same classes of hydrocarbons as diesel fuel.
- HFO contains some diesel fuel.
- The emission characteristics of a marine diesel engine using HFO are similar to those of a diesel engine using diesel fuel.
- The general classes of PM exhaust components from a marine diesel engine using HFO are similar to a diesel engine using diesel fuel.
- The particle size distribution of the exhaust emissions from a marine diesel engine using HFO is similar to the particle size distribution from a diesel engine using diesel fuel.

For more detailed information regarding the reasons listed above, see Section II. Subsection C of the *Initial Statement of Reasons for Proposed*

Rulemaking - Fuel Sulfur and Other Operational Requirements for Ocean-Going Vessels Within California Waters and 24 Nautical Miles of the California Baseline – June 2008 (CARB, 2008).

II. EMISSIONS INVENTORY

In order to conduct the localized HRA and the regional mortality and illness analysis, it is necessary to have information regarding the amount of pollutants being emitted by the sources. CARB staff estimated emissions of DPM from at berth activities by vessel type and the statewide PM2.5 and NOx emission reductions by air basin. The DPM emissions are based on vessel auxiliary engine operations, which currently utilize a distillate diesel fuel. Emissions are based on the best available information regarding past, current, and projected future at berth activities. Information on the assumptions and methodology for the emissions inventory can be found in Appendix H – Emissions Inventory.

Vessels have both main propulsion and auxiliary diesel engines. A single large, slow-speed, two-stroke direct drive diesel engine propels most vessels, with smaller medium-speed four-stroke auxiliary engines that provide electrical power for lighting, navigation equipment, and other shipboard uses. An exception to this configuration are diesel-electric vessels, such as those on passenger cruise and a subset of tanker vessels. Diesel-electric vessels use large four-stroke medium speed engines coupled to generators to provide electrical power for both main propulsion and shipboard electrical power.

The majority of vessels are also equipped with auxiliary boilers. Boilers are fuel-fired combustion equipment designed primarily to produce steam for uses other than propulsion, such as heating of residual fuel and liquid cargo, heating of water for crew and passengers, powering steam turbine discharge pumps, freshwater generation, and space heating of cabins. In addition, a subset of tanker vessels use large auxiliary boilers to generate steam to power pumps used for off-loading cargo, such as crude oil, while at berth. It is important to note that the PM emissions from auxiliary boilers are not categorized as DPM due to the differences in combustion processes, and are not included in the HRA portion of the health analysis. CARB staff recognizes that there may be potential cancer risk health impacts from boiler emissions due to the air toxics that are released in their operations. However, the data for speciated air toxics in marine boiler emissions are limited. Identifying these air toxics and assessing their contributions to risk can be considered when more data becomes available.

For the HRA, CARB staff evaluated the health impacts at three ports. Staff selected ports based on port size, vessel activity, emissions, and proximity to disadvantaged communities. POLA and POLB represent large ports. The Richmond Complex (the public Port of Richmond and the private Chevron Marine Terminal) represents small ports. POLA and POLB combined account for more than half of the at berth emissions in California, while the Richmond Complex has the second largest emissions for tanker vessels in California. Additional information on port selection can be found in Section III. B. Selection of Three California Ports.

A. POLA and POLB Emission Inventory

Table 2 shows the DPM auxiliary engine emissions inventory delineated by vessel type at POLA and POLB. This table shows emissions for the Existing Regulation in 2020 (full implementation), 2021, 2023, 2025, 2027 and 2031. The table also shows the estimated emissions with the Proposed Regulation for five years, three of which are implementation years (2021, 2025, and 2027). Although 2023 and 2031 are not implementation years in the Proposed Regulation, they are provided for informational purposes because they are key attainment dates for the South Coast Air Basin under the SIP.

Table 2. POLA and POLB Estimated At Berth DPM Emissions (tons per year)[1]

Vessel Type	2020	2021		2023		2025		2027		2031	
	Existing	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed
Container	12.80	13.40	9.32	14.69	8.50	16.11	5.90	17.37	6.12	20.44	6.86
Tanker	6.29	6.38	6.38	6.46	6.46	6.55	6.55	6.63	2.49	6.78	2.55
Cruise	2.90	3.01	2.83	3.24	2.85	3.48	2.50	3.74	2.69	4.32	3.10
Ro-Ro	1.59	1.68	1.68	1.84	1.84	2.02	0.84	2.16	0.90	2.36	0.98
Bulk	0.83	0.86	0.86	0.87	0.87	0.88	0.88	0.88	0.88	0.90	0.90
General	0.73	0.76	0.76	0.83	0.83	0.90	0.90	0.97	0.97	1.12	1.12
Reefer	0.28	0.29	0.08	0.32	0.08	0.34	0.05	0.37	0.06	0.43	0.07
Total	25.42	26.38	21.91	28.24	21.42	30.27	17.60	32.11	14.10	36.36	15.57

1. Bulk and general cargo vessels not subject to control requirements in the Proposed Regulation.

Overall, when comparing the Proposed Regulation to the Existing Regulation at each phase, implementation in 2021 would reduce the total DPM emissions by approximately 17 percent, implementation in 2025 would reduce the DPM emissions by approximately 42 percent, and implementation in 2027 would reduce the DPM emissions by approximately 56 percent at POLA and POLB.

B. Richmond Complex Emission Inventory

Table 3 shows the emission inventory of DPM from auxiliary engines delineated by vessel type at the Richmond Complex. This table shows emissions for the Existing Regulation in 2020 (full implementation), 2021, and 2023, and for the two implementation years beginning in 2025 and 2029. Note implementation year 2021 would not apply because there are no container, reefer, or cruise ships port calls to the Richmond Complex. Although 2023 and 2031 are not implementation years in the Proposed Regulation, they are provided for informational purposes because they are key attainment dates under the SIP.

Table 3. Richmond Complex Estimated At Berth DPM Emissions (tons per year)[1]

Vessel Type	2020	2021	2023	2025		2029		2031	
	Existing	Existing	Existing	Existing	Proposed	Existing	Proposed	Existing	Proposed
Tanker	2.38	2.40	2.43	2.47	2.47	2.60	1.05	2.68	1.08
Ro-Ro	0.55	0.57	0.60	0.63	0.26	0.69	0.29	0.73	0.31
Bulk/ General	0.19	0.19	0.20	0.21	0.21	0.22	0.22	0.23	0.23
Total	3.13	3.16	3.23	3.30	2.94	3.52	1.57	3.64	1.62

1. Bulk vessels not subject to control requirements in the Proposed Regulation. No general cargo vessels visit the Richmond Complex.

Overall, compared to the Existing Regulation, implementation of the Proposed Regulation in 2025 and 2029 would reduce the total DPM emissions by approximately 11 percent and 55 percent, respectively. Tanker vessel emissions would be the largest contributor to the total remaining DPM emissions under the Proposed Regulation, accounting for approximately 84 percent and 67 percent in 2025 and 2029 implementation, respectively.

C. Statewide At Berth Emissions by Air Basin

Tables 4 through 7 show the statewide PM2.5 and NOx emission reductions that would result from the Existing Regulation and Proposed Regulation. These statewide reductions are used when estimating the ability of the Proposed Regulation to lower the regional PM2.5 mortality and illness impacts in each air basin. To estimate these benefits, the methodology requires the reductions by air basin for each year covered by the Proposed Regulation. The five air basins covered under the Proposed Regulation include the San Diego Air Basin, San Francisco Bay Area Air Basin, San Joaquin

County Air Basin, South Central Coast Air Basin, and South Coast Air Basin. As a result, reductions are shown from 2021-2032 for each of these air basins.

The air basin abbreviations in the following tables mean:

SF: San Francisco Bay Area Air Basin
SC: South Coast Air Basin
SCC: South Central Coast Air Basin
SD: San Diego Air Basin
SJV: San Joaquin County Air Basin

Table 4. At Berth Existing Regulation PM2.5 Emissions by Air Basin (tons per year)

Year	SF	SC	SCC	SD	SJV
2021	36.89	61.50	2.07	4.74	3.08
2022	37.64	62.98	2.11	4.91	3.14
2023	38.43	64.54	2.15	5.06	3.21
2024	39.25	66.17	2.19	5.23	3.28
2025	40.09	67.87	2.24	5.42	3.36
2026	41.08	69.02	2.28	5.59	3.45
2027	42.11	70.34	2.33	5.77	3.53
2028	43.16	71.65	2.37	5.95	3.63
2029	44.26	73.04	2.42	6.14	3.72
2030	45.39	74.51	2.47	6.34	3.82
2031	46.64	76.67	2.52	6.55	3.93
2032	47.93	78.89	2.57	6.78	4.05

Table 5. At Berth Proposed Regulation PM2.5 Emissions by Air Basin (tons per year)

Year	SF	SC	SCC[1]	SD	SJV
2021	35.75	57.39	2.19	4.60	3.08
2022	36.45	58.58	2.24	4.76	3.14
2023	36.22	58.26	2.28	4.78	3.21
2024	36.93	59.51	2.33	4.95	3.28
2025	35.63	56.22	1.67	3.94	3.36
2026	36.44	56.89	1.71	4.07	3.45
2027	37.28	43.68	1.74	4.20	3.53
2028	38.15	44.33	1.78	4.35	3.63
2029	28.16	45.04	1.81	4.49	3.54
2030	28.93	45.80	1.85	4.64	3.64
2031	29.78	47.23	1.89	4.81	3.75
2032	30.66	48.70	1.92	4.98	3.86

1. Years 2021-2024 show a slight increase as compared to the Existing Regulation due to the lower projected shore power usage in the Proposed Regulation at the Port of Hueneme.

Table 6. At Berth Existing Regulation NOx Emissions by Air Basin (tons per year)

Year	SF	SC	SCC	SD	SJV
2021	1212.6	2099.9	93.5	227.1	116.5
2022	1238.1	2147.8	94.8	231.1	119.2
2023	1262.6	2201.7	96.4	235.0	121.7
2024	1288.7	2259.9	98.2	242.0	125.0
2025	1315.9	2323.3	100.0	249.3	128.4
2026	1345.5	2374.8	101.8	255.7	132.3
2027	1379.0	2434.8	103.7	262.3	136.2
2028	1411.6	2495.0	104.8	269.1	140.4
2029	1441.5	2556.2	105.5	273.5	144.2
2030	1475.4	2612.1	107.3	257.5	145.7
2031	1494.5	2645.8	108.2	262.2	146.4
2032	1525.1	2434.4	110.3	267.2	135.2

Table 7. At Berth Proposed Regulation NOx Emissions by Air Basin (tons per year)

Year	SF	SC	SCC[1]	SD	SJV
2021	1127.0	1828.2	101.5	217.4	116.5
2022	1148.5	1857.6	102.8	221.1	119.2
2023	1103.9	1793.2	104.7	216.2	121.7
2024	1123.6	1828.7	106.6	222.5	125.0
2025	1008.4	1571.5	62.5	151.3	128.4
2026	1029.7	1593.8	63.7	155.6	132.3
2027	1053.0	1242.2	65.0	160.0	136.2
2028	1073.7	1264.5	65.9	164.6	140.4
2029	787.7	1287.4	66.6	168.3	132.6
2030	807.7	1306.6	67.7	147.5	134.3
2031	820.6	1323.7	67.8	150.4	135.3
2032	840.1	1303.8	69.2	153.1	124.2

1. Years 2021-2024 show a slight increase as compared to the Existing Regulation due to the lower projected shore power usage in the Proposed Regulation at the Port of Hueneme.

III. HEALTH RISK ASSESSMENT FOR POLA, POLB, AND THE RICHMOND COMPLEX

A. Health Risk Assessment Overview

Risk assessment is a complex process that requires the analysis of many variables to model real-world situations. This HRA is consistent with the methodology presented in the *OEHHA Air Toxics Hot Spots Program Risk Assessment Guidelines: The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments* (OEHHA, 2015) (OEHHA Guidance Manual). The standard approach used for this HRA involves four steps: 1) hazard identification, 2) exposure assessment, 3) dose-response assessment, and 4) risk characterization. These four steps are briefly discussed below.

1. Hazard Identification

For this assessment, the pollutant of concern is DPM from internal combustion engines. In 1998, CARB identified DPM as a toxic air contaminant based on its potential to cause cancer and other health impacts under the Assembly Bill (AB) 1807 Toxic Air Contaminant Identification and Control Program (CARB, 1998a).

2. Exposure Assessment

The risk assessor estimates the extent of public exposure to emitted substances. This involves emissions quantification, modeling of environmental transport, evaluation of environmental fate, identification of exposure routes and exposed populations, and estimation of exposure levels. For at berth operations, the receptors most likely to be exposed include residents and off-site workers located near the port. On-site workers could also be impacted by the emissions; however, they are not included in this HRA because the California Department of Industrial Relations, Division of Occupational Safety and Health (better known as Cal/OSHA) has jurisdiction over on-site exposure to workers who are employed at the facility. DPM only has health values for the inhalation pathway, as a result, inhalation is the only pathway evaluated. The magnitude of exposure is assessed through DPM emission estimates and computer air dispersion modeling, resulting in downwind ground-level concentrations of DPM at near-source locations.

3. Dose Response

The assessor characterizes the relationship between exposure to a pollutant and the incidence or occurrence of an adverse health effect. This step of the HRA is based on the standardized values developed by OEHHA. OEHHA supplies these dose-response relationships in the form of CPFs for carcinogenic effects and RELs for non-carcinogenic effects. The CPFs and RELs that are used in California can be found in the OEHHA Guidance Manual. The inhalation CPF for diesel particulate from internal combustion engines used for this HRA is 1.1 milligrams per kilogram body weight day $(mg/kg\text{-}day)^{-1}$. The chronic REL for DPM from internal combustion engines used for this

HRA is 5.0 micrograms per cubic meter ($\mu g/m^3$). DPM does not have an associated acute REL.

4. Risk Characterization

Finally, the risk assessor combines information derived from the previous steps. Modeled concentrations, which are determined through exposure assessment, are combined with the CPF for cancer risk and noncancer RELs determined under the dose-response assessment. This step integrates the information used to quantify the potential cancer risk and/or chronic or acute noncancer effects. For this HRA, both individual and population-wide potential cancer risks were quantified, along with the noncancer chronic hazard index.

B. Selection of California Ports

The Proposed Regulation would regulate emissions from ocean-going vessels while at berth in most California ports and marine terminals. Figures 1 and 2 show the maps for the Northern and Southern California ports and marine terminals affected by the Proposed Regulation. The maps also display the disadvantaged communities surrounding the ports. CalEPA currently defines a disadvantaged community, from an environmental hazard and socioeconomic standpoint, as a community that scores within the top 25 percent of the census tracts, as analyzed by the California Communities Environmental Health Screening Tool Version 3.0 (CalEnviroScreen). Communities that score within the top 25 percent of the census tracts have a higher Pollution Burden.[3] CalEnviroScreen uses a screening methodology to identify communities currently disproportionately burdened by multiple sources of pollution (OEHHA, 2018). In addition to being surrounded by disadvantaged communities, most of these ports are located in highly-populated urban areas.

[3] Pollution Burden represents the potential exposures to pollutants and the adverse environmental conditions caused by pollution.

Figure 1. Affected Northern California Seaports and Marine Terminals

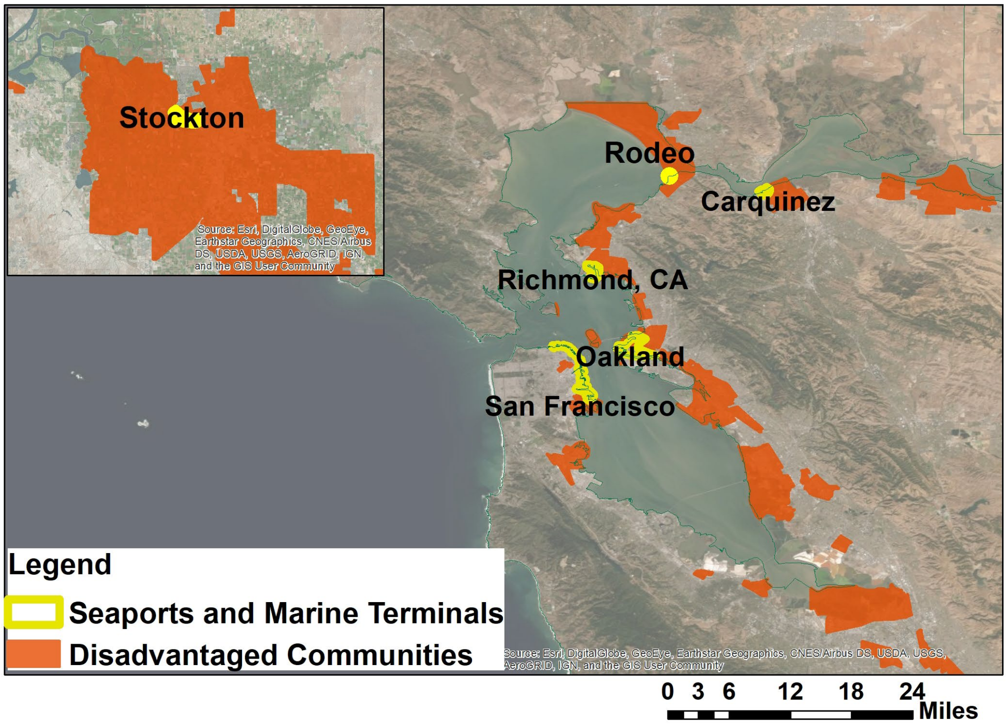
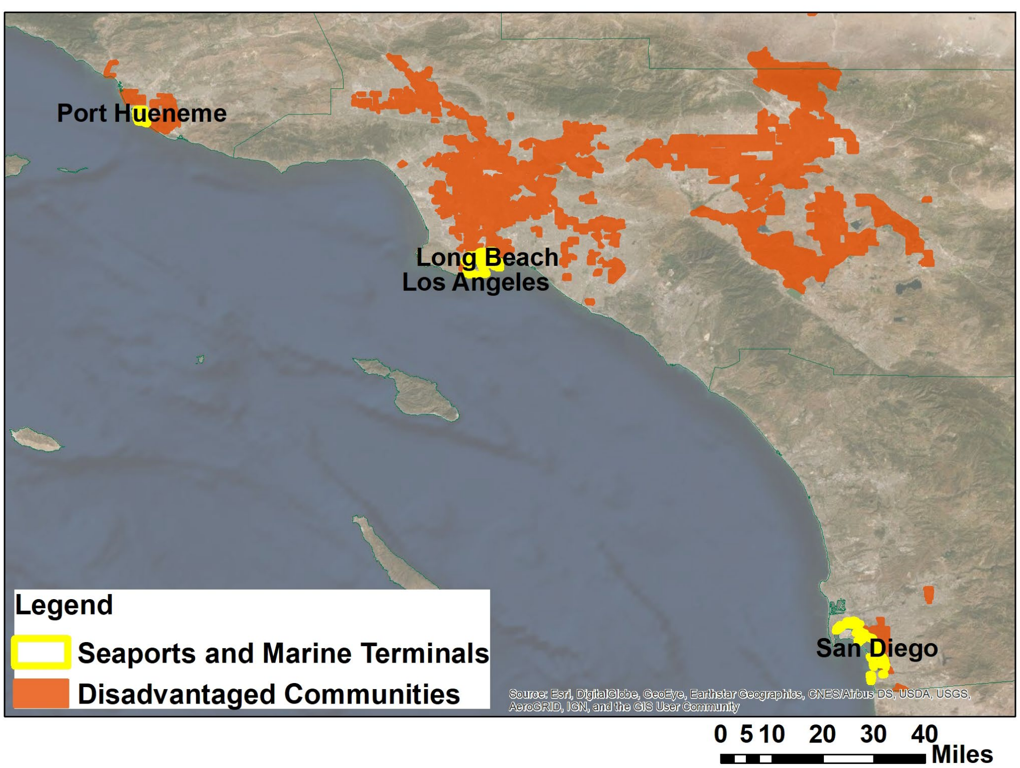


Figure 2. Affected Southern California Seaports and Marine Terminals



1. California Ports Selected

To characterize the existing cancer risk and the effectiveness of the Proposed Regulation, CARB staff evaluated the health impacts at large and small ports. Staff selected ports based on port size, vessel activity, emissions, and proximity to disadvantaged communities. Staff selected POLA and POLB to represent large ports. The Richmond Complex was selected to represent small ports. POLA and POLB combined represent more than half of the at berth emissions in California while the Richmond Complex represents the second largest emissions for tanker vessels in California. All ports are surrounded by disadvantaged communities that are often disproportionally impacted by higher levels DPM. One of CARB's highest priorities is to reduce exposure to air pollution in disadvantaged communities.

