Appendix G

Health Analyses

Proposed Amendments to the Commercial Harbor Craft Regulation

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I. Overview

California Air Resources Board staff conducted health analyses to evaluate the potential health impacts of diesel particulate matter (DPM), PM2.5, and oxides of nitrogen (NOx) emissions from Commercial Harbor Craft (CHC) operating along the coast of California and within its waterways. These health analyses compare the present and future health impacts from CHC operating under the existing CHC Regulation (Current Regulation), against the health benefits achieved through the implementation of the Proposed Amendments. This document presents two separate analyses that quantify different health outcomes, a health risk assessment (HRA) and a particulate matter (PM) mortality and illness analysis. For the purposes of these health analyses, staff modeled emissions from all CHC vessel types, combined into 16 categories, which include: barge ATB, barge bunker, barge other, barge towed petrochemical, commercial fishing, commercial passenger fishing, crew and supply, dredge, excursion, ferry (catamaran, monohull, and short run ferries were combined), pilot, research, tug ATB, tug escort/ship assist, tug push/tow, and workboat vessels.

The HRA evaluates the potential health impacts associated with CHC operations under the Current Regulation and Proposed Amendments for people living in the South Coast Air Basin (SCAB) and San Francisco Bay Area Air Basins (BAAB). Staff determined health impacts by:

- Estimating the DPM concentrations using an air dispersion model.
- Estimating the DPM exposure and the health impacts expected from those concentrations.
- Comparing the results for both cancer and noncancer chronic health impacts associated with DPM exposure.

The HRA further projects how implementation of the Proposed Amendments would reduce DPM exposure and its associated health impacts.

The PM mortality and illness analysis evaluates regional health impacts and focuses on PM2.5, either directly emitted from vessel engines, or formed in the atmosphere from emissions of oxides of nitrogen (NOx). Exposure to PM2.5 can result in health outcomes that include premature death from cardiopulmonary disease, hospitalizations for cardiovascular and respiratory illness, emergency room (ER) visits for asthma, and incidences of nonfatal heart attacks. The PM mortality and illness analysis uses DPM concentrations obtained from the CALPUFF dispersion model (which were converted to PM2.5 concentrations), PM2.5 and NOx emission inventory data, and county-specific statistics on health outcomes to estimate the reductions in health outcomes with the implementation of the Proposed Amendments and to valuate those avoided health outcomes.

A. Approaches Used in the Health Analyses

The approach used for each of these two health analyses is outlined below:

Health Risk Assessment:

- Select the California air basin(s) to evaluate.
- Develop a CHC emission inventory for DPM that reflects the anticipated amount of DPM released annually after the implementation of the Current Regulation and the Proposed Amendments.
- 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 CHC emission inventory for primary PM2.5 and NOx that reflects the anticipated amount of each pollutant released annually after the implementation of the Current Regulation and the Proposed Amendments.
- Estimate Statewide PM2.5 noncancer mortality and illness health impacts associated with exposure to primary PM2.5, and secondary PM2.5 from NOx emissions.

B. Years Evaluated in the Health Analyses

For the health analyses, staff evaluated specific years based on the implementation schedule of the Current Regulation and Proposed Amendments. For the HRA, staff evaluated the year 2023 (the year when full implementation of the Current Regulation occurs) and 2038 (a few years after most compliance extensions are expected to expire and when the full emissions benefits of the Proposed Amendments are expected to be achieved). For the PM2.5 mortality and illness analysis, staff evaluated the health benefits over a 16-year period from 2023 to 2038.

II. Emissions Inventory

In order to conduct the HRA and mortality and illness analyses, it is necessary to have information about the amount of pollutants emitted by each source. The CHC vessel categories considered in these health analyses include: barge (ATB, bunker, other, and towed petrochemical), commercial fishing, commercial passenger fishing, crew and supply, dredge, excursion, ferry, pilot, research, tug (ATB, escort/ship assist, and push/tow), and workboat vessels. For each category, staff used estimated statewide DPM, PM2.5, and NOx emissions and AIS data to break those emissions down by air basin. More detail on the spatial allocation of emissions can be found in Section III.C.3.

DPM emissions are based on propulsion engine operations (with the exception of barges) and auxiliary engine operations. While the propulsion (or main) engines generally have far more horsepower, auxiliary engines can also contribute to health impacts as they are often run continuously over long periods at or near ports, marine terminals, and population centers. Emissions are based on the best available information regarding past, current, and projected future engine data. Engine data includes, but is not limited to: population, growth, activity, load factor, and emission factor data. Information on the methodology for the emission inventory can be found in Appendix H – Statewide CHC Emission Inventory.

For the health analyses, staff evaluated the health impacts within two air basins: the South Coast Air Basin (SCAB) and San Francisco Bay Area Air Basin (BAAB). The emission inventories for SCAB and BAAB are described below. Staff selected these air basins based on the size of ports and marine terminals, vessel activity, emissions, and proximity to coastal and disadvantaged communities (DAC).

Many of the public and private port and terminal facilities in California are located adjacent to or near disadvantaged communities which experience inequities in air pollution exposures and health impacts. In California, pursuant to State Bill (SB) 535, CalEPA has defined DACs as communities that rank within the top 25 percent scoring communities in CalEnviroScreen.[1] There are 21 CalEnviroScreen indicators used in scoring each community including socioeconomic factor indicators, sensitive population indicators, environmental effect indicators, and exposure indicators. Research showed that DACs are exposed to seven percent higher air pollution from marine sources than the state average.[2] This comparison was based on the average exposure for the population living in all DACs in CA, regardless of their proximity to marine emissions. Therefore, it is expected that some of the DACs surrounding ports and harbors might be impacted even more due to their proximity to marine emissions. For example, a modeling simulation for SCAB showed that the highest concentrations of DPM occurred around the Ports of Los Angeles and Long Beach.[3] Meanwhile, the neighboring communities surrounding the ports also had the highest cancer risks from air pollution in this basin.[3] Similarly, this HRA shows higher DPM concentration and cancer risk values around the ports of Los Angeles, Long Beach, San Francisco, Oakland, and Richmond and its surrounding communities.