2. POLA and POLB

POLA and POLB are located next to each other in San Pedro Bay as two separate entities. POLA and POLB are owned by the City of Los Angeles and the City of Long Beach, respectively, and are operated and managed under a State Tidelands Trust that grants local municipalities jurisdiction over ports. Collectively, the two ports encompass approximately 10,700 acres and more than 50 miles of waterfront. Each port has more than 20 terminals for handling all types of vessels and cargo.

3. Richmond Complex

The Richmond Complex is a major shipping terminal in the San Francisco Bay, located in the City of Richmond. The Richmond Complex is comprised of two distinct entities, the public Port of Richmond located in the southeastern area of the complex and the private Chevron Marine Terminal associated with the Chevron refinery located in the western area of the complex. The Richmond Complex contains five city-owned terminals and 10 privately-owned terminals for handling bulk liquids, bulk materials, vehicles, and general cargo. The Chevron Marine Terminal is approximately one-half mile in length and connects to the shore with a one-half mile long causeway. This terminal is primarily used for handling crude oil.

C. Air Dispersion Modeling

In this section, we describe the air dispersion modeling performed to estimate the downwind concentration of DPM emitted from the at berth operations at the ports. A description of the air quality modeling parameters, including air dispersion model selection, modeling domain, emission source allocation, model parameters, meteorological data selection, and the model receptor network, is provided.

1. Air Dispersion Model Selection

Air quality models can be used to simulate physical and chemical processes that affect air toxics as they disperse and react in the atmosphere. The selection of an air dispersion model depends on many factors, such as: characteristics of emission sources (e.g., point, area, volume, or line), the type of terrain (e.g., flat or complex) at the emission source locations, and the relationship between sources and receptors. For this HRA, CARB staff selected United States Environmental Protection Agency's (U.S. EPA) AERMOD, Version 18081 (U.S. EPA, 2018) to simulate the impacts of at berth ocean-going vessel DPM emissions on nearby receptors. AERMOD is a steady-state plume model that incorporates air dispersion based on a planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources for distances up to 50 kilometers (km) in both flat and complex terrain.

2. Modeled Source Type and Parameters

Since emissions from ocean-going vessels while at berth typically come from the vessel's stack, CARB staff simulated these emissions as individual point sources. Modeling parameters for point sources include emission rate, stack height, stack diameter, stack exhaust temperature, and stack exhaust exit velocity. The point source parameters used in this HRA are based on the modeling parameters for hoteling from the *Diesel Particulate Matter Exposure Assessment Study for the Ports of Los Angeles and Long Beach* (CARB, 2006). The modeling parameters are summarized below.

- Stack height: 43 meters (m).
- Stack exhaust temperature: 618 Kelvin (K), 653 Fahrenheit (F).
- Stack exit velocity: 16 meters/second (m/s).
- Stack diameter: 0.5 m.
- Sources are assumed to operate continuously.

Figures 3 and 4 show the locations of the modeled point sources at each port. Staff used the following sources to determine the locations of the point sources.

For POLA and POLB, staff used the following information sources to determine the emission source locations:

- Port of Los Angeles Berths, Docks, Slips GIS data.[4]
- Port of Los Angeles Terminal Map.[5]

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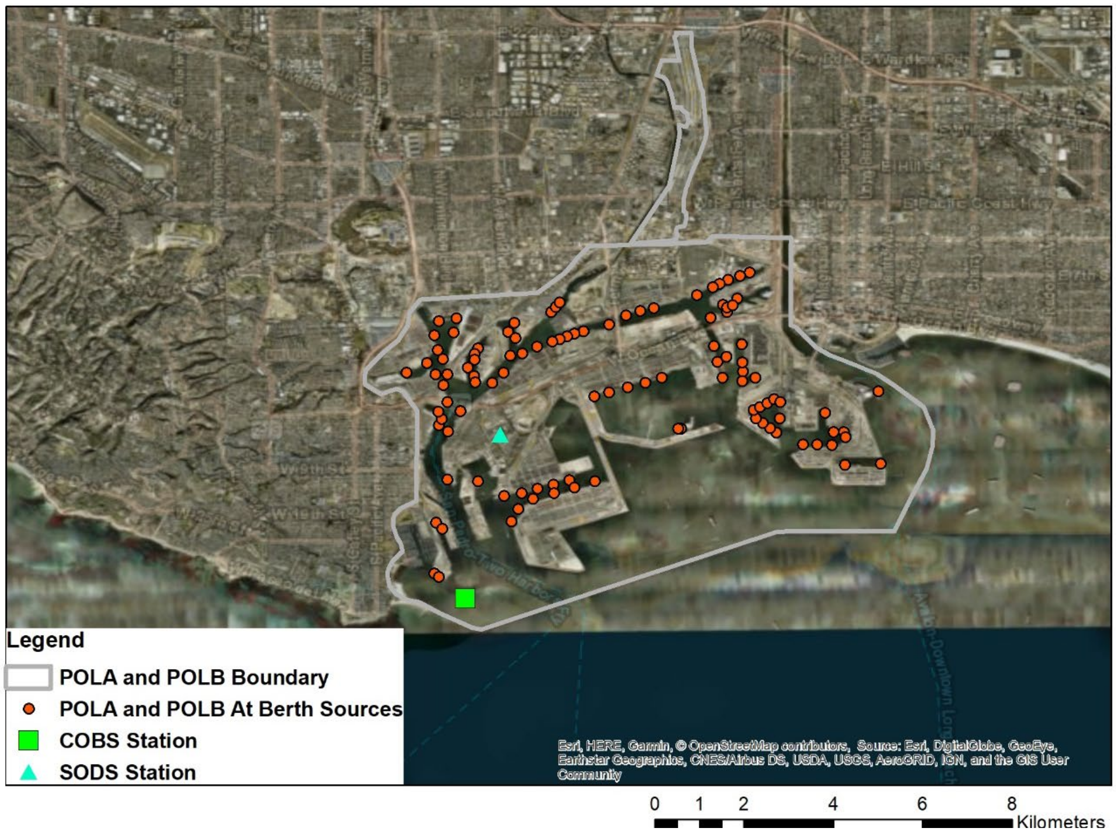
[4] Port of Los Angeles Berths, Docks, Slips GIS data https://egis3.lacounty.gov/dataportal/2015/07/15/port-of-los-angeles-berths-docks-slips/, accessed October 19, 2018.
[5] Port of Los Angeles Terminal Map, https://www.portoflosangeles.org/pdf/POLA_Terminals_Map.pdf, accessed October 19, 2018.

- Port of Long Beach Terminal Map.[6]
- Environmental Impact Report for Port of Long Beach Middle Harbor Redevelopment Project.[7]

Figure 3. Locations of Surface Meteorological Stations and Modeled Sources at POLA and POLB[1]



1. COBS: Coastal Boundary Station (B46 station); SODS: Source-Dominated Station (Terminal Island station).

For the Richmond Complex, staff used the following information sources to determine the emission source locations:

- United States (U.S.) Department of Homeland Security, U.S Coast Guard Navigation Center, AIS Encoding Guide and U.S. Destinations Codes.[8]

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[6] Port of Long Beach Terminal Map, http://www.polb.com/civica/filebank/blobdload.asp?BlobID=6907, accessed October 19, 2018.
[7] Port of Long Beach, Environmental Impact Report for Port of Long Beach Middle Harbor Redevelopment Project, April 2009.
[8] US Department of Homeland Security, United States Coast Guard Navigation Center. AIS Encoding Guide and U.S. Destinations Codes, https://www.navcen.uscg.gov/?pageName=locode, accessed October 19, 2018.

Figure 4. Locations of Surface Meteorological Stations and Modeled Sources at the Richmond Complex

3. Meteorological Data

AERMOD requires hourly meteorological data as inputs to the model. Meteorological parameters include wind speed, wind direction, atmospheric stability, and ambient temperature. These parameters are recorded by meteorological stations. For this HRA, CARB staff selected meteorological stations based on their representativeness to the modeled port areas.

a) POLA and POLB

For the POLA and POLB HRAs, POLA provided CARB staff with meteorological data for two on-site meteorological stations designated as the Coastal Boundary Station (COBS, B46 station) and Source-Dominated Station (SODS, Terminal Island station) (see Figure 3 above). In consultation with POLA and SCAQMD, CARB staff determined the SODS station to be the most representative station because the land use categories surrounding the SODS station are similar to the land uses surrounding the sources. With most of the berths concentrated near the SODS station, staff believes it is appropriate to use this one station to represent all berths.

Staff evaluated the SODS station meteorological data from 2011 to 2017. Of those seven years, the 2011, 2012, 2013, 2015, and 2017 data meet U.S. EPA's meteorological data completeness requirements (i.e., less than 10 percent of missing data in each calendar quarter of the year). CARB staff, in consultation with South Coast Air Quality Management District (SCAQMD) staff, processed an AERMOD-ready meteorological data set using the following modeling options in AERMET (Version 18081). AERMET is a meteorological preprocessor for AERMOD.

- Include the U-star adjustment option.
- Wind speed threshold: 0.5 m/s.[9]
- AERSURFACE precipitation condition assignment: The precipitation condition for each modeling year (i.e., wet, dry, or average) are based on the annual average precipitation value to the 30-year (1981-2010) normal precipitation value.[10]
- Month/season assignment: AERSURFACE default values.[11]

In addition, CARB staff processed the data using the cloud coverage data from Long Beach International Airport and upper air data from San Diego Airport. CARB staff selected San Diego Airport because it provides the most complete data available in proximity to POLA and POLB. Figure 5 presents the wind rose at the SODS site. Based on the yearly statistics, the average wind speed at SODS was 1.8 m/s with the predominant wind directions from the northwest and south. In combination with the meteorological data set, staff set the urban dispersion coefficients by using a population of 9,818,605 in AERMOD since the area at the impacted receptors is comprised of industrial, commercial, and compact residential land uses. This population was obtained from the SCAQMD modeling guidance (SCAQMD, 2018) and represents the population in Los Angeles County based on 2010 census data from the U.S. Census Bureau.

[9] The use of a wind speed threshold of 0.5 m/s is recommended by SCAQMD staff and is consistent with SCAQMD modeling guidance, available at http://www.aqmd.gov/home/air-quality/meteorological-data/modeling-guidance.

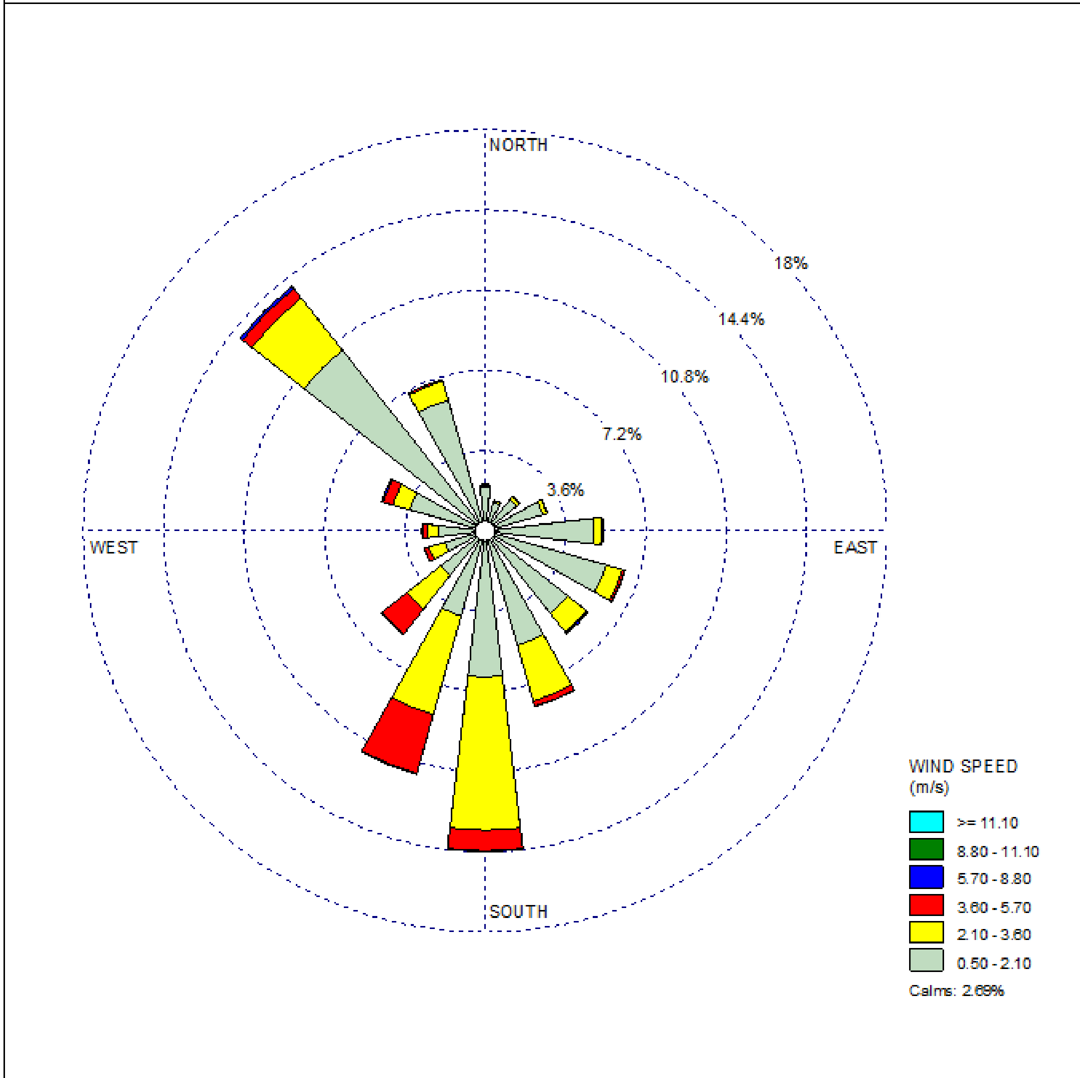
[10] If the annual average precipitation value > 70 percentile of the 30 normal value, then the precipitation condition is set to wet; If the annual average precipitation value < 30 percentile of the 30 normal value, then the precipitation condition is set to dry; otherwise, the precipitation condition is set to average.

[11] Late Autumn/Winter without Snow: December, January and February; Transitional Spring: March, April and May; Mid-summer: June, July and August; Autumn: September, October and November.

Figure 5. Wind Rose of SODS Station Used for POLA and POLB Modeling

WIND ROSE PLOT:
Wind Rose of SODS Station
2011-2013, 2015 and 2017

DISPLAY:
Wind Speed
Direction (blowing from)



COMMENTS:

DATA PERIOD:
Start Date: 1/1/2011 - 00:00
End Date: 12/31/2017 - 23:59

COMPANY NAME:

MODELER:

CALM WINDS:
2.69%

TOTAL COUNT:
43803 hrs.

AVG. WIND SPEED:
1.75 m/s

DATE:
8/31/2018

PROJECT NO.:

WRPLOT View - Lakes Environmental Software

b) Richmond Complex

The at berth emission sources at the Richmond Complex are located in two distinct areas. The Port of Richmond is located in the southeastern area of the complex and the Chevron Marine Terminal (a private marine oil terminal) is located in the western area of the complex. Bay Area Air Quality Management District (BAAQMD) staff provided CARB staff with two AERMOD-ready meteorological data sets located at Point San Pablo and the Chevron Refinery. The Point San Pablo station is located in a coastal area and the Chevron Met Station is located in an inland area (see Figure 4). A third met station is located at Chevron Richmond Long Wharf at the National Oceanic and Atmospheric Administration's (NOAA) National Buoy Data Center.[12]

CARB staff worked with Chevron staff to determine if the data from the met station on the Chevron Richmond Long Wharf could be utilized for modeling. It was determined that the data from this station had significant gaps. As a result, it was not used in this assessment.