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[1] California Office of Environmental Health Hazard Assessment, SB 535 Disadvantaged Communities, last accessed July 21, 2021, *https://oehha.ca.gov/calenviroscreen/sb535*.

[2] Apte et al., A Method to Prioritize Sources for Reducing High PM2.5 Exposures in Environmental Justice Communities in California, November 21, 2019, last accessed July 22, 2021, *https://ww2.arb.ca.gov/sites/default/files/classic/research/apr/past/17rd006.pdf*

[3] South Coast Air Quality Management District, Final Report: Multiple Air Toxics Exposure Study in the South Coast Air Basin, May 2015, last accessed July 21, 2021, *https://www.aqmd.gov/docs/default-source/air-quality/air-toxic-studies/mates-iv/mates-iv-final-draft-report-4-1-15.pdf?sfvrsn=7*.

A. South Coast Air Basin Emissions Inventory

Table G-1 shows the CHC DPM emission inventory from main propulsion and auxiliary diesel engines operating in SCAB. This table shows emissions for the Current Regulation in 2023 and 2038 and for the Proposed Amendments in 2038.

Table G-1 South Coast Air Basin Estimated DPM Emissions (Tons/Year)

Current Regulation - 2023	Current Regulation - 2038	Proposed Amendments - 2038
49.2	43.3	4.5

When comparing the Proposed Amendments to the Current Regulation for the year 2038, implementation of the Proposed Amendments would reduce the total DPM emissions by approximately 90 percent in SCAB.

B. San Francisco Bay Area Air Basin Emissions Inventory

Table G-2 shows the CHC DPM emission inventory from main propulsion and auxiliary diesel engines operating in BAAB. This table shows emissions for the Current Regulation in 2023 and 2038 and Proposed Amendments in 2038.

Table G-2 San Francisco Bay Area Air Basin Estimated DPM Emissions (Tons/Year)

Current Regulation - 2023	Current Regulation - 2038	Proposed Amendments - 2038
62.5	57.2	5.2

When comparing the Proposed Amendments to the Current Regulation for the year 2038, implementation of the Proposed Amendments would reduce the total DPM emissions by approximately 91 percent in BAAB.

C. Statewide Commercial Harbor Craft Emissions by Vessel Category

Table G-3 shows the 2023 statewide DPM emissions by vessel type. The emissions are used to determine the baseline emission rates for each vessel category operating within BAAB and SCAB. Vessel DPM emission rates are an input in the air dispersion model, and the resulting concentrations from the air dispersion model are used in the HRA and mortality and illness analysis. More detail on how emission rates are calculated can be found in Section III.C.3.

Table G-3 2023 Statewide DPM Emissions by Vessel Type

Vessel Category	DPM Emissions (Tons/Year)
Barge-ATB	1.15
Barge-Bunker	0.88
Barge-Other	0.99
Barge-Towed Petrochemical	1.82
Commercial Fishing	42.28
Commercial Passenger Fishing	22.83
Crew/Supply	13.32
Dredge	3.39
Excursion	11.32
Ferry[4]	19.75
Pilot Vessel	2.95
Research Vessel	3.62
Tugboat-ATB	18.39
Tugboat-Escort/Ship Assist	13.46
Tugboat-Push/Tow	14.51
Workboat	23.16

D. Commercial Harbor Craft Emissions by Air Basin

Tables G-4 and G-5 show the PM2.5 emissions by air basin for years 2023 to 2038 that would result from both the Current Regulation and implementation of the Proposed Amendments, respectively. Table G-6 shows the percent PM2.5 emission reductions by air basin for years 2023 to 2038 when comparing the Current Regulation to the implementation of the Proposed Amendments.

Tables G-7 and G-8 show the NOx emissions by air basin for years 2023 to 2038 that would result from both the Current Regulation and implementation of the Proposed Amendments, respectively. Table G-9 shows the percent NOx emission reductions by air basin for years 2023 to 2038 when comparing the Current Regulation to the implementation of the Proposed Amendments.

The PM2.5 and NOx percent emission reductions achieved from the implementation of the Proposed Amendments, as shown in Tables G-6 and G-9, are used to estimate the reduction of PM2.5 mortality and illness impacts for each air basin. The nine air

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[4] Ferries include catamaran, monohull, and shortrun ferries

basins covered under the Proposed Amendments include the Lake Tahoe, North Central Coast, North Coast, Sacramento Valley, San Diego County, San Francisco Bay Area, San Joaquin Valley, South Central Coast, and South Coast Air Basins.