For the two AERMOD-ready met data sets provided by BAAQMD, staff determined the Point San Pablo station is more representative for modeling the Chevron Marine Terminal since the land use surrounding this station is similar to the land use surrounding the Chevron Marine Terminal. Staff also determined that the Chevron Met Station is more representative for modeling the Richmond Complex because the land use surrounding this station is similar to the land use surrounding the Richmond Complex.

In combination with the meteorological data sets, staff ran AERMOD using the rural option, as the area within 3 km of the port facility is considered predominantly rural because it is surrounded on three sides by water (U.S. EPA, 2017b).

The Point San Pablo AERMOD-ready meteorological data set includes years 2010 to 2014. The Chevron Met Station AERMOD-ready meteorological data set includes years 2009 to 2013. Figures 6 and 7 present the wind rose at each site. The average wind speed at the Point San Pablo site was 4.8 m/s with the predominant wind directions from the southwest. The average wind speed at the Chevron Met Station was 4.0 m/s with the predominant wind directions from the south.

[12] National Oceanic and Atmospheric Administrations' (NOAA) National Buoy Data Center, available at: https://www.ndbc.noaa.gov/station_page.php?station=rcmc1, accessed October 19, 2018.

The following information summarizes how BAAQMD processed the meteorological data sets (BAAQMD, 2019).

- No U-star adjustment option.[13]
- Wind speed threshold: 0.223 m/s.
- Cloud coverage and upper air data from the Oakland Airport.

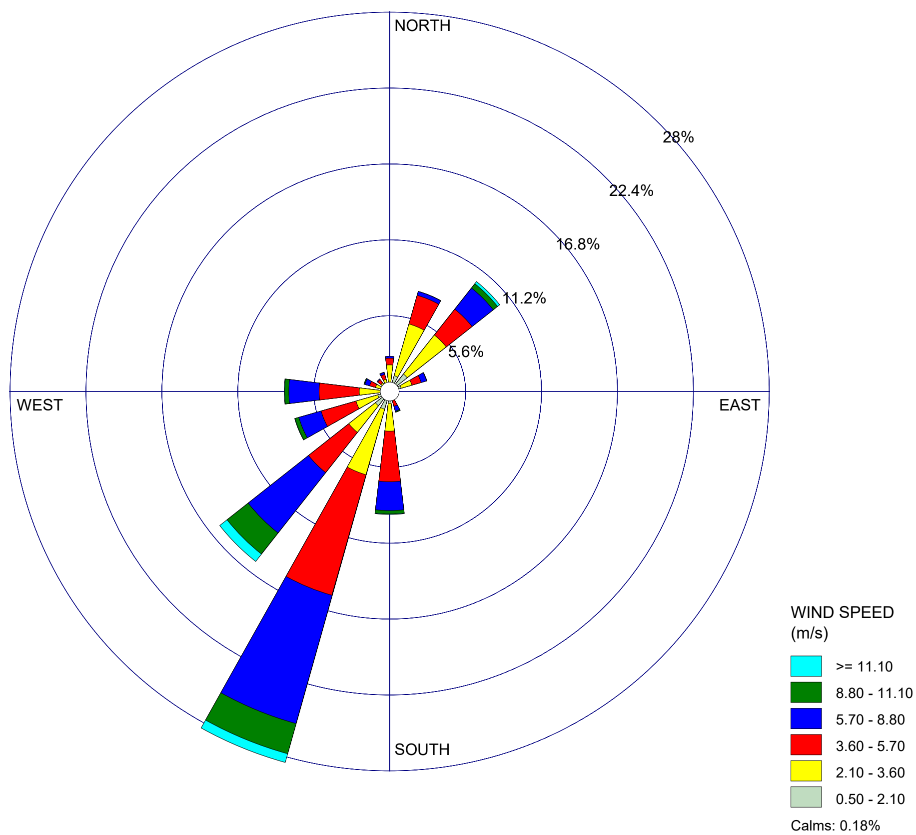
For AERSURFACE precipitation condition assignment CARB staff used the following:

- The precipitation condition for the each modeling year (i.e., wet, dry, or average) was based on the annual average precipitation value to the 30-year (1981-2010) normal precipitation value.

[13] According to AERMOD guidance "The ADJ_U* option may be used as a regulatory option in AERMET with NWS data or with site-specific data that does not include turbulence (i.e., sigma-w and/or sigma-theta)". The turbulence data (Sigma-theta data) was included in the BAAQMD on-site data, so the U-star option was not selected. (U.S. EPA, 2018)

Figure 6. Wind Rose of Point San Pablo Met Station Used for Modeling Chevron Marine Terminal Sources

WIND ROSE PLOT:	DISPLAY:
Wind Rose of Point San Pablo Station 2010-2014	**Wind Speed Direction (blowing from)**



COMMENTS:	DATA PERIOD:	COMPANY NAME:	
	Start Date: 1/1/2010 - 00:00 **End Date: 12/31/2014 - 23:59**	MODELER:	
	CALM WINDS: **0.18%**	TOTAL COUNT: **43788 hrs.**	
	AVG. WIND SPEED: **4.78 m/s**	DATE: **8/31/2018**	PROJECT NO.:

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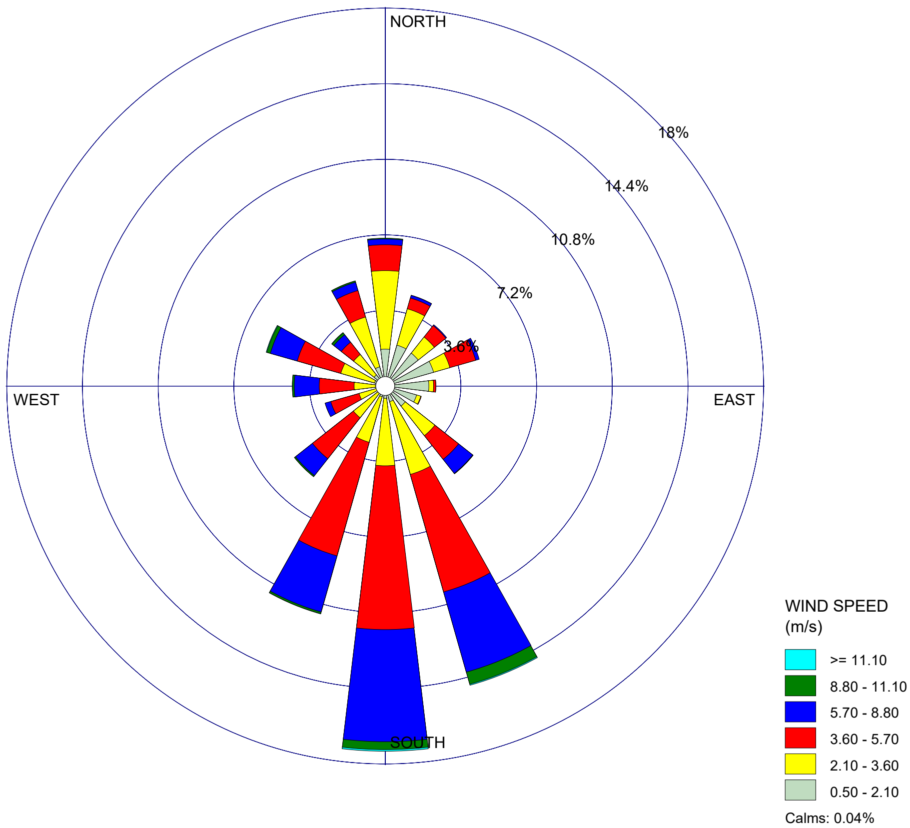
Figure 7. Wind Rose of Chevron Met Station Used for Modeling the Richmond Complex

WIND ROSE PLOT:
Wind Rose of Chevron Met Station 2009-2013

DISPLAY:
Wind Speed
Direction (blowing from)



COMMENTS:

DATA PERIOD:
Start Date: 1/1/2009 - 00:00
End Date: 12/31/2013 - 23:59

COMPANY NAME:

MODELER:

CALM WINDS:
0.04%

TOTAL COUNT:
43785 hrs.

AVG. WIND SPEED:
4.00 m/s

DATE:
10/3/2018

PROJECT NO.:

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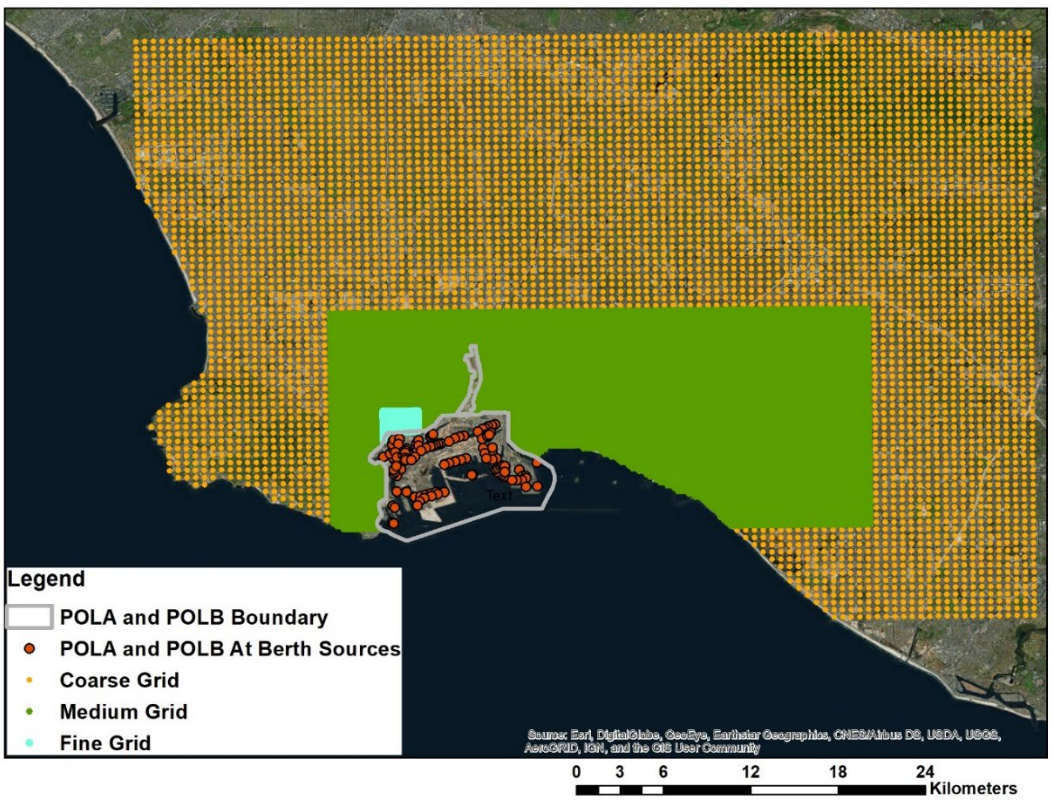
4. Model Domain and Receptor Network

The modeling domain includes the ports, the ocean surrounding the ports, and nearby residential areas. Cartesian grid receptors were placed around the ports where concentrations were estimated by the model. A number of on-site marina receptors were also included in the modeling. However, the focus of this evaluation was on off-port receptors. The flagpole height option was not applied to any receptors in this HRA.

a) POLA and POLB

A coarse 50 km x 40 km Cartesian grid with a grid spacing of 500 m was placed around POLA and POLB. This evaluation indicated that higher off-site potential cancer risks were located adjacent to the ports. Therefore, to better define concentrations in these areas, fine and medium grids were nested within the coarse grid. The fine and medium grid spacing were 50 m and 200 m, respectively (see Figure 8).

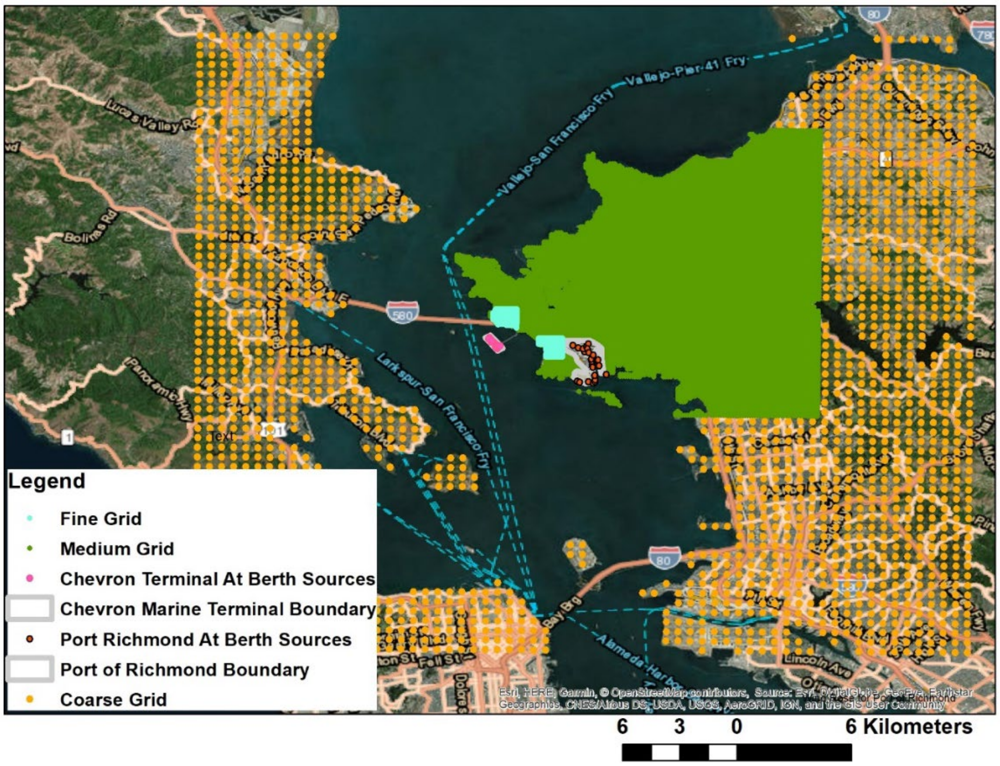
Figure 8. Modeling Setup for POLA and POLB



b) Richmond Complex

A coarse 30 km x 30 km Cartesian grid with a grid spacing of 500 m was centered at the Richmond Complex. Initial screening analyses indicated that higher off-site potential cancer risks were located adjacent to the ports. To better define concentrations in those areas, fine and medium grids were nested within the coarse grid. The fine and medium grid spacing were 50 m and 100 m, respectively (see Figure 9).

Figure 9. Modeling Setup for the Richmond Complex



5. Model Inputs

AERMOD requires four types of inputs: control, source, meteorological, and receptor. Control inputs are required to specify the global model options for the model run. The control options include dispersion coefficients, averaging time, terrain, and receptor elevations. The regulatory default options were selected for these inputs in both HRAs.

Source inputs require source identification and source type (e.g., point, area, volume, or open pit). Each source type requires specific parameters to define the source. For example, the required inputs for a point source are emission rate, release height, exhaust exit temperature, exhaust exit velocity, and stack diameter.

The requirements for meteorological and receptor inputs have been discussed in the Meteorological Data and Model Domain and Receptors Network Section. Table 8 lists the modeling input parameters used in AERMOD. These parameters are based on at berth operations (e.g., hoteling) of ocean-going vessels from the Diesel Particulate Matter Exposure Assessment Study for the Ports of Los Angeles and Long Beach (CARB, 2006).

Table 8. Modeling Input Parameters and Description

Modeling Parameters	Values or Description
Model Used	AERMOD (Version 18081)
Control Options	Regulatory Defaults
Source Type	Point
Urban Population	9,818,605 for POLA and POLB (Richmond was run as rural)
Meteorological Data	• SODS (2011, 2012, 2013, 2015, and 2017) for POLA and POLB • Point San Pablo Station (2010-2014) and Chevron Met Station (2009-2013) for the Richmond Complex
Receptor Flagpole Height	0 m
Stack Parameters	-
Stack Diameter	0.5 m
Stack Height	43 m
Stack Exhaust Temperature	618 K
Stack Exhaust Flow Rate	16 m/s
Stack Emission Rate	All sources used a unit emission rate of 1 gram/second (g/s) (The next section provides more information on how the modeled results were scaled to yield the actual DPM ground-level concentrations for POLA, POLB, and the Richmond Complex.)
Time Emission Emitted	24 hours per day, 365 days per year

6. Scaling of the Modeled Results

The HRA evaluates multiple emission inventory years for the Proposed Regulation and Existing Regulation. To reduce computer run time, CARB staff ran the air dispersion analysis once for each port and then scaled the modeled results obtained from AERMOD for each inventory year. This section provides the basic procedures on how staff scaled the modeled results. These procedures are consistent with the OEHHA Guidance Manual.

Staff used AERMOD to estimate the annual average concentrations for POLA, POLB, and the Richmond Complex. For each at berth emission source, staff inputted a unit emission rate of 1 gram per second (g/s). In addition, staff obtained the individual source contributions from AERMOD since multiple at berth sources were modeled at the same time. These individual source contributions were needed prior to scaling and summing the modeled results.

Next, staff treated the modeled results as non-pollutant-specific air concentrations expressed in micrograms per cubic meter per gram per second ($\mu g/m^3$)/(g/s). The non-pollutant-specific air concentration is commonly referred to as a χ/Q where χ is the modeled downwind air concentration based on an emission rate (Q) of 1 g/s.

To scale the modeled results for each at berth source, staff multiplied the χ/Q at each receptor point by the corresponding source-specific DPM emission rate in g/s to yield the actual DPM ground-level concentration in units of $\mu g/m^3$. After the ground-level concentrations were scaled for each at berth source, staff summed the ground-level concentration to yield the total DPM ground-level concentration at each receptor point. This process was repeated for each emission inventory year.

D. Risk Exposure Scenarios

To analyze the health impacts from the Proposed Regulation and the Existing Regulation, staff evaluated the maximum exposed individual resident (MEIR), maximum exposed individual worker (MEIW), population-wide cancer risks, and noncancer chronic risks. Staff calculated the health impacts using the methodology consistent with the OEHHA Guidance Manual. Since the Proposed Regulation contains multiple implementation dates, the health impacts were evaluated for the years 2021, 2025, 2027 (POLA and POLB only), and 2029 (Richmond Complex only). For all three ports, 2023 and 2031 were evaluated for SIP purposes. The description of the exposure scenarios and assumptions are presented below.

1. Exposure Scenarios for Inhalation Cancer Risk

The OEHHA Guidance Manual provides a description of the risk algorithms, recommended exposure variates, and health values for calculating cancer risk. Cancer risk is calculated by converting an annual average concentration to a dose and then comparing it to a pollutant-specific health value. Cancer risk is calculated by age bins (i.e., third trimester, 0<2, 2<9, 2<16, 16<30, or 16-70) and then summed for the exposure duration of interest (e.g., 30 years) to yield a total cancer risk. The bins allow age-specific exposure variates to be applied. Exposure variates include breathing rates, age sensitive factors, fraction of time at home (FAH), and exposure duration. For example, age sensitivity factors will multiply the risk by a factor of 10 for age bins less than two and use by a factor of three for age bins between two and 16.

Staff also applied the CARB and the California Air Pollution Control Officers Association (CAPCOA) risk management policy (RMP) for inhalation based cancer risk assessment (RMP, 2015). The policy recommends using a combination of the 95th percentile and 80th percentile daily breathing rates (DBR) as the minimum exposure inputs for risk management decisions. Specifically, the policy recommends using the 95th percentile breathing rates for age bins less than two years old and the 80th percentile breathing rates for age bins greater than or equal to two years old. This policy was used for calculating the MEIR and population wide risks. Finally, staff compared modeling results from the air dispersion analysis to the DPM inhalation CPF of 1.1 $(mg/kg\text{-}day)^{-1}$.

Table 9 provides a description of the exposure scenarios used in the HRA. Tables 10 and 11 summarize the exposure assumptions for each scenario.

Table 9. Exposure Scenario Descriptions

Risk Scenario	Descriptions
70-year Population-wide Cancer Risk	A population-wide cancer risk is used for sources with large emissions footprints (e.g., ports, refineries, rail yards, etc.) and is critical to provide an illustration of the potential impacts since a large number of people may be exposed to these emissions. This scenario assumes that a population will live in the impacted zone for 70 years, which is an assumed lifetime of a person and is health-protective for populations that stay within the emissions footprint of a source. Staff used 2010 U.S. census block population data to estimate the number of people within a given area.
30-year Individual Residential Cancer Risk	An individual residential cancer risk assumes that a resident is exposed to the emission source for 30 years. This is a high-end estimate that assumes an individual will live at a single location for 30 years. Although cancer risks are estimated for all receptors around the emission sources, staff report the MEIR. The MEIR represents the highest cancer risk to an individual residential receptor.
Off-site Worker Cancer Risk	An off-site worker cancer risk assumes that a worker who operates outside the port area is exposed to the emission sources for 25 years, 8 hours per day, and 250 day per year. For this HRA, the sources are assumed to emit continuously. Thus, no adjustment factor was applied to the annual concentration. In addition, the Guidance Manual recommends an 8-hour breathing rate for moderate intensity activities. Although the worker cancer risks are estimated for all receptors around the emission sources, staff report the MEIW. The MEIW represents the highest cancer risk to an off-site worker.

Table 10. Summary of Exposure Parameters

Risk Scenario	Exposure Duration			Breathing Rate (BR)	FAH	Pathway Evaluated
	Hours per Day	Days per Year	Years			
70-year Population-wide Cancer Risk	24	350	70	RMP (95^{th} percentile DBRs for age bins less than 2 years and 80^{th} percentile DBRs for age bins greater than 2 years)	Not applied (All age bins use 1)	Inhalation only
30-year Individual Residential Cancer Risk	24	350	30		1 for age bins less than 16 years 0.73 for age bins greater than 16 years	
Off-site Worker Cancer Risk	8	250	25	8-hour moderate intensity BRs	Not applied (All age bins use 1)	

Table 11. Age Bin Exposure Duration Distribution

Risk Scenario	Age Bins					Total
	3^{rd} Trimester	0<2	2<16	16<30	16-70	
70-year Population-wide Cancer Risk	0.25	2 years	14 years	-	54 years	70 years
30-year Individual Residential Cancer Risk	0.25	2 years	14 years	14 years	-	30 years
Off-site Worker Cancer Risk	-	-	-	-	25 years	25 years

2. Exposure Scenarios for Noncancer Chronic Risk

The chronic health hazard index is calculated by dividing annual average DPM concentration by the DPM inhalation chronic REL. If the hazard index yields a value above one, this may indicate a potential health impact and requires further evaluation. The DPM inhalation chronic REL presented in the OEHHA Guidance Manual is 5 $\mu g/m^3$ with one target organ identified as respiratory.

E. Summary of Health Risk Assessment Results

To illustrate the effectiveness of the Proposed Regulation in reducing health risks to the population living near the ports, CARB staff provided figures which display the risk isopleths for both the Existing Regulation and Proposed Regulation for the implementation and SIP years. Tables are also provided which estimate the number of people exposed to various risk levels, including those living in disadvantaged communities. The MEIR and MEIW tables show the potential health impacts to the maximum exposed resident and worker. CARB staff has also included a discussion along with the results.

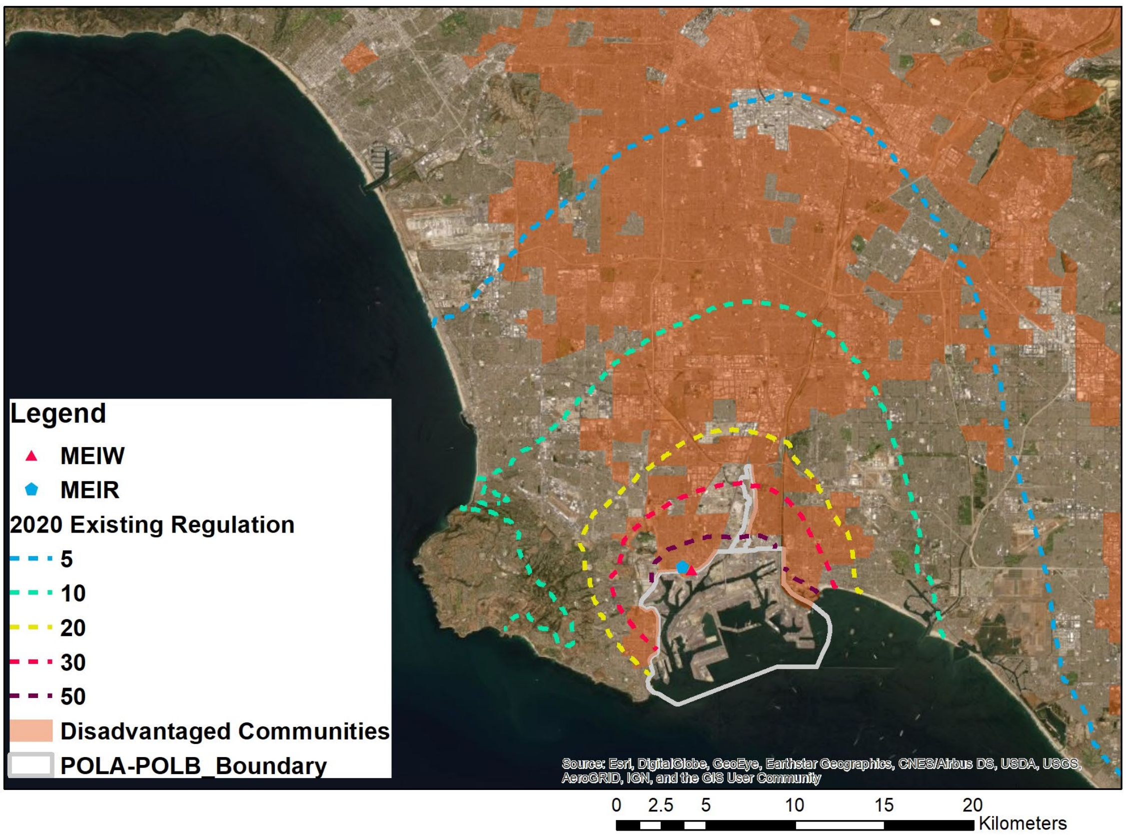
1. POLA and POLB Results

a) Population-wide Potential Cancer Risk

For POLA and POLB, CARB staff evaluated the potential population-wide cancer risk to the surrounding communities under the Existing Regulation and the Proposed Regulation. Figures 10 through 15 present the predicted cancer risk isopleths for DPM emissions from ocean-going vessels operating at berth. Isopleths are lines that connect points that have the same risk value. In Figures 11 through 15, dotted lines show the Existing Regulation cancer risk isopleths and solid lines display the Proposed Regulation cancer risk isopleths. These figures also illustrate how the area within risk isopleths would be reduced as the Proposed Regulation is implemented. In addition, the figures display the locations of the MEIR and MEIW for informational purposes. The population impacted within each risk isopleth is shown in Tables 12 and 13.

Figure 10 below shows the risk isopleth for the Existing Regulation in 2020, when the Existing Regulation is fully implemented. This risk isopleth does not account for any risk reduction from the Proposed Regulation. This is because the Proposed Regulation control requirements would begin in 2021.

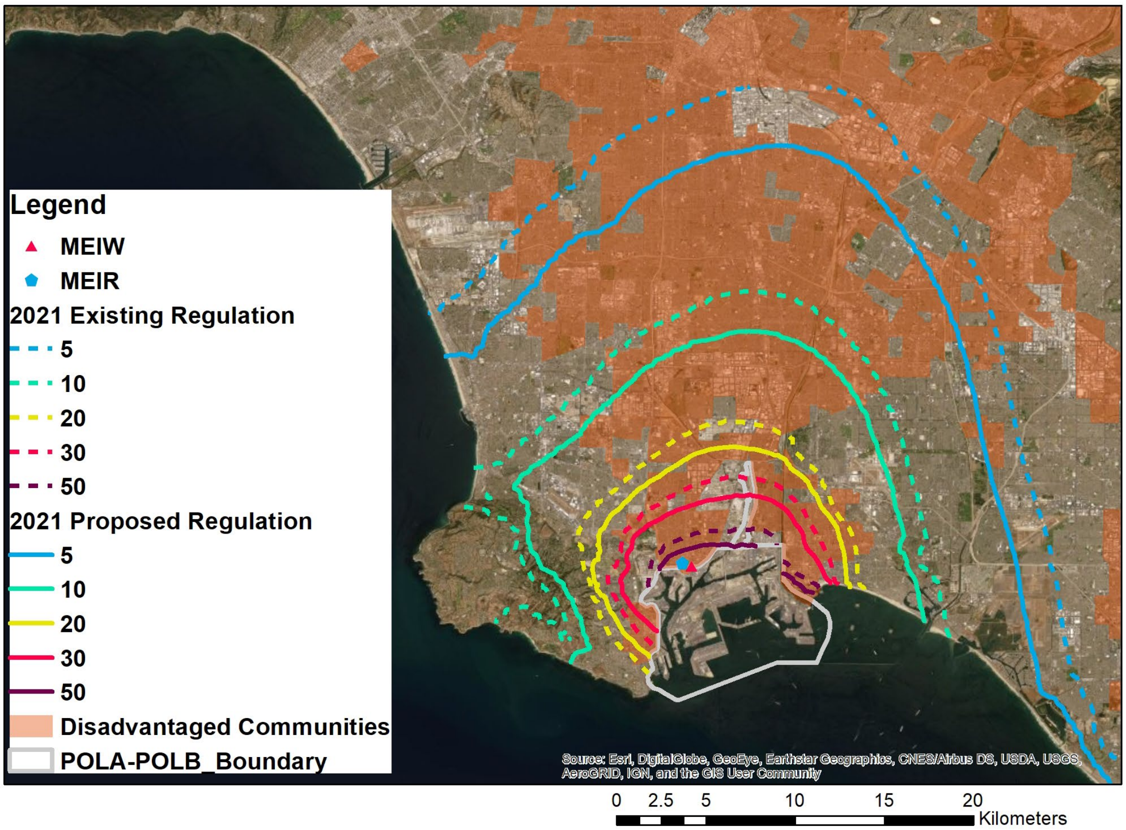
Figure 10. 2020 Impacts of Vessels At Berth for the Existing Regulation – POLA and POLB Potential Cancer Risk Isopleths (chances per million)[1]



1. Assumes exposure duration of 70 years using the RMP method (95th/80th percentile DBR). FAH equals 1 for all age bins.

Figure 11 below shows risk isopleths for both the Existing Regulation and the Proposed Regulation in 2021. This figure shows that with implementation of the Proposed Regulation in 2021, the areas within the risk isopleths would become smaller (as compared to the 2021 Existing Regulation). This risk reduction is a result of emissions control requirements for container, cruise, and reefer vessels.

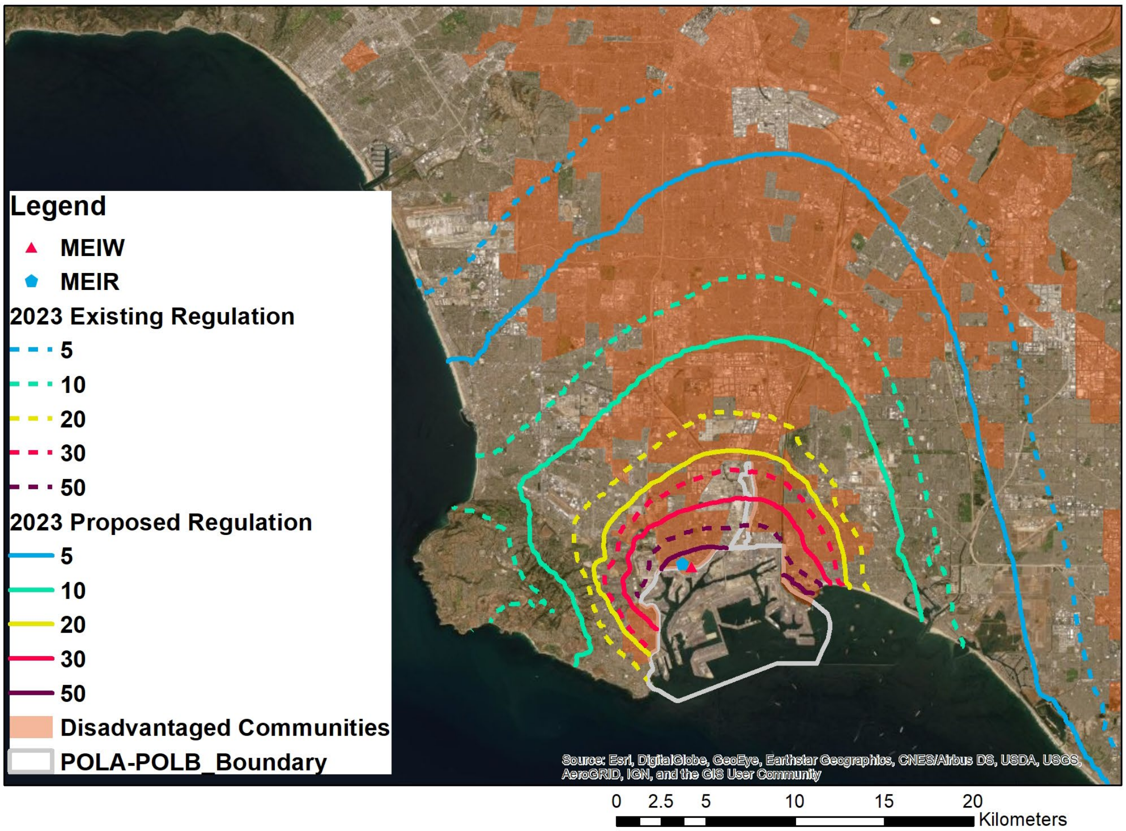
Figure 11. 2021 Impacts of Vessels At Berth for the Existing Regulation and the Proposed Regulation – POLA and POLB Potential Cancer Risk Isopleths (chances per million)[1]



1. Assumes exposure duration of 70 years using the RMP method (95th/80th percentile DBR). FAH equals 1 for all age bins.

Figure 12 below shows risk isopleths for both the Existing Regulation and the Proposed Regulation in 2023. This figure shows that the risk isopleths would stay relatively the same as compared with the 2021 Proposed Regulation. The change from 2021 to 2023 is the result of predicted growth in vessel visits. There are no additional control requirements between 2021 and 2023.