The air basin abbreviations used in the following tables represent the air basins listed below:

- LT: Lake Tahoe Air Basin
- NCC: North Central Coastal Air Basin
- NC: North Coast Air Basin
- SV: Sacramento Valley Air Basin
- SDC: San Diego County Air Basin
- SF: San Francisco Bay Area Air Basin
- SJV: San Joaquin Valley Air Basin
- SCC: South Central Coast Air Basin
- SC: South Coast Air Basin

Table G-4 CHC PM2.5 Emissions Under the Current Regulation by Air Basin (Tons/Year)

Year	LT	NCC	NC	SV	SDC	SF	SJV	SCC	SC
2023	0.72	2.65	8.03	0.64	20.85	59.78	0.43	25.06	47.04
2024	0.71	2.63	7.98	0.63	20.71	60.13	0.41	24.91	47.11
2025	0.71	2.60	7.90	0.63	20.52	60.29	0.39	24.71	47.07
2026	0.70	2.57	7.82	0.62	20.31	60.35	0.38	24.48	46.95
2027	0.69	2.54	7.74	0.62	20.07	60.18	0.36	24.21	46.71
2028	0.68	2.51	7.65	0.61	19.81	59.94	0.35	23.92	46.40
2029	0.68	2.47	7.54	0.60	19.53	59.61	0.33	23.59	46.03
2030	0.67	2.43	7.43	0.59	19.23	59.22	0.32	23.25	45.62
2031	0.66	2.39	7.32	0.58	18.94	58.76	0.31	22.89	45.18
2032	0.65	2.35	7.21	0.57	18.65	58.27	0.30	22.53	44.72
2033	0.65	2.31	7.11	0.56	18.36	57.75	0.29	22.17	44.26
2034	0.64	2.27	7.00	0.55	18.06	57.20	0.28	21.79	43.77
2035	0.63	2.23	6.89	0.54	17.75	56.64	0.27	21.40	43.26
2036	0.63	2.19	6.77	0.53	17.43	56.06	0.26	21.01	42.73
2037	0.62	2.14	6.59	0.51	17.02	55.41	0.25	20.55	42.10
2038	0.62	2.09	6.41	0.50	16.60	54.72	0.25	20.08	41.44

Table G-5 CHC PM2.5 Emissions Under the Proposed Amendments by Air Basin (Tons/Year)

Year	LT	NCC	NC	SV	SDC	SF	SJV	SCC	SC
2023	0.39	1.66	5.59	0.59	15.98	43.08	0.13	20.27	35.80
2024	0.35	1.40	5.42	0.54	15.22	37.66	0.11	18.85	32.53
2025	0.33	1.34	5.18	0.48	14.71	32.90	0.11	18.08	30.11
2026	0.18	1.20	5.06	0.43	14.24	27.53	0.09	17.31	27.64
2027	0.18	1.06	4.91	0.37	13.74	23.83	0.07	16.60	25.69
2028	0.18	0.92	4.79	0.34	12.62	21.62	0.06	15.25	23.36
2029	0.10	0.79	4.51	0.31	11.40	19.01	0.05	13.84	20.76
2030	0.08	0.50	3.27	0.27	8.64	15.34	0.05	11.21	16.58
2031	0.07	0.34	1.80	0.22	5.62	11.79	0.03	8.39	11.96
2032	0.07	0.27	1.30	0.18	4.06	9.04	0.03	6.39	8.88
2033	0.07	0.25	1.25	0.13	2.69	6.21	0.03	4.46	5.29
2034	0.07	0.24	1.22	0.07	2.44	4.88	0.03	2.77	4.21
2035	0.07	0.25	1.23	0.06	2.47	4.91	0.03	2.78	4.25
2036	0.07	0.25	1.25	0.06	2.49	4.94	0.03	2.78	4.28
2037	0.07	0.25	1.26	0.06	2.52	4.96	0.03	2.78	4.31
2038	0.07	0.25	1.28	0.06	2.54	4.98	0.03	2.78	4.33

Table G-6 CHC PM2.5 Percent Emission Reductions Achieved Under the Proposed Amendments as Compared to the Current Regulation by Air Basin (%)

Year	LT	NCC	NC	SV	SDC	SF	SJV	SCC	SC
2023	45.8	37.4	30.4	7.8	23.4	27.9	69.8	19.1	23.9
2024	50.7	46.8	32.1	14.3	26.5	37.4	73.2	24.3	30.9
2025	53.5	48.5	34.4	23.8	28.3	45.4	71.8	26.8	36.0
2026	74.3	53.3	35.3	30.6	29.9	54.4	76.3	29.3	41.1
2027	73.9	58.3	36.6	40.3	31.5	60.4	80.6	31.4	45.0
2028	73.5	63.3	37.4	44.3	36.3	63.9	82.9	36.2	49.7
2029	85.3	68.0	40.2	48.3	41.6	68.1	84.8	41.3	54.9
2030	88.1	79.4	56.0	54.2	55.1	74.1	84.4	51.8	63.7
2031	89.4	85.8	75.4	62.1	70.3	79.9	90.3	63.3	73.5
2032	89.2	88.5	82.0	68.4	78.2	84.5	90.0	71.6	80.1
2033	89.2	89.2	82.4	76.8	85.3	89.2	89.7	79.9	88.0
2034	89.1	89.4	82.6	87.3	86.5	91.5	89.3	87.3	90.4
2035	88.9	88.8	82.1	88.9	86.1	91.3	88.9	87.0	90.2
2036	88.9	88.6	81.5	88.7	85.7	91.2	88.5	86.8	90.0
2037	88.7	88.3	80.9	88.2	85.2	91.0	88.0	86.5	89.8
2038	88.7	88.0	80.0	88.0	84.7	90.9	88.0	86.2	89.6

Table G-7 CHC NOx Emissions Under the Current Regulation by Air Basin (Tons/Year)