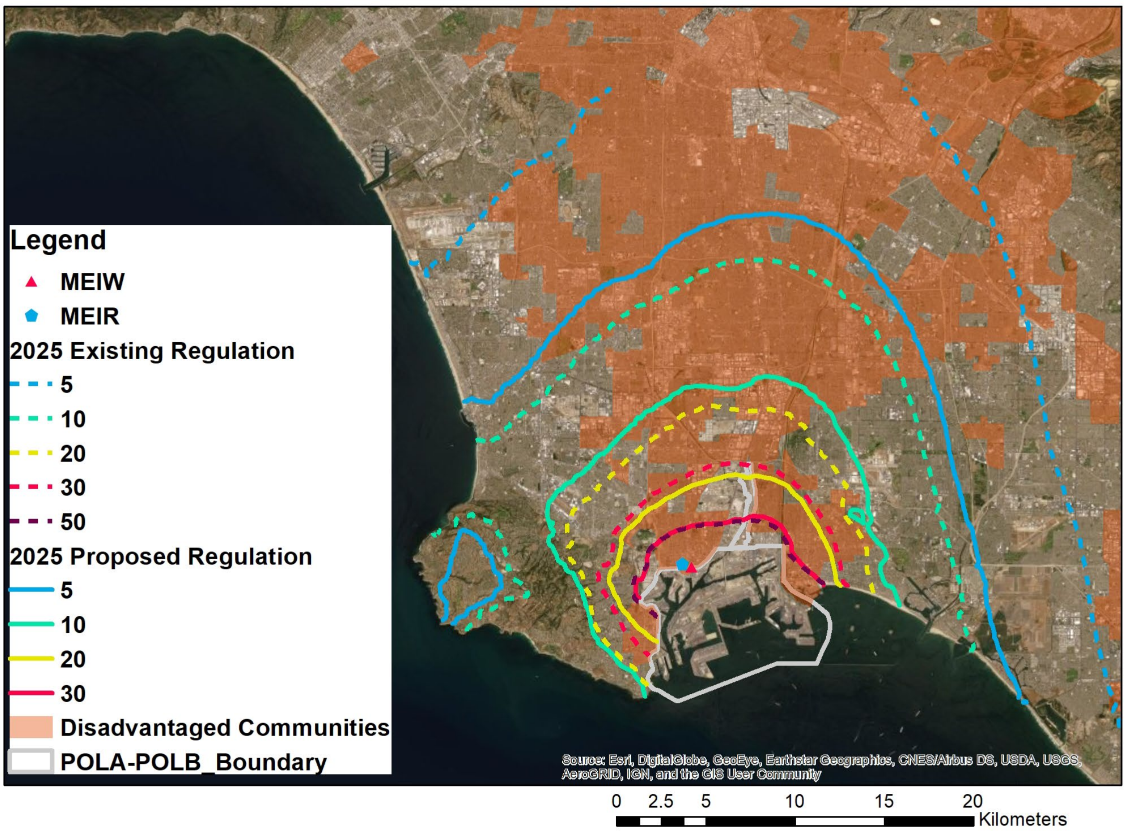
Figure 12. 2023 Impacts of Vessels At Berth for the Existing Regulation and the Proposed Regulation – POLA and POLB Potential Cancer Risk Isopleths (chances per million)[1]



1. Assumes exposure duration of 70 years using the RMP method (95th/80th percentile DBR). FAH equals 1 for all age bins.

Figure 13 below shows risk isopleths for both the Existing Regulation and the Proposed Regulation in 2025. This figure shows that by implementing the 2025 Proposed Regulation, the areas within the risk isopleths would continue to shrink (as compared to the 2025 Existing Regulation). In 2025, none of the modeled receptors has a risk value of 50 chances per million. As a result, the 50 chances per million risk isopleth would be eliminated in 2025. This risk reduction reflects the implementation of the 2025 Proposed Regulation ro-ro/auto carrier category vessel requirements.

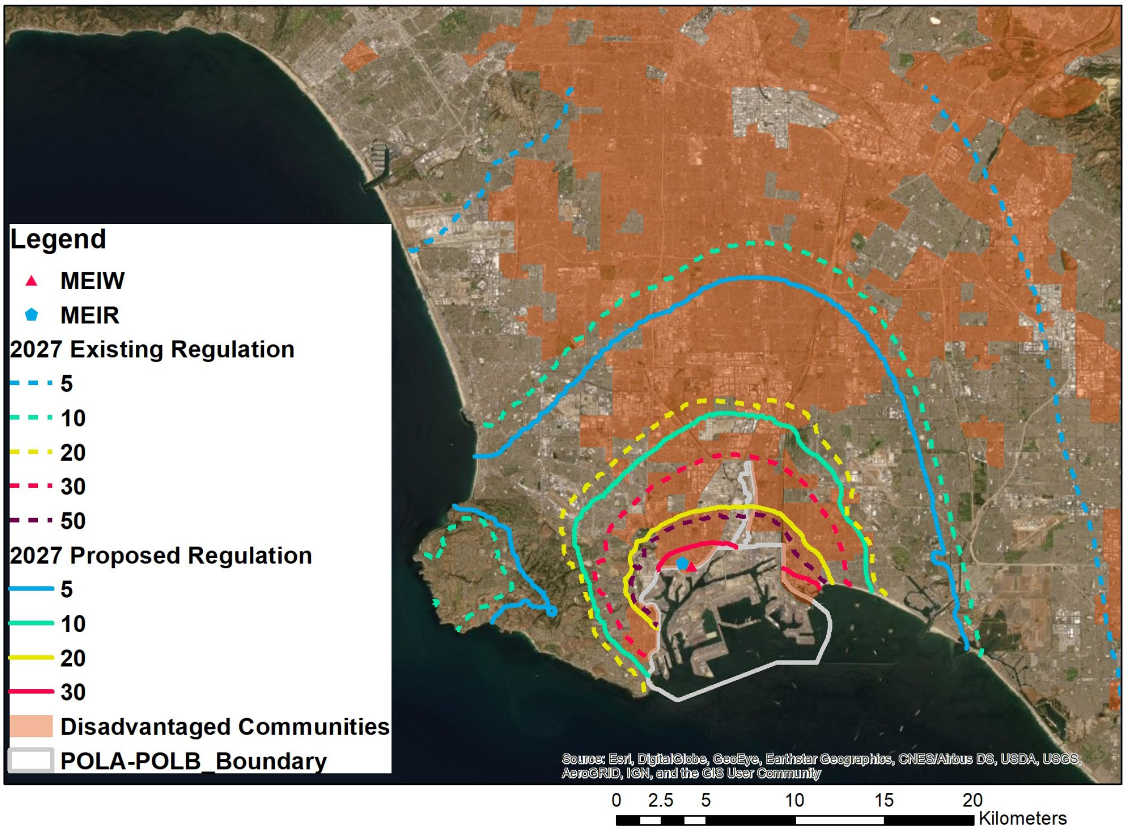
Figure 13. 2025 Impacts of Vessels At Berth for the Existing Regulation and the Proposed Regulation – POLA and POLB Potential Cancer Risk Isopleths (chances per million)[1]



1. Assumes exposure duration of 70 years using the RMP method (95th/80th percentile DBR). FAH equals 1 for all age bins.

Figure 14 below shows risk isopleths for both the Existing Regulation and the Proposed Regulation in 2027. This figure shows that by implementing the 2027 Proposed Regulation, the areas within the risk isopleths would continue to shrink (as compared to the 2027 Existing Regulation). This risk reduction reflects the implementation of the 2027 Proposed Regulation requirements for tanker vessels.

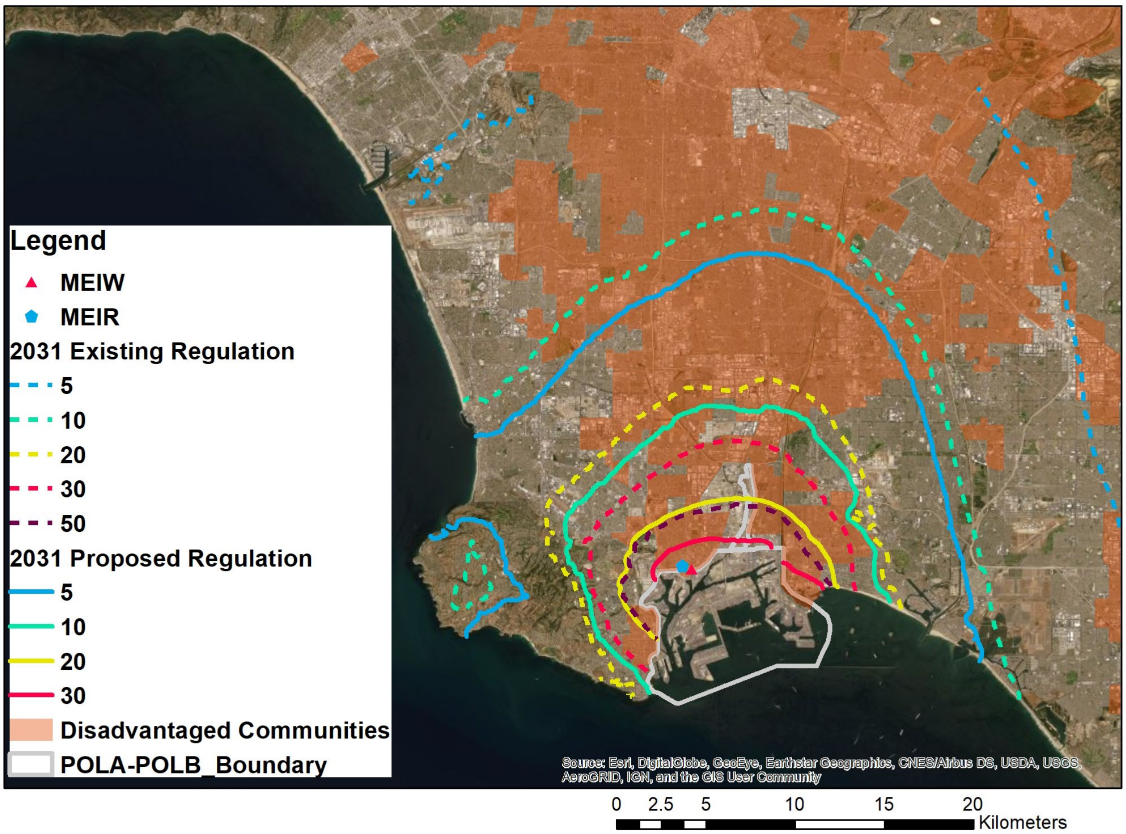
Figure 14. 2027 Impacts from Vessels At Berth for the Existing Regulation and the Proposed Regulation – POLA and POLB Potential Cancer Risk Isopleths (chances per million)[1]



1. Assumes exposure duration of 70 years using the RMP method ($95^{th}/80^{th}$ percentile DBR). FAH equals 1 for all age bins.

Figure 15 below shows risk isopleths for both the Existing Regulation and the Proposed Regulation in 2031. This figure shows that risk isopleths would stay relatively the same as compared with the 2027 Proposed Regulation. This is because there are no additional control requirements between 2027 and 2031 at POLA and POLB.

Figure 15. 2031 Impacts from Vessels At Berth for the Existing Regulation and the Proposed Regulation – POLA and POLB Potential Cancer Risk Isopleths (chances per million)[1]



1. Assumes exposure duration of 70 years using the RMP method (95th/80th percentile DBR). FAH equals 1 for all age bins.

Using the U.S. Census Bureau's data from the 2010 census, CARB staff estimated the population within the isopleth boundaries. Table 12 shows the estimated affected general population that fall within the potential cancer risk ranges of greater than five chances per million, 10 chances per million, 20 chances per million, 30 chances per million, and 50 chances per million. A similar presentation is provided in Table 13 showing the population affected in the disadvantaged communities[14] within the modeling domain.

[14] As defined by the 25 percent highest scoring census tracts in CalEnviroScreen3.0

Table 12. Estimated Population Impacts by Potential Cancer Risk Level at POLA and POLB[1]

Risk Level[2]	2020	2021		2023		2025		2027		2031	
	Existing	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed
>50	25,500	30,000	7,900	40,100	5,900	55,000	0	71,000	0	110,500	0
>30	176,800	193,500	120,600	225,500	112,900	262,900	58,700	297,500	11,400	367,500	26,500
>20	398,100	414,900	318,700	448,600	307,300	485,000	203,300	527,200	109,000	612,500	150,200
>10	954,400	1,008,300	789,900	1,118,600	767,700	1,227,000	605,600	1,353,400	449,700	1,654,200	511,900
>5	2,771,600	2,897,100	2,294,400	3,119,900	2,215,800	3,313,100	1,609,500	3,445,200	1,122,300	3,711,800	1,295,100

1. Population numbers have been rounded. Population-wide cancer risk estimates are based on a 70-year exposure duration using the RMP method ($95^{th}/80^{th}$ percentile DBR). FAH equals 1 for all age bins.
2. Risk levels are presented in chances per million.

Table 13. Estimated Population Impacts for Disadvantaged Communities by Potential Cancer Risk Level at POLA and POLB[1]

Risk Level[2]	2020	2021		2023		2025		2027		2031	
	Existing	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed
>50	25,400	29,800	7,900	39,700	5,900	54,100	0	69,400	0	104,600	0
>30	156,100	168,800	113,800	192,000	107,000	217,600	58,100	240,300	11,400	280,000	26,200
>20	292,700	299,600	251,000	311,900	245,300	325,700	175,300	339,600	101,600	364,000	135,300
>10	558,900	587,600	458,700	646,400	443,300	707,400	364,700	782,600	311,800	966,600	335,100
>5	1,716,900	1,798,100	1,406,400	1,949,100	1,342,400	2,061,900	942,200	2,110,100	647,300	2,207,500	742,800

1. Population numbers have been rounded. Population-wide cancer risk estimates are based on a 70-year exposure duration with $95^{th}/80^{th}$ percentile DBR RMP method. FAH equals 1 for all age bins.
2. Risk levels are presented in chances per million.

As shown in Tables 12 and 13, the Proposed Regulation would be effective at reducing the number of people exposed to each risk level. In addition, as the Proposed Regulation is implemented, potential cancer risk levels of greater than 50 chances per million would be eliminated beginning in 2025. Overall, at POLA and POLB in 2027, when comparing the Existing Regulation to full implementation of the Proposed Regulation, more than 2.3 million people would have their potential cancer risk reduced, of which about 1.5 million live in disadvantaged communities.

b) Potential Cancer Risk for MEIR and MEIW

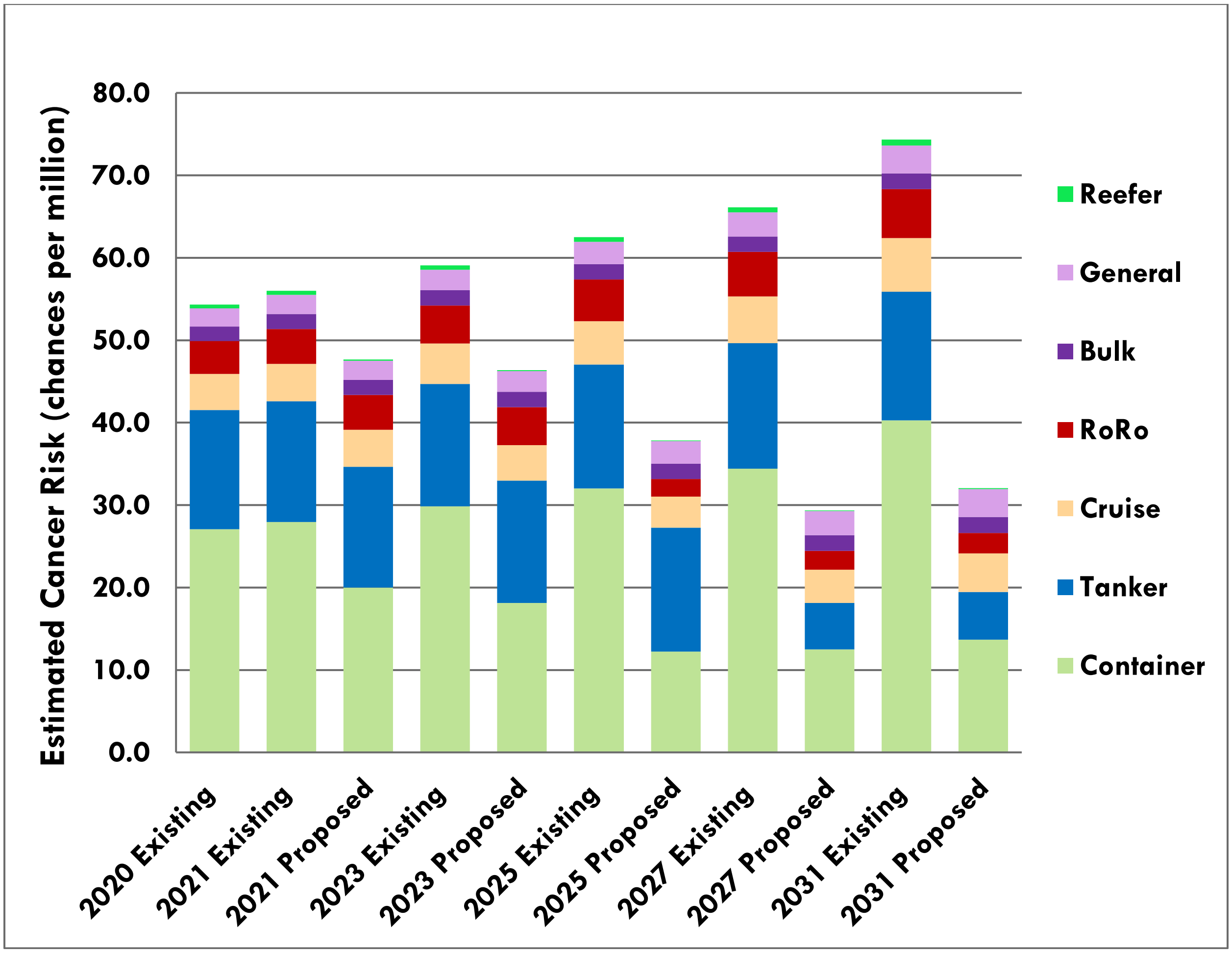
The Proposed Regulation would provide significant risk reductions by reducing the potential cancer risk to the MEIR and MEIW. Table 14 and Figure 16 below show the MEIR potential cancer risk by vessel type for the three implementation years of the Proposed Regulation. Staff also included 2023 and 2031 for informational purposes since that date is associated with the SIP for the South Coast Air Basin. The table and figure show that with full implementation of the Proposed Regulation, potential cancer risk would be significantly reduced.

Table 14. POLA and POLB At Berth MEIR Cancer Risks (chances per million)[1,2]

Vessel Type	2020	2021		2023		2025		2027		2031	
	Existing	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed
Container	27	28	20	30	18	32	12	34	12	40	14
Tanker	14	15	15	15	15	15	15	15	5.6	16	5.8
Cruise	4.4	4.5	4.5	4.9	4.3	5.2	3.8	5.6	4.1	6.5	4.7
Ro-Ro	4.0	4.2	4.2	4.6	4.6	5.1	2.1	5.4	2.3	5.9	2.5
Bulk[2]	1.8	1.8	1.8	1.8	1.8	1.9	1.9	1.9	1.9	1.9	1.9
General[2]	2.2	2.3	2.3	2.5	2.5	2.7	2.7	2.9	2.9	3.4	3.4
Reefer	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total	54	56	48	59	46	63	38	65	29	74	32

1. MEIR cancer risk estimates are based on a 30-year exposure duration of individual resident cancer risk with 95th/80th percentile DBR RMP method. FAH equals 1 for age bins <16 years, and FAH equals 0.73 for age bin 16-30 years. Fine grid receptor spacing is 50 m. Coarse grid receptor spacing is 200 m and 500 m.
2. Bulk and general cargo vessels not subject to control requirements in the Proposed Regulation.