Year	LT	NCC	NC	SV	SDC	SF	SJV	SCC	SC
2023	29	80	219	21	596	2,209	13	766	1,589
2024	29	79	218	21	594	2,219	13	764	1,592
2025	29	79	216	21	591	2,225	12	761	1,593
2026	29	79	215	21	587	2,228	12	758	1,592
2027	29	78	213	20	583	2,224	12	753	1,587
2028	29	78	212	20	579	2,219	12	748	1,582
2029	29	77	210	20	574	2,212	11	743	1,575
2030	28	76	209	20	569	2,204	11	737	1,567
2031	28	76	207	20	564	2,194	11	731	1,559
2032	28	75	205	20	560	2,183	11	725	1,551
2033	28	75	204	19	555	2,171	10	719	1,541
2034	28	74	202	19	550	2,158	10	712	1,532
2035	28	73	200	19	545	2,144	10	705	1,522
2036	28	73	198	19	540	2,131	10	698	1,512
2037	28	72	196	19	533	2,116	10	690	1,500
2038	28	71	193	18	527	2,100	10	682	1,488

Table G-8 CHC NOx Emissions Under the Proposed Amendments by Air Basin (Tons/Year)

Year	LT	NCC	NC	SV	SDC	SF	SJV	SCC	SC
2023	23	65	193	20	540	1,955	8	701	1,434
2024	22	60	190	19	521	1,769	7	669	1,331
2025	21	59	184	17	508	1,596	7	650	1,245
2026	20	57	182	16	496	1,393	6	630	1,152
2027	20	54	179	14	485	1,277	5	614	1,086
2028	20	52	176	14	463	1,220	5	586	1,035
2029	20	50	173	13	442	1,160	5	559	984
2030	20	45	148	12	385	1,077	5	505	897
2031	20	42	125	11	334	1,000	5	454	813
2032	20	41	114	10	301	938	5	412	748
2033	20	41	114	9	287	908	5	383	709
2034	20	41	114	8	285	898	5	362	698
2035	20	41	114	8	286	902	5	363	701
2036	20	41	115	8	287	907	5	364	704
2037	20	41	115	8	288	911	5	365	707
2038	20	41	116	8	289	915	5	365	709

Table G-9 CHC NOx Percent Emission Reductions Achieved Under the Proposed Amendments as Compared to the Current Regulation by Air Basin (%)

Year	LT	NCC	NC	SV	SDC	SF	SJV	SCC	SC
2023	21.9	19.2	11.7	4.5	9.5	11.5	41.7	8.5	9.7
2024	23.8	24.2	12.8	11.1	12.3	20.3	44.1	12.4	16.4
2025	26.4	25.6	14.6	17.9	14.1	28.3	43.7	14.5	21.8
2026	32.3	28.3	15.4	25.0	15.5	37.5	54.0	16.9	27.7
2027	32.0	30.3	16.2	28.0	16.9	42.6	57.3	18.5	31.5
2028	31.6	33.0	16.8	31.6	20.0	45.0	57.2	21.6	34.6
2029	31.4	34.9	17.7	35.4	23.0	47.5	53.2	24.8	37.5
2030	29.2	40.8	29.1	40.1	32.3	51.1	53.0	31.5	42.8
2031	29.1	44.1	39.4	44.9	40.7	54.4	53.0	37.9	47.8
2032	29.1	45.3	44.3	49.5	46.2	57.0	52.9	43.1	51.8
2033	29.0	45.6	44.2	51.4	48.3	58.2	48.1	46.7	54.0
2034	28.9	44.5	43.6	55.6	48.2	58.4	48.0	49.1	54.4
2035	28.9	43.6	42.8	55.6	47.5	57.9	47.9	48.5	53.9
2036	28.8	43.4	42.0	55.5	46.8	57.5	47.9	47.8	53.4
2037	28.7	42.5	41.2	55.5	45.9	57.0	47.9	47.1	52.9
2038	28.7	41.6	40.1	53.0	45.1	56.4	47.9	46.4	52.4

III. Health Risk Assessment for The South Coast and San Francisco Bay Area Air Basins

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 Office of Environmental Health Hazard Assessment (OEHHA) Air Toxics Hot Spots Program Risk Assessment Guidelines: The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments (OEHHA Guidance Manual).[5] The standard approach used for this HRA involves four steps: 1) hazard identification,

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[5] Office of Environmental Health Hazard Assessment, The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments, February 2015, last accessed June 3, 2021, *https://oehha.ca.gov/media/downloads/crnr/2015guidancemanual.pdf*.

2) exposure assessment, 3) dose-response assessment, and 4) risk characterization. These four steps are briefly discussed below.

1. Hazard Identification

Hazard Identification is the process of determining the substances that can cause an increase in adverse health effects and their likely impacts to humans. For this assessment, the pollutant of concern is DPM from internal combustion engines. In 1998, CARB identified DPM as a toxic air contaminant (TAC) based on its potential to cause cancer and other health impacts under the Assembly Bill (AB) 1807 Toxic Air Contaminant Identification and Control Program.[6]

2. Exposure Assessment

Exposure assessment is an estimate of the level, duration, and frequency of exposures of an individual or population to a substance. 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 the HRA, the receptors exposed to CHC DPM emissions are residential receptors. 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 air dispersion modeling, resulting in downwind ground-level concentrations of DPM at defined receptors in modeling domains.

3. Dose Response

Dose response describes the amount of exposure (the dose) and its relation to the likelihood and severity of adverse health effects (the 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 uses the health values developed by OEHHA. OEHHA supplies these dose response relationships in the form of cancer potency factors (CPF) for carcinogenic effects and reference exposure levels (REL) for noncarcinogenic effects. See the OEHHA guidelines for a list of health values.

Staff used an inhalation CPF of 1.1 milligrams per kilogram body weight day $(mg/kg\text{-}day)^{-1}$ and a chronic REL of 5.0 micrograms per cubic meter ($\mu g/m^3$) for DPM emitted by diesel engines. DPM does not have an associated acute REL.