Figure 16. POLA and POLB At Berth MEIR Cancer Risk[1,2]



1. MEIR cancer risk estimates are based on a 30-year exposure duration of individual resident cancer risk with 95th/80th percentile DBR RMP method. FAH equals 1 for age bins <16 years and 0.73 for age bin 16-30 years. Fine grid receptor spacing is 50 m. Coarse grid receptor spacing is 200 m and 500 m.
2. Bulk and general cargo vessels not subject to control requirements in the Proposed Regulation.

The overall MEIR potential cancer risk decreases throughout the three implementation years of the Proposed Regulation. For 2021, compared to the Existing Regulation, the MEIR potential cancer risk would be reduced by approximately 14 percent, from 56 chances per million to 48 chances per million. For 2025, compared to the Existing Regulation, the potential cancer risk would be reduced approximately 40 percent, from 63 chances per million to 38 chances per million. In 2027 at full implementation, compared to the Existing Regulation, the MEIR potential cancer risk would be reduced approximately 55 percent, from 65 chances per million to 29 chances per million.

Without the Proposed Regulation, the potential cancer risk to the MEIR would increase approximately 20 percent, from approximately 54 chances per million to 65 chances per million between 2020 and 2027. This demonstrates that without the Proposed Regulation potential cancer risk would increase due to growth in cargo activity.

For the Existing Regulation, in 2021, container and tanker vessels account for the greatest contribution of overall MEIR potential cancer risk, accounting for approximately 50 percent and 27 percent of the MEIR total risk, respectively. In 2027, with the Existing Regulation, container and tanker vessels would still account for the greatest contribution of overall MEIR potential cancer risk, accounting for approximately 52 percent and 23 percent of the MEIR total risk, respectively.

Table 15 shows the potential cancer risk at the MEIW. The MEIW is defined as the maximum exposed individual (off-site) worker located outside of the port boundary. More information on the MEIW analysis and assumptions can be found in Section III. D. Risk Exposure Scenarios.

Table 15. POLA and POLB At Berth MEIW Cancer Risks (chances per million)[1,2]

Vessel Type	2020	2021		2023		2025		2027		2031	
	Existing	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed
Container	2.3	2.4	1.7	2.6	1.5	2.7	1.0	2.9	1.1	3.4	1.2
Tanker	1.3	1.4	1.4	1.4	1.4	1.4	1.4	1.4	0.5	1.4	0.5
Cruise	0.4	0.4	0.4	0.4	0.3	0.4	0.3	0.5	0.3	0.5	0.4
Ro-Ro	0.3	0.3	0.3	0.4	0.4	0.4	0.2	0.4	0.2	0.5	0.2
Bulk[3]	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
General[3]	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3
Reefer	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.0
Total	4.7	4.9	4.1	5.1	4.0	5.4	3.3	5.7	2.5	6.4	2.8

1. Worker cancer risk estimates are based on a 25-year exposure duration with 95th percentile 8-hour DBR of moderate intensity activities. All numbers are rounded.
2. Bulk and general cargo vessels not subject to control requirements in the Proposed Regulation.

Overall, in 2027 with full implementation of the Proposed Regulation, the MEIW potential cancer risk would be reduced approximately 56 percent, from about 5.7 chances per million to 2.5 chances per million.

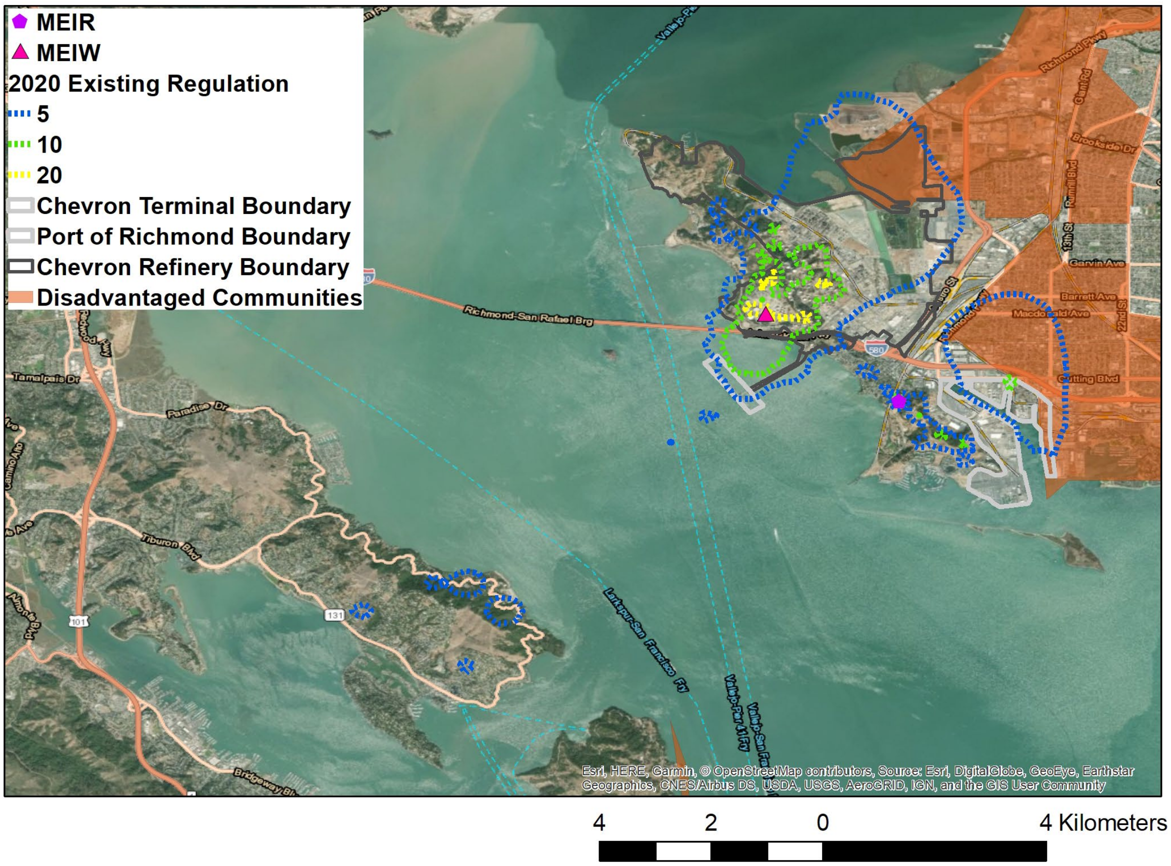
2. Richmond Complex Results

a) Population-wide Potential Cancer Risk

For the Richmond Complex, CARB staff evaluated the potential population-wide cancer risk to the surrounding communities under the Existing Regulation and the Proposed Regulation. Figures 17 through 20 present the predicted cancer risk isopleths for DPM emissions from vessels operating at berth. Isopleths are lines that connect points that have the same risk value. In Figures 18 through 20, dotted lines show the Existing Regulation cancer risk isopleths and the solid lines display the Proposed Regulation cancer risk isopleths. These figures show how the areas within the risk isopleths would be reduced as the Proposed Regulation is implemented beginning in 2025. In addition, the figures display the locations of the MEIR and MEIW for informational purposes. The population impacted within each risk isopleth is shown later in this section in Tables 16 and 17.

Figure 17 below shows the risk isopleth for the Existing Regulation in 2020, when the Existing Regulation is fully implemented. These risk isopleths do not account for any risk reduction from the Proposed Regulation. This is because the control requirements for the vessel types that visit the Richmond Complex begin in 2025.

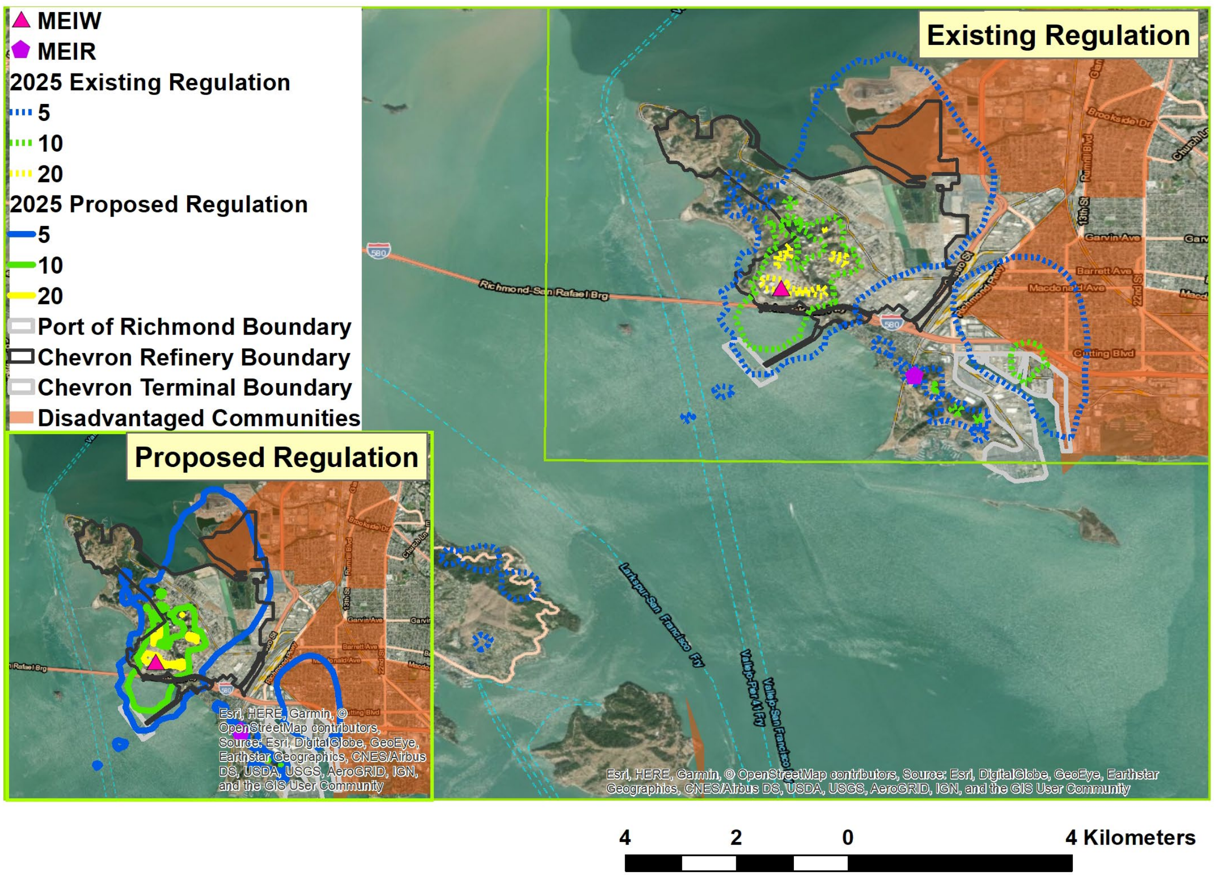
Figure 17. 2020 Impacts of Vessels At Berth for the Existing Regulation - Richmond Complex Potential Cancer Risk Isopleths (chances per million)[1]



1. Assumes exposure duration of 70 years using the RMP method (95th/80th percentile DBR). FAH equals 1 for all age bins.

Figure 18 below shows the risk isopleth for both the Existing Regulation and Proposed Regulation in 2025. With the Proposed Regulation, the areas within the isopleths become smaller (as compared to the 2025 Existing Regulation). This is due to the emissions control requirement for vessel types that visit the Richmond Complex beginning in 2025.

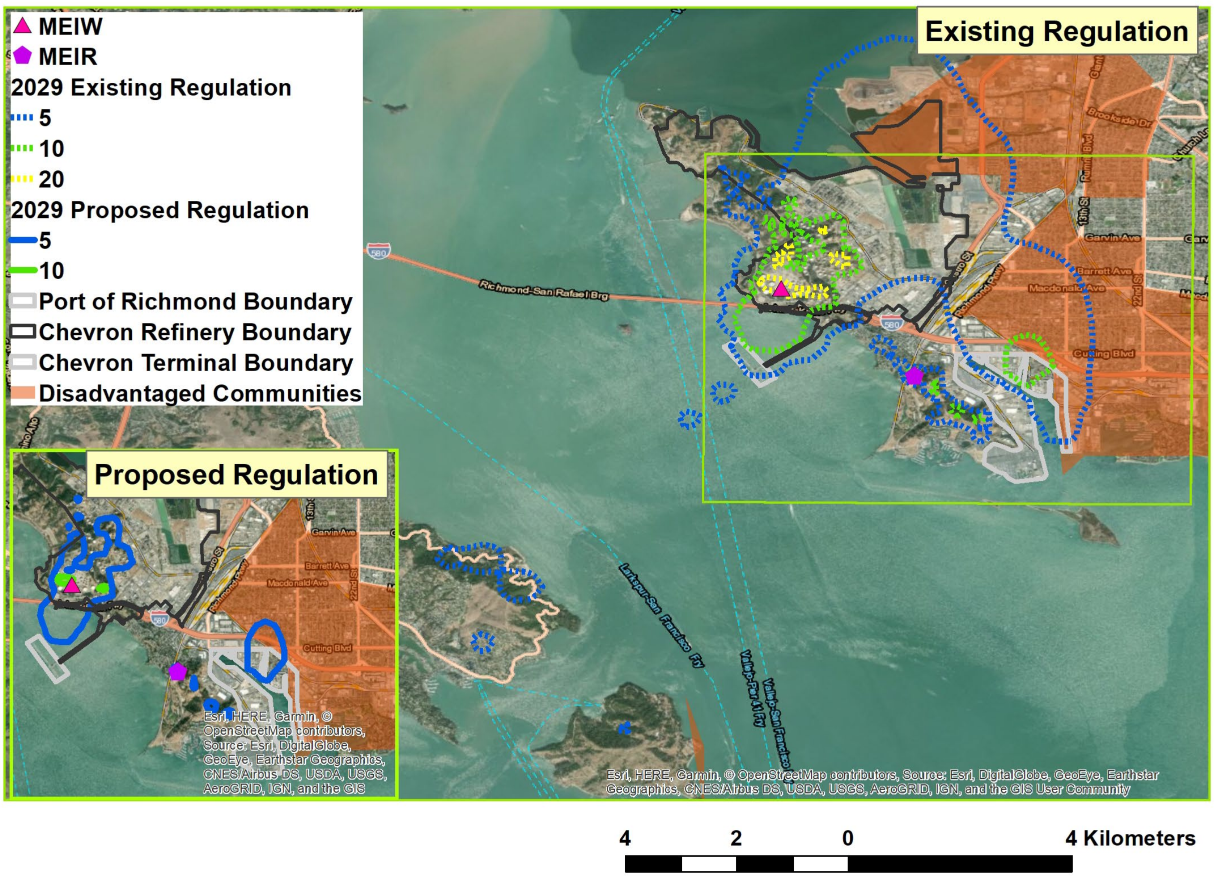
Figure 18. 2025 Impacts from Vessels At Berth for the Existing Regulation and the Proposed Regulation – Richmond Complex Potential Cancer Risk Isopleths (chances per million)[1]



1. Assumes exposure duration of 70 years using the RMP method (95th/80th percentile DBR). FAH equals 1 for all age bins.

Figure 19 shows the risk isopleth for both the Existing Regulation and Proposed Regulation in 2029. The areas within the isopleth for the Existing Regulation would continue to expand if the Proposed Regulation was not implemented. Under the Existing Regulation, the highest risk isopleth is 20 chances per million. With the Proposed Regulation, the isopleth becomes smaller and the 20 chances per million isopleth would be eliminated. This is due to the emissions control requirement for vessel types that visit the Richmond Complex.

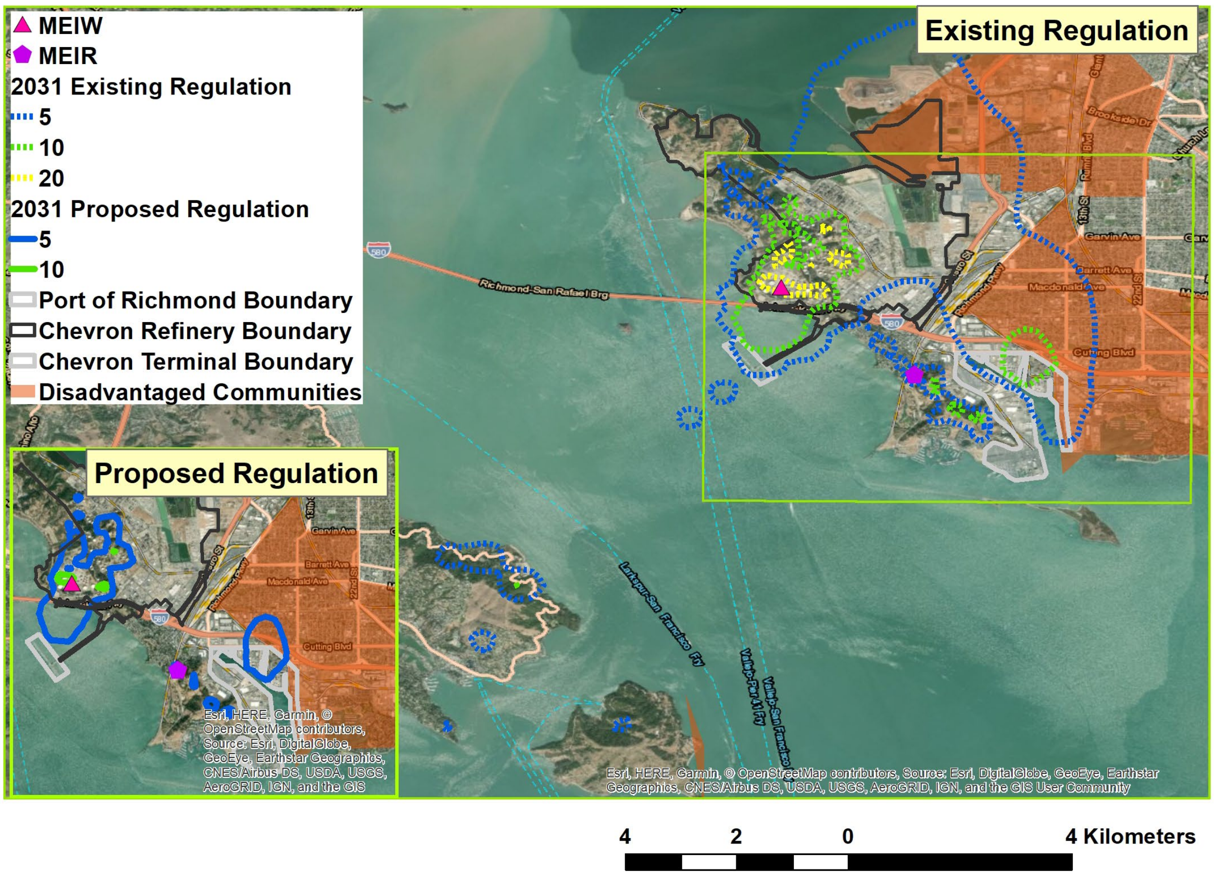
Figure 19. 2029 Impacts from Vessels At Berth for the Existing Regulation and the Proposed Regulation – Richmond Complex Potential Cancer Risk Isopleths (chances per million)[1]



1. Assumes exposure duration of 70 years using the RMP method (95th/80th percentile DBR). FAH equals 1 for all age bins.

Figure 20 below shows risk isopleths for both the Existing Regulation and the Proposed Regulation in 2031. This figure shows that the areas within the risk isopleths would stay relatively the same as compared with the 2029 Proposed Regulation. This is because there are no additional control requirements between 2029 and 2031.

Figure 20. 2031 Impacts from Vessels At Berth for the Existing Regulation and the Proposed Regulation – Richmond Complex Potential Cancer Risk Isopleths (chances per million)[1]



1. Assumes exposure duration of 70 years using the RMP method (95th/80th percentile DBR). FAH equals 1 for all age bins.

Using the 2010 U.S. Census Bureau's census data, CARB staff estimated the population within the isopleth boundaries. Table 16 shows the estimated affected general population that fall within the potential cancer risk ranges of greater than five chances per million, 10 chances per million, and 20 chances per million. No population is affected at greater than 30 chances per million and 50 chances per million. A similar presentation is provided in Table 17 showing the population affected in disadvantaged communities within the modeling domain.

Table 16. Estimated Population Impacts by Potential Cancer Risk Levels at the Richmond Complex[1,2]

Risk Level[2]	2020	2021	2023	2025		2029		2031	
	Existing	Existing	Existing	Existing	Proposed	Existing	Proposed	Existing	Proposed
>50	0	0	0	0	0	0	0	0	0
>30	0	0	0	0	0	0	0	0	0
>20	0	0	0	0	0	0	0	10	0
>10	140	150	180	240	110	540	10	760	10
>5	8,710	8,930	9,540	10,460	6,280	13,340	760	15,200	950

1. Population numbers have been rounded. Population-wide cancer risk estimates are based on a 70-year exposure duration using the RMP method (95th/80th percentile DBR). FAH equals 1 for all age bins.
2. Risk levels are presented in chances per million.

Table 17. Estimated Population Impacts in Disadvantaged Communities by Potential Cancer Risk Levels at the Richmond Complex[1,2]

Risk Level[2]	2020	2021	2023	2025		2029		2031	
	Existing	Existing	Existing	Existing	Proposed	Existing	Proposed	Existing	Proposed
>50	0	0	0	0	0	0	0	0	0
>30	0	0	0	0	0	0	0	0	0
>20	0	0	0	0	0	0	0	0	0
>10	10	20	30	80	0	350	0	570	0
>5	7,520	7,740	8,330	9,220	5,150	11,990	610	13,460	800

1. Population numbers have been rounded. Population-wide cancer risk estimates are based on a 70-year exposure duration with 95th/80th percentile DBR, RMP method. FAH equals 1 for all age bins.
2. Risk levels are presented in chances per million.

As shown in Tables 16 and 17, the Proposed Regulation would provide significant benefits by reducing the number of people exposed to each impacted risk level. In addition, by full implementation of the Proposed Regulation in 2029, potential cancer risk levels would be significantly reduced. Potential cancer risk levels greater than 10 chances per million would be eliminated in disadvantaged communities. Overall, at

Richmond Complex in 2029, when comparing the Existing Regulation to full implementation of the Proposed Regulation, more than 12,500 people would have their potential cancer risk reduced, of which about 11,000 live in disadvantaged communities.

b) Potential Cancer Risk for MEIR and MEIW

As shown in Tables 18 and 19, the Proposed Regulation would provide significant risk reductions by reducing the potential cancer risk to the MEIR and MEIW. Table 18 and Figure 21 below show the MEIR potential cancer risk by vessel type for both the Existing Regulation and with the two implementation years for the Proposed Regulation. The table shows that with full implementation of the Proposed Regulation potential cancer risk would be significantly reduced.

In 2025, compared to the Existing Regulation, the potential cancer risk to the MEIR would be reduced about 7 percent, from 14 chances per million to 13 chances per million. In 2029 with full implementation, the MEIR would be reduced by about 53 percent, from 15 chances per million to 7.1 chances per million.

Without the Proposed Regulation, the potential cancer risk to the MEIR would increase approximately 7 percent between 2021 and 2029, from approximately 14 chances per million to 15 chances per million due to growth in cargo activity.

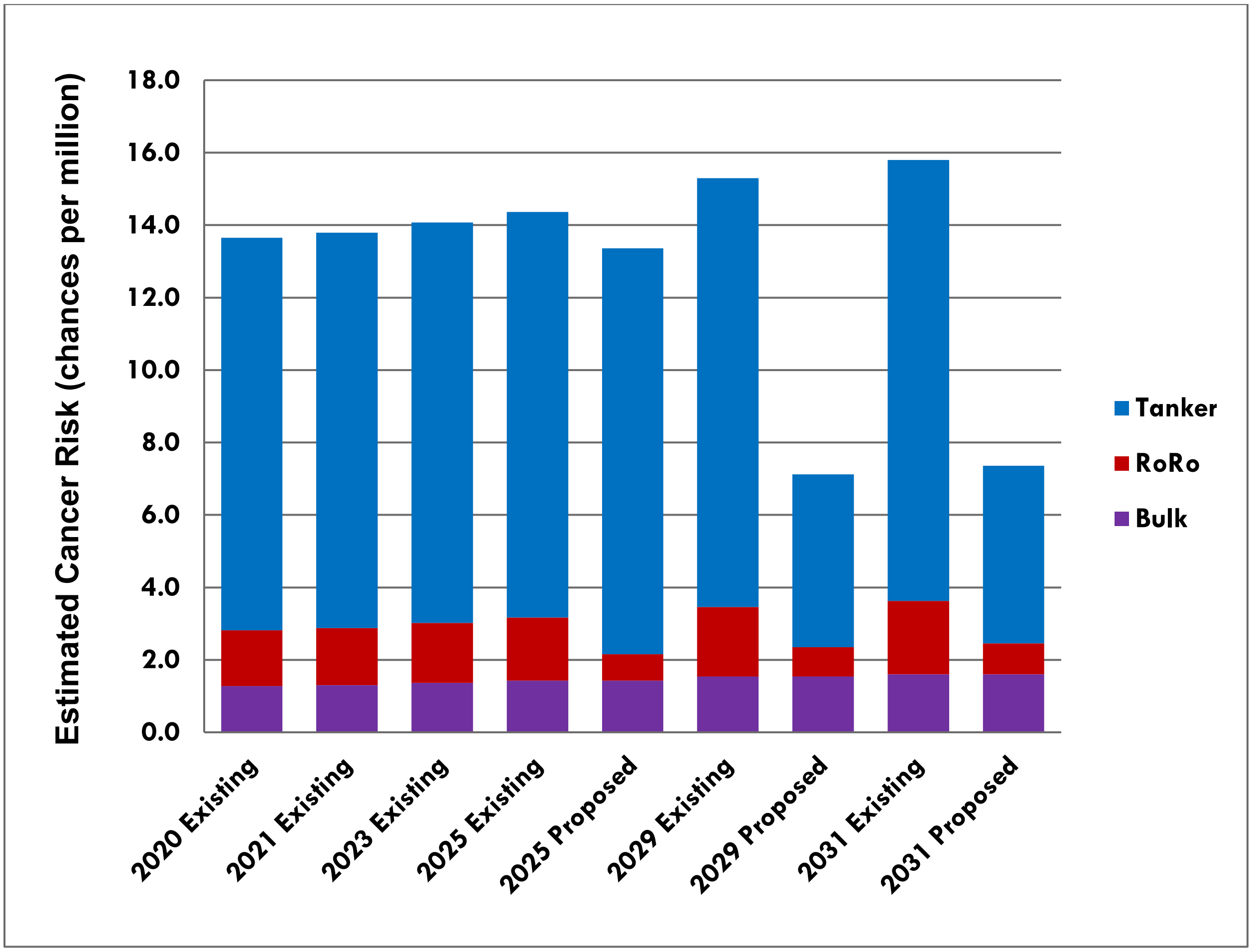
Figure 21 graphically demonstrates the contribution of each vessel type to the total MEIR potential cancer risk for the Existing Regulation and the Proposed Regulation. In all scenarios, tanker vessels account for largest contribution to the MEIR.

Table 18. Richmond Complex At Berth MEIR Cancer Risks (chances per million)[1,2]

Vessel Type	2020	2021	2023	2025		2029		2031	
	Existing	Existing	Existing	Existing	Proposed	Existing	Proposed	Existing	Proposed
Tanker	11	11	11	11	11	12	4.8	12	4.9
Ro-Ro	1.5	1.6	1.7	1.7	<1	1.9	<1	2.0	<1
Bulk	1.3	1.3	1.4	1.4	1.4	1.5	1.5	1.6	1.6
Total	14	14	14	14	13	15	7.1	16	7.4

1. MEIR cancer risk estimates are based on a 30-year exposure duration of individual resident cancer risk with 95th/80th percentile DBR RMP method. FAH equals 1 for age bins <16 years and 0.73 for age bin 16-30 years. All numbers are rounded.
2. Bulk vessels not subject to control requirements in the Proposed Regulation.

Figure 21. Richmond Complex At Berth MEIR Cancer Risk[1,2]



1. MEIR cancer risk estimates are based on a 30-year exposure duration of individual resident cancer risk with 95th/80th percentile DBR RMP method. FAH equals 1 for age bins <16 and 0.73 for age bin 16-30.
2. Bulk vessels not subject to control requirements in the Proposed Regulation.

Table 19 shows the potential cancer risk at the MEIW. The MEIW is defined as the maximum exposed (off-site) individual worker located outside the port boundary. The MEIW potential cancer risk would be reduced over 55 percent, from about 2.2 chances per million in 2020 to less than one chance per million in 2029.

Table 19. Richmond Complex At Berth MEIW Cancer Risks (chances per million)[1,2]

Vessel Type	2020	2021	2023	2025		2029		2031	
	Existing	Existing	Existing	Existing	Proposed	Existing	Proposed	Existing	Proposed
Tanker	2.1	2.1	2.1	2.2	2.2	2.3	<1	2.3	<1
Ro-Ro	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bulk	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total	2.2	2.2	2.2	2.3	2.2	2.4	<1	2.4	<1

1. Worker cancer risk estimates are based on a 25-year exposure duration with 95th percentile 8-hour DBR of moderate intensity activities. All numbers are rounded.
2. Bulk vessels not subject to control requirements in the Proposed Regulation.

3. Noncancer Chronic Health Impacts

CARB staff evaluated the noncancer chronic hazard index (HI) of the DPM modeled concentrations in the communities surrounding the three ports. The HI is a ratio of annual average concentrations of DPM to the chronic inhalation REL. OEHHA has adopted a chronic REL of 5 µg/m^3. CARB staff used the highest modeled annual average concentration at POLA and POLB and the Richmond Complex, and determined the HI at the MEIR was 0.02 and 0.004, respectively. Generally, a hazard index below one indicates that adverse chronic health impacts are not expected. Although the HI from DPM is below one, additional chronic health impacts may be associated with secondary formation of pollutants from diesel engines as evaluated in Section IV (Regional PM2.5 Mortality and Illness Analysis for California Air Basins). For example, NOx emissions from diesel engines can undergo chemical reactions in the atmosphere leading to the formation of PM2.5 and ozone.

F. Uncertainty Associated with the Health Risk Assessment

HRA is a complex procedure which requires the integration of many variables and assumptions. The estimated DPM concentrations and potential health risks produced by a risk assessment are based on several assumptions, many of which are designed to be health protective so that potential risks to individuals are not underestimated.

1. Uncertainty Associated with Health Values

The toxicity of toxic air contaminants is often established based on available epidemiological studies or use of data from animal studies where data from humans are not available. The DPM CPF is based on long-term studies of railyard workers exposed to diesel exhaust in concentrations approximately 10 times greater than typical ambient exposures. The differences within human populations usually cannot be easily quantified and incorporated into risk assessments. Factors including metabolism, target site sensitivity, diet, immunological responses, and genetics may influence the response to toxicants.

Human exposures to DPM are often based on limited availability of data and are mostly derived based on estimates of emissions and duration of exposure. Different epidemiological studies also suggest somewhat different levels of risk. When the Scientific Review Panel (SRP) identified DPM as a toxic air contaminant (CARB, 1998a), the panel members endorsed a range of inhalation CPF (1.3×10^{-4} to 2.4×10^{3} $(\mu g/m^3)^{-1}$) and a risk factor of 3×10^{-4} $(\mu g/m^3)^{-1}$, as a reasonable estimate of the unit risk. From the unit risk factor an inhalation CPF of 1.1 $(mg/kg\text{-}day)^{-1}$ was calculated by OEHHA, which is used in this HRA. There are many epidemiological studies that support the finding that diesel exhaust exposure elevates relative risk for lung cancer. However, the quantification of each uncertainty applied in the estimate of cancer potency is very difficult and can be itself uncertain.

2. Uncertainty Associated with Air Dispersion Models

As mentioned previously, there is no direct measurement technique to measure DPM in ambient air (e.g., ambient air monitoring). This analysis used air dispersion modeling to estimate the concentrations to which the public is exposed. While air dispersion models are based on state-of-the-art formulations using the best science, uncertainties are associated with the models.

The air dispersion model predictions have been improved over the years because of better representations in the model structure. In 2006, the U.S. EPA modeling guidance adopted AERMOD as the preferred model for near-field dispersion of emissions for distances up to 50 km. Many updated formulations have been incorporated into the model structure for better predictions from the air dispersion process. The U.S. EPA preferred air dispersion model, AERMOD, was selected for use in this HRA.

3. Uncertainty Associated with the Model Inputs

The model inputs include emission rates, modeling source parameters, meteorological conditions, and dispersion coefficients. Each of the model inputs has uncertainty associated with it. Among these inputs, emission rates and meteorological conditions have the greatest effect on modeling results.

The emission rate for each source was estimated from the emission inventory. The emission inventory has several sources of uncertainty including: emission factors, equipment population and age, equipment activity, load factors, and fuel type and quality. The uncertainties in the emission inventory can lead to over predictions or under predictions in the modeling results. CARB staff estimated at berth vessel emissions based on the best available information regarding past, current, and projected future at berth activities.

The modeling source parameters also have several sources of uncertainty including: stack height, stack temperature, stack exit velocity, and building downwash parameters. These parameters vary from vessel to vessel. To be consistent with other HRA analyses for modeling at berth emissions, the source parameters used in this HRA are based on the modeling parameters for hoteling from the *Diesel Particulate Matter Exposure Assessment Study for the Ports of Los Angeles and Long Beach* (CARB, 2006).

IV. REGIONAL PM2.5 MORTALITY AND ILLNESS ANALYSIS FOR CALIFORNIA AIR BASINS

A. PM Mortality and Illness Analysis Overview

PM2.5 is associated with adverse health outcomes such as the risk of premature deaths, hospitalizations and emergency room visits (U.S. EPA, 2010). As a result, reductions in PM2.5 emissions are associated with reduction in these health outcomes. NOx includes nitrogen dioxide, a potent lung irritant, but its most serious impact on human health comes about when atmospheric processes convert NOx into fine particles of ammonium nitrate. PM2.5 formed in this manner is termed secondary PM2.5 to distinguish it from primary PM2.5, which is emitted directly from a source, such as soot from engine exhaust.

As part of the health analyses, CARB staff conducted a PM mortality and illness analysis based on the statewide emission reductions of PM2.5 and NOx that would be achieved by the implementation of the Proposed Regulation. The methods used to estimate the premature deaths and other health outcomes related to PM2.5 exposure are based on a peer-reviewed methodology developed by U.S. EPA (U.S. EPA, 2010) and CARB's incidence-per-ton (IPT) methodology.[15] Unlike the HRA, the PM mortality and illness analysis presents the statewide health benefits in dollar amounts.

CARB staff used two methods to estimate the health benefits of the Proposed Regulation. For the South Coast Air Basin, health benefits were estimated using the air dispersion results from the HRA. For all other air basins, where basin-wide air dispersion results were unavailable, staff used the IPT methodology. For a detailed explanation of estimating health impacts, see the CARB document *Estimate of Premature Deaths Associated with Fine Particle Pollution (PM2.5) in California Using a U.S. Environmental Protection Agency* Methodology (CARB, 2010a.).

1. Health Outcomes for the South Coast Air Basin

The air dispersion analysis performed in the HRA for POLA and POLB covered a large enough domain to represent the South Coast Air Basin. Using the air dispersion results in this manner is an approved method for estimating ambient concentrations of PM2.5. The reductions in PM2.5 concentrations estimated by the air dispersion analysis were then inputted into CARB's health model to estimate health benefits. The inputs to the health model are a concentration-response function (CRF), population data, baseline incidence rates, and measured or modeled PM2.5 concentrations.