4. Risk Characterization

Finally, risk characterization communicates the results of the risk evaluation as well as the assumptions and uncertainties inherent in the assessment. Modeled concentrations, which are determined through exposure assessment, are combined

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[6] California Air Resources Board, Report to the Air Resources Board on the Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant, Part A, Exposure Assessment, April 22, 1998, last accessed July 17, 2021, *https://ww2.arb.ca.gov/sites/default/files/classic/toxics/id/summary/diesel_a.pdf*.

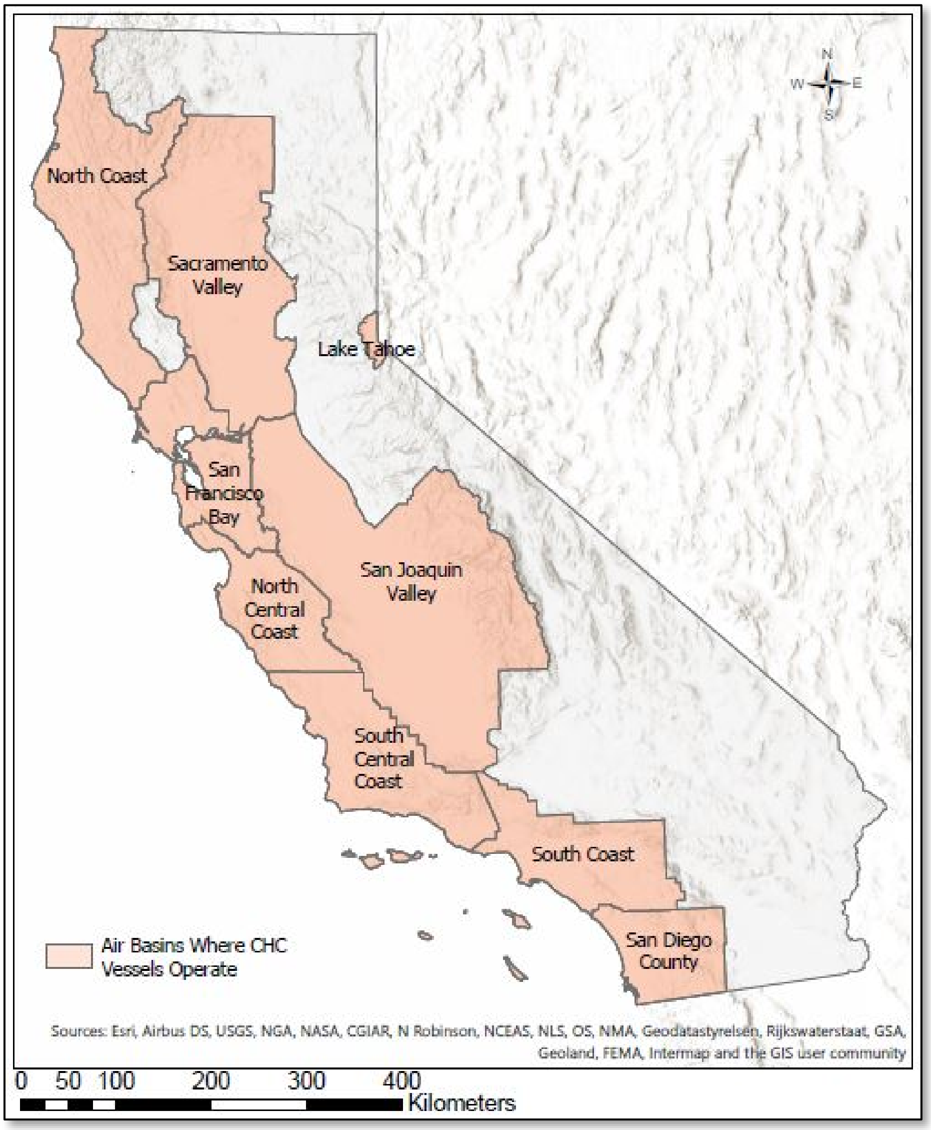
with CPF and REL values determined under the dose-response assessment. This step integrates the information used to quantify the potential cancer and noncancer risks.

B. Selection of California Air Basins

California has a wide variety of climates, physical features, and emission sources that play a role in local and regional air quality. The State is divided into fifteen air basins, nine of which include RCW where CHC operate. An air basin generally has similarities in meteorological and geographical conditions throughout the region.

The Proposed Amendments would regulate emissions from CHC vessels while operating within California waterways and up to 24 nautical miles from the California shoreline. Figure G-1 shows a map of the nine California air basins for which there is an emissions inventory of CHC operations. These air basins include: Lake Tahoe, North Central Coast, North Coast, Sacramento Valley, San Diego County, San Francisco Bay Area, San Joaquin Valley, South Central Coast, and South Coast Air Basins. CHC vessels may operate in other air basins but are not currently accounted for in the statewide emissions inventory or these health analyses.

Figure G-1 California Air Basins Where CHC Vessels Operate[7]



1. California Air Basins Selected

To characterize the cancer risk associated with the current regulation as compared to the Proposed Amendments, staff evaluated the health impacts in SCAB and BAAB. Staff selected these air basins based on the size of ports and marine terminals, vessel activity, emissions, and proximity to coastal and disadvantaged communities. SCAB

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[7] The CHC inventory is based on best available data. However, estimates may be subject to greater uncertainty in some parts of the State due to lack of data, such as at the Colorado River in Mojave Desert Air Basin, or in other air basins, especially internal waters, where CHC may operate periodically, but do not have a homeport at all locations where they operate. CHC vessels may operate in other air basins but are not currently accounted for in the statewide emissions inventory or these health analyses.

and BAAB combined represent 65 percent of the 2023 statewide CHC DPM emissions in California.