[15] CARB's Methodology for Estimating the Health Effects of Air Pollution, https://www.arb.ca.gov/resources/documents/carbs-methodology-estimating-health-effects-air-pollution, accessed September 3, 2019.

a) Concentration-Response Function

A CRF is an equation that relates concentrations of air pollutants such as PM2.5 to health outcomes such as cardiopulmonary mortality, hospitalizations for cardiovascular illness, hospitalizations for respiratory illness, and emergency room visits. CARB uses a subset of CRFs used by U.S. EPA.[16] One CRF is used for premature death.[17] Other CRFs are used for cardiovascular and respiratory hospital admissions[18] and emergency room visits.[19] The selection process for the CRFs is described briefly in CARB's 2010 report on PM2.5 mortality[20] and in detail in the U.S. EPA's 2010 Health Risk Assessment for Particulate Matter (U.S. EPA, 2010). CRFs are not unique for a specific source category.

b) Population Data

Population data are taken from the U.S. Census Bureau[21] data at a census tract level, and are broken into 17 five-year age brackets. The age brackets start with ages 0-4 and go up to ages 80-84, plus an additional age bracket for ages 85 and greater. The population in any given year was estimated by taking 2010 census data for total population by age bracket and projecting it to the year in question using county population projections from the California Department of Finance.[22]

c) Baseline Incidence Rates

Baseline incidence rates are the underlying rates of death and illness in the population before the effects of air pollution are considered. Incidence data are at the county level for premature death and at the statewide level for hospitalizations and emergency room visits. They are distributed into the same age brackets as population data. Incidence

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[16] CARB 2010a. Estimate of Premature Deaths Associated with Fine Particle Pollution ($PM_{2.5}$) in California Using a U.S. Environmental Protection Agency Methodology. https://www.arb.ca.gov/research/health/pm-mort/pm-report_2010.pdf

[17] Krewski et al., 2009. Extended Follow-Up and Spatial Analysis of the American Cancer Society Study Linking Particulate Air Pollution and Mortality. Health Effects Institute Research Report 140. https://ephtracking.cdc.gov/docs/RR140-Krewski.pdf

[18] Bell et al., 2008. Seasonal and Regional Short-term Effects of Fine Particles on Hospital Admissions in 202 US Counties, 1999–2005. Am J Epidemiol. 2008 Dec 1; 168(11): 1301–1310. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2732959/

[19] Ito et al., 2007. Characterization of PM2.5, gaseous pollutants, and meteorological interactions in the context of time-series health effects models. J Expo Sci Environ Epidemiol. Vol. 17 Suppl 2: S45-60. http://www.nature.com/jes/journal/v17/n2s/full/7500627a.html

[20] [CARB 2010a Estimate of Premature Deaths Associated with Fine Particle Pollution (PM2.5) in California Using a U.S. Environmental Protection Agency Methodology, https://www.arb.ca.gov/research/health/pm-mort/pm-report_2010.pdf

[21] U.S. Census Bureau. American Fact Finder. https://factfinder.census.gov/faces/nav/jsf/pages/download_center.xhtml, accessed August 29, 2019

[22] CDOF. California Department of Finance population projection web site. http://www.dof.ca.gov/Forecasting/Demographics/Estimates/, accessed August 29, 2019

data were taken from the CDC Wonder[23] database and the U.S. EPA's BenMAP health benefits mapping software.[24]

2. Health Outcomes using the IPT Methodology for All Other Air Basins

CARB uses the IPT methodology to quantify the health benefits of emission reductions in cases where dispersion modeling results are not available. CARB's IPT methodology is based on the methodology developed by U.S. EPA (Fann et. al. 2009, 2012, 2018). It is used to estimate the benefits of reductions in primary PM2.5 emitted directly from sources and secondary PM2.5 formed from precursors by chemical processes in the atmosphere. More information on the IPT methodology can be found on CARB's web site (https://www.arb.ca.gov/resources/documents/carbs-methodology-estimating-health-effects-air-pollution).

Under the IPT methodology, changes in emissions are approximately proportional to changes in health outcomes. IPT factors are derived by calculating the number of health outcomes associated with exposure to PM2.5 for a baseline scenario using measured concentrations, and dividing by the emissions of PM2.5 or a precursor. The calculation is performed separately for each air basin:

$$IPT = \frac{number\ of\ health\ outcomes\ in\ air\ basin}{annual\ emissions\ in\ air\ basin}$$

Multiplying the emission reductions from a regulation in an air basin by the IPT factor then yields an estimate of the reduction in health outcomes achieved by the Proposed Regulation. For future years, the number of outcomes is adjusted to account for population growth. CARB's current IPT factors are based on a 2014-2016 baseline scenario, which represents the most recent data available at the time the current IPT factors were computed. IPT factors are computed for two types of PM2.5: Primary PM2.5 and secondary ammonium nitrate aerosol.

a) Adjustment of IPT Results for At Berth Sources

Emissions from vessels at berth are assumed to be equally potent at causing health impacts as emissions from diesel engines. However, because diesel engines are used in both on-road and off-road vehicles and equipment, they are more widely dispersed throughout any given air basin, whereas, emissions from vessels are specifically located at ports. In addition, exhaust stacks on diesel engines are typically lower and have

[23] U.S. CDC Wonder Database, https://wonder.cdc.gov/, Accessed August 29, 2019

[24] U.S. EPA BenMAP. Benefits Mapping and Analysis Software. BenMAP-Community Edition v1.5 (March 2019). Available at https://www.epa.gov/benmap/benmap-downloads

different temperatures and velocities than the exhaust coming from vessel stacks. Because of these differences, the IPT factors used for on-road DPM have to be adjusted before they can be applied to at berth sources.

Primary PM2.5: As previously stated, concentrations of PM2.5 in the South Coast Air Basin are based on air dispersion modeling results for at berth sources which allow health outcomes to be directly estimated from concentrations predicted by the model. The modeled concentrations were approximately 40 percent of the IPT estimates that would be used for on-road diesel engines. Accordingly, estimates for the other air basins and scenarios were adjusted by a factor of 0.4. This is an approximation as the adjustment factor depends on local conditions.

Secondary PM2.5: Estimates of health outcomes resulting from reductions in NOx emissions were not adjusted because they are due to secondary ammonium nitrate formation, which takes place downwind from emission sources. Impacts are assumed to take place over a wide geographic area.

B. Uncertainties Associated with the Mortality and Illness Analysis

Although the health outcome estimates presented in this report are based on the best methodologies currently available, they are subject to uncertainty. The uncertainty ranges on health estimates in this analysis only take into account the uncertainty of the relative risk, which is a parameter in the CRF that determines how changes in air quality translate into changes in health outcomes. Other sources of uncertainty include:

- Air quality data is subject to natural variability from meteorological conditions, local activity, etc.
- The assumption that changes in concentrations of pollutants are proportional to changes in emissions of those pollutants or their precursors is an approximation. There may be cases where actual changes in concentrations are higher or lower than predicted.
- The estimation of DPM2.5 concentrations and DPM2.5/NOx emission ratios are subject to uncertainty. Emissions are reported at an air basin resolution, and do not capture local variations.
- Inverse distance-squared weighting, a spatial interpolation method, is used to estimate concentrations each census tract. Compared with other geospatial estimation methods (such as Kriging), inverse distance-squared interpolation has the virtue of simplicity, and does not require selection of parameters. When data are abundant, most simple interpolation techniques give similar results (Jarvis et al., 2001). All geospatial estimation techniques exhibit greater uncertainty when data points are sparser, and uncertainty increases with distance from the nearest data points.

- Future population estimates are subject to increasing uncertainty as they are projected further into the future. For reasons of computational efficiency, the spatial resolutions of population estimates are limited to census tract resolution.
- Observed baseline incidence rates change over time, and are subject to random year-to-year variation and systematic shifts as population characteristics and medical treatments evolve. Sample size requirements necessitate estimating baseline incidence rates at large geographic scales (state or county).
- Relative risks in the concentration-response function are estimated with uncertainty and reported as confidence ranges.
- IPT factors were developed for on-road diesel sources and NOx sources. Application to other sources is subject to availability of relative potency factors

C. PM Mortality and Illness: Reduction in Health Outcomes

CARB staff estimated the reduction in health outcomes from reduced emissions of PM2.5 from the Proposed Regulation. These health outcomes include cardiopulmonary mortality, hospital admissions, and emergency room visits. Based on the analysis, staff estimates that the total number of cases statewide that would be reduced due to the implementation of the Proposed Regulation are as follows:

- 230 premature deaths (180 to 281, 95 percent confidence interval (CI)).
- 72 hospital admissions (9 to 135, 95 percent CI).
- 116 emergency room visits (73 to 158, 95 percent CI).

Tables 20 through 22 show the estimated reductions in health outcomes resulting from the Proposed Regulation summed over a 12-year period from 2021 to 2032. The values in parentheses represent the 95 percent confidence interval for each health outcome.

Table 20. Proposed Regulation: Reductions in Health Outcomes from PM2.5

Air Basin	Premature Deaths	Hospital Admissions	Emergency Room Visits
North Coast	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
Sacramento Valley	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
San Diego County	1 (0 - 1)	0 (0 - 0)	0 (0 - 0)
San Francisco Bay	5 (4 - 6)	1 (0 - 3)	3 (2 - 4)
San Joaquin Valley	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
South Central Coast	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
South Coast	24 (19 - 30)	4 (1 - 7)	8 (5 - 11)
Total	30 (23 - 37)	6 (1 - 10)	11 (7 - 15)

Table 21. Proposed Regulation: Reductions in Health Outcomes from NOx

Air Basin	Premature Deaths	Hospital Admissions	Emergency Room Visits
North Coast	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
Sacramento Valley	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
San Diego County	6 (5 - 7)	2 (0 - 3)	2 (2 - 3)
San Francisco Bay	23 (18 - 29)	8 (1 - 14)	13 (8 - 18)
San Joaquin Valley	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
South Central Coast	1 (1 - 2)	0 (0 - 1)	1 (0 - 1)
South Coast	169 (132 - 206)	57 (7 - 106)	89 (56 - 121)
Total	200 (157 - 244)	67 (9 - 124)	105 (66 - 143)

Table 22. Proposed Regulation: Total Reductions in Health Outcomes[1]

Air Basin	Premature Deaths	Hospital Admissions	Emergency Room Visits
North Coast	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
Sacramento Valley	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
San Diego County	7 (5 - 8)	2 (0 - 3)	3 (2 - 4)
San Francisco Bay	28 (22 - 34)	9 (1 - 17)	16 (10 - 22)
San Joaquin Valley	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
South Central Coast	2 (1 - 2)	0 (0 - 1)	1 (0 - 1)
South Coast	194 (151 - 236)	61 (8 - 114)	96 (61 - 132)
Total	230 (180 - 281)	72 (9 - 135)	116 (73 - 158)

1. PM2.5 estimates for the South Coast Air Basin were obtained by direct estimation of health outcomes. Other estimates were obtained using IPT factors.

Aside from its role in the formation of secondary PM2.5, NOx is also a precursor to the formation of ozone. However, when the valuations for NOx and PM2.5 are monetized, the monetary impacts of PM2.5 tend to overwhelm the ozone valuations, relative to NOx. As a result, this analysis only monetizes the value of reductions in PM2.5. In accordance with U.S. EPA practice, health outcomes were monetized by multiplying incidence by a standard value derived from economic studies.[25] This valuation per incident is provided in Table 23. The valuation for avoided premature mortality is based on willingness to pay.[26] This value is a statistical construct based on the aggregated dollar amount that a large group of people would be willing to pay for a reduction in their individual risks of dying in a year. This is not an estimate of how much any single individual would be willing to pay to prevent a certain death of any particular person,[27] nor does it consider any specific costs associated with mortality such as hospital expenditures.

Unlike premature mortality valuation, the valuation for avoided hospitalizations and emergency room visits is based on a combination of typical costs associated with hospitalization and the willingness of surveyed individuals to pay to avoid adverse outcomes that occur when hospitalized. These include hospital charges, post-hospitalization medical care, out-of-pocket expenses, and lost earnings for both individuals and family members, lost recreation value, and lost household protection (e.g., valuation of time-losses from inability to maintain the household or provide childcare).[28]

Table 23. Valuation per Incident Avoided Health Outcomes

Outcome	Valuation per Incident[1]
Avoided Premature Deaths	$9,744,432
Avoided Acute Respiratory Hospitalizations	$51,062
Avoided Cardiovascular Hospitalizations	$58,541
Avoided Emergency Room Visits	$838

1. Values are for the 2019 dollar year.

Statewide valuation of health benefits were calculated by multiplying the avoided health outcomes by the valuation per incident. Staff quantified the total statewide valuation

[25] National Center for Environmental Economics et al., *Appendix B: Mortality Risk Valuation Estimates, Guidelines for Preparing Economic Analyses* (EPA 240-R-10-001, Dec. 2010) available at https://www.epa.gov/sites/production/files/2017-09/documents/ee-0568-22.pdf.

[26] United States Environmental Protection Agency Science Advisory Board (U.S. EPA-SAB), *An SAB Report on EPA's White Paper Valuing the Benefits of Fatal Cancer Risk Reduction* (EPA-SAB-EEAC-00-013, July 2000), available at http://yosemite.epa.gov/sab%5CSABPRODUCT.NSF/41334524148BCCD6852571A700516498/$File/eeacf013.pdf.

[27] United States Environmental Protection Agency, *Mortality Risk Valuation – What does it mean the place a value on a life?*, available at https://www.epa.gov/environmental-economics/mortality-risk-valuation#means (accessed August 29, 2019).

[28] Lauraine G. Chestnut et. al., *The Economic Value Of Preventing Respiratory And Cardiovascular Hospitalizations* (Contemporary Economic Policy, 24: 127–143. doi: 10.1093/CEP/BYJ007, Jan. 2006), available at http://onlinelibrary.wiley.com/doi/10.1093/cep/byj007/full.

due to avoided health outcomes between 2021 and 2032. These values are summarized in Table 24. The spatial distribution of these benefits follow the distribution of emission reductions and avoided adverse health outcomes; therefore, most benefits to individuals would occur in the South Coast and San Francisco Bay Area air basins.

Table 24. Statewide Valuation from Avoided Adverse Health Outcomes between 2021 and 2032 as a Result of the Proposed Regulation[1]

Outcome	Valuation
Avoided Premature Deaths	$2,241,110,000
Avoided Hospitalizations	$4,000,000
Avoided Emergency Room Visits	$97,000
Total Valuation	$2,245,207,000

1. Values have been rounded and are based on the 2019 dollar year.

D. Additional Potential Toxics Valuation Metrics for Future Regulations

Although PM mortality and illness valuation has been, and continues to be, a useful metric for valuating the health benefits of regulations, it only represents a portion of those benefits. Given this, the full health benefits of a regulation are expected to be underestimated because all adverse health outcomes associated with air toxics are not monetized. A more robust evaluation of outcomes, including, but not limited to, preterm birth, neural tube defects, nonfatal cancers, and fatal cancers would provide a more complete perspective of the benefits from reduced exposure to air toxics. This would allow the public to have a better understanding of the benefits from reducing toxic emissions such as DPM to their lowest achievable levels and moving toward zero-emission technologies. This understanding is important to the successful implementation of various emission reduction strategies to protect public health.

In 2019, U.S. EPA recognized the importance of including nonfatal cancers, fatal cancers, and benign tumors in the economic analyses of their rulemaking process. The *Final Rule for the Regulation of Methylene Chloride Used in Consumer Paint and Coating Removal Processes* (U.S. EPA, 2019) (methylene chloride rulemaking) introduced a new metric for evaluating the health benefits of new regulations using three key components: value of mortality risk (VMR), willingness-to-pay (WTP), and the cost of illness (COI) methodology. A discussion of the three components of the methodology used in the methylene chloride rulemaking is presented below.

In March 2019, U.S. EPA released the methylene chloride rulemaking. In the economic analysis, U.S. EPA estimated the value of reducing the risk of liver and lung cancer by weighting the average of the following values:

- Reduced fatal liver and lung cancers (calculated using the VMR).
- Reduced nonfatal liver and lung cancers (calculated using the WTP).
- Estimated cost for benign mammary gland tumors (calculated using the COI methodology).

Value of Mortality Risk: U.S. EPA used a value of $10.38 (2017 dollars) per "micro-risk" (one chance per million) per year for the VMR. U.S. EPA defines the VMR as the estimated value of avoiding a risk of premature death due to an adverse health outcome, such as fatal lung cancer. Methodologies using the VMR, have been used by many agencies in cost-benefit analyses for federal rulemakings. Some of those agencies include: the Food and Drug Administration, Department of Health and Human Services, and Department of Transportation.

Willingness-to-Pay: U.S. EPA measured the WTP to analyze nonfatal cancers. WTP is the value a person would place on an avoided cancer case including: avoided treatment costs, avoided pain and suffering, and loss productivity, as well as other adverse health impacts. In December 2005, U.S. EPA released the Economic Analysis for the Final Stage 2 Disinfectants and Disinfection Byproducts Rule (Byproducts Rule). In this rulemaking, U.S. EPA used the WTP to avoid bronchitis and lymphoma as a proxy for avoiding a nonfatal case of bladder cancer (U.S. EPA, 2005). Similar to the Byproducts Rule, U.S. EPA used the WTP to avoid bronchitis and lymphoma as a proxy for avoiding a case of nonfatal lung or liver cancer in the methylene chloride rulemaking. In the analysis, U.S. EPA calculated a low estimate of $0.86 (2017 dollars) per micro-risk per year and a high estimate of $6.05 per micro-risk per year for both nonfatal lung and liver cancers.

Cost of Illness Methodology: U.S. EPA estimated the value of an avoided case of a benign tumor using a COI methodology. The COI includes the expected medical costs and costs associated with the illness from the year of diagnosis to a predetermined age post-diagnosis. It takes into account the possibility of the individual dying of other causes in each year of the analysis. Although, the analysis does not include the WTP to avoid pain and suffering, U.S. EPA included the initial costs of diagnosis and treatment and the continuing care cost for each additional year of treatment. Based on the analysis, U.S. EPA estimated an initial cost of $1,181 to $3,307 for outpatient and associated costs, dependent upon age and whether or not the tumor was surgically removed in the first year. If the tumor was not removed in the first year, there is an annual cost of $910 for subsequent years.

The methylene chloride rulemaking sets a precedent for considering other health benefits and for using the VMR, WTP, and COI when analyzing the cost-benefits of a new regulation. Although the metric and expanded list of health outcomes needs further investigation and review by CARB and other scientific experts, it presents a promising approach to better analyze the health benefits of regulations. Once that process is completed, the avoided costs associated with this metric along with the current PM mortality and illness analysis will allow CARB to perform more comprehensive cost-benefit analyses for future regulations.

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