Additionally, SCAB and BAAB are home to four ports with the highest CHC activity in the State: Port of Los Angeles, Port of Long Beach, Port of San Francisco, and Port of Oakland. Many of the public and private port and terminal facilities in California are located adjacent to or near disadvantaged communities which experience inequities in air pollution exposures and health impacts. One of CARB's highest priorities is to reduce exposure to air pollution in disadvantaged communities.

2. South Coast Air Basin

The South Coast Air Basin includes four counties: portions of Los Angeles, Riverside and San Bernardino counties and all of Orange County. Also, located within SCAB are the two busiest marine ports in the nation, the Port of Los Angeles and Port of Long Beach.[8] The air basin covers an area of 6,745 square miles[9] and has an estimated population of 15 million people based the 2010 census data (2020 census data was not available when the health analyses were conducted). Figure G-2 shows the SCAB and disadvantaged communities within the modeling domain.

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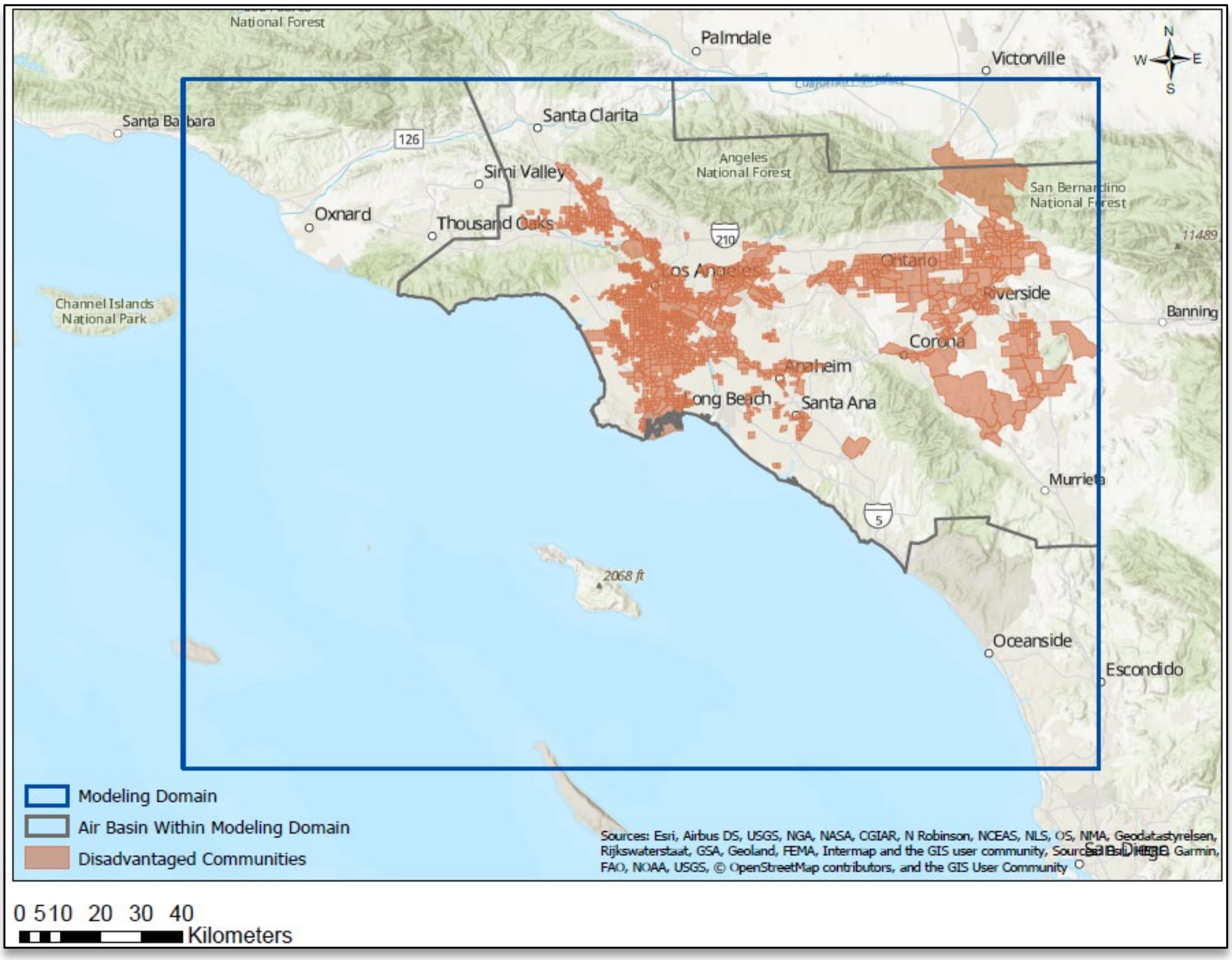
[8] South Coast Air Quality Management District, Commercial Marine Ports Working Group, last accessed June 3, 2021, *https://www.aqmd.gov/home/air-quality/clean-air-plans/air-quality-mgt-plan/facility-based-mobile-source-measures/comm-ports-wkng-grp*.

[9] South Coast Air Quality Management District, Southern California Air Basins, 1999, last accessed June 3, 2021, *http://www.aqmd.gov/docs/default-source/default-document-library/map-of-jurisdiction.pdf*.

Figure G-2 South Coast Modeling Domain, Air Basin Boundary, and Disadvantaged Communities



3. San Francisco Bay Area Air Basin

The San Francisco Bay Area Air Basin includes nine counties: the southern portions Solano and Sonoma County and all of Alameda, Contra Costa, Santa Clara, San Francisco, San Mateo, Marin, and Napa County. Major ports and marine terminals located within SCAB include the Port San Francisco, Port of Oakland, and Port of Richmond. The air basin covers an area of approximately 5,600 square miles[10] and has a population of 7 million people based on the 2010 census data (2020 census data was not available while the health analyses were conducted). Figure G-3 shows the BAAB and disadvantaged communities within the modeling domain.

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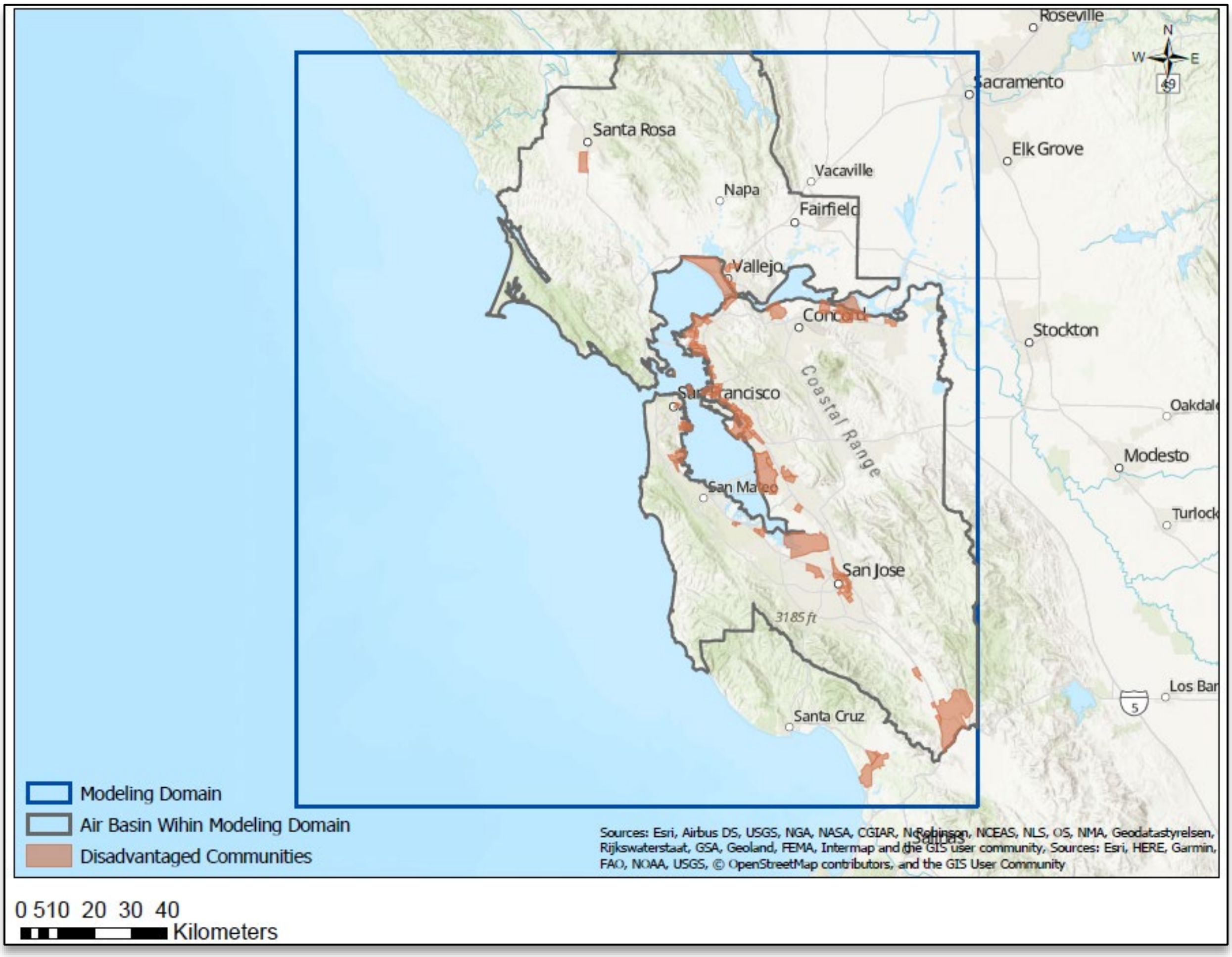
[10] Contra Costa County, Draft Environmental Impact Report Del Hombre Apartments Project: Air Quality, pg. 3.2-1, September 10, 2019, last accessed June 3, 2021, *https://www.contracosta.ca.gov/DocumentCenter/View/61025/32-Air-Quality-PDF*.

Figure G-3 San Francisco Bay Area Modeling Domain, Air Basin Boundary, and Disadvantaged Communities



Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community, Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

C. Air Dispersion Modeling

To estimate the downwind concentration of DPM emitted from CHC operations, staff used air dispersion modeling. This section describes the rationale and methodology for the air dispersion model selection, modeling domain selection, emission source allocation, modeling parameters, meteorological data selection, and the model receptor locations.

1. Air Dispersion Model Selection

Air dispersion models simulate physical and chemical processes that affect air pollutants as they disperse in the atmosphere. The selection of an air dispersion model depends on many factors, such as the characteristics of emission sources (e.g., point, area, volume, or line), the relationship between sources and receptors, the meteorological and topographic complexities of the modeled area, and the spatial scale required for the analysis. For this HRA, staff selected the United States

Environmental Protection Agency's (U.S. EPA) CALPUFF Model, Version 5.8.5[11] to simulate the dispersion of DPM, emitted by CHC, to nearby receptors. CALPUFF is a multi-layer, multi-species, non-steady state, Lagrangian puff dispersion model that accounts for changing meteorological conditions at discrete elevations above the surface that vary both geographically and over time. CALPUFF is a short to long-range dispersion model and can simulate air concentrations of pollutants in distances ranging from tens to hundreds of kilometers. Considering the large scale of the modeling domains, coastal effects, and complexity of terrain and meteorological conditions in the South Coast and San Francisco Bay Area air basins, staff determined that CALPUFF is the most suitable model.

2. Modeled Source Type and Parameters

Since CHC travel in broad geographic areas along the coast, in and around ports and marine terminals, and within inland waterways, CARB staff simulated CHC DPM emissions using elevated area sources. Based on the vessel categories identified in the Proposed Amendment, 16 CHC source categories were modeled. The parameters used to define these area sources in the dispersion model include emission rates (g/sec-m^2), release heights (m), and the initial vertical dimensions (σ_{zo}). The following is a description of the method used to define each of these parameters.

a) Area Source Size and Location

To define the areas where DPM was emitted from each CHC source category, staff used data transmitted from vessels known as Automatic Identification System (AIS) data, along with Geographic Information System (GIS) mapping tools obtained from the MarineCadastre.gov website.[12] Using the AIS data, staff identified the geographic areas where vessel activity occurs and defined area sources around geographic areas with similar levels of traffic intensity. Since the vessels in each category operate differently, staff defined different area sources for each category. These area source polygons are limited to within 24 nautical miles from the mainland shoreline. Section III.C.3 provides details of the spatial allocation process.

b) Source Emission Rates

For some vessels, the exhaust exits the vessel's hull at or below the waterline. There is the potential for exhaust systems exiting at the waterline or water muffler systems to potentially impact the amount of the particulate matter from the exhaust that enters the air; however, there are no reliable sources of data to quantify that effect. Therefore, staff assumed that all particulate matter generated by vessel engines was released into the air.

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[11] U.S. EPA, Air Dispersion Modeling Alternatives, last accessed July 16, 2021, *https://www.epa.gov/scram/air-quality-dispersion-modeling-alternative-models#calpuff*.

[12] MarineCadastre.gov, Vessel Traffic Data, last accessed June 3, 2021, *https://marinecadastre.gov/ais/*.

The emission rate of each area source was weighted by relating the intensity of AIS vessel traffic and the statewide emissions for each source category. Section III.C.3 details the methodology for the DPM emission rate calculations of each source.

c) Source Release Height and Initial Vertical Dimension

CHC are powered by diesel engines equipped with exhaust stacks. However, the height, orientation and angle of these exhaust stacks can vary depending on the vessel category and operation. Even within the same vessel category, there is a range of variability. To model concentrations of DPM from each vessel category, staff used an average stack height to represent the emission release height above the waterline. The stack height data for vessel categories was obtained from the 2019 Commercial Harbor Craft Survey for Vessel Owners and Operators. For vessels with exhaust stacks below the waterline, the stack height was assumed to be zero when calculating the average stack heights. To account for the variation in stack angles, all stacks were assumed to be at a 45-degree angle.

When emissions from CHC exit from exhaust stacks, the plume continues to rise after leaving the stack. A term called the effective release height was used as in input to the CALPUFF model. Effective release height is calculated by taking the initial release height from the exhaust stack and adding plume rise. Initial release heights were determined by averaging the reported stack heights for each vessel category. Plume rise was calculated using plume rise equations.[13] These equations take into consideration stack exit velocity, stack diameter, stack exit temperature, ambient temperature, average vessel speed and average annual wind speed. In addition, the initial vertical dimension (σ_{zo}) of the area source plume is used to account for the initial growth of the plume after it is released. Staff calculated σ_{zo} by dividing the effective release height by a standard deviation of 2.15, which is consistent with the dispersion model guidelines.

Table G-10 and Table G-11 summarize the effective release height and initial vertical dimension (σ_{zo}) of the 16 source categories used in the dispersion model for SCAB and BAAB, respectively.

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[13] Lakes Environmental, ISCST3 Tech Guide Plume Rise Formulas, last accessed July 20, 2021, *https://www.weblakes.com/guides/iscst3/section6/6_1_4.html*.

Table G-10 South Coast Air Basin CHC Emission Source Modeling Parameters

Vessel Category	Effective Release Height (m)	σ_{zo} (m)
Barge-ATB	11.92	5.55
Barge-Bunker	12.26	5.70
Barge-Other	11.13	5.18
Barge-Towed Petrochemical	11.74	5.46
Commercial Fishing	4.18	1.95
Commercial Passenger Fishing	1.82	0.85
Crew Supply	1.89	0.88
Dredge	20.85	9.70
Excursion	2.82	1.31
Ferry	3.29	1.53
Pilot Vessel	1.31	0.61
Research Vessel	4.53	2.11
Tug-ATB	14.79	6.88
Tug-Escort/Ship Assist	3.94	1.83
Tug-Push/Tow	3.93	1.83
Workboat	2.67	1.24

Table G-11 Bay Area Air Basin CHC Emission Source Modeling Parameters

Vessel Category	Effective Release Height (m)	σ_{zo} (m)
Barge-ATB	11.78	5.48
Barge-Bunker	11.81	5.49
Barge-Other	11.03	5.13
Barge-Towed Petrochemical	11.65	5.42
Commercial Fishing	4.13	1.92
Commercial Passenger Fishing	1.64	0.76
Crew Supply	1.80	0.84
Dredge	20.46	9.52
Excursion	2.62	1.22
Ferry	3.48	1.62
Pilot Vessel	1.86	0.86
Research Vessel	4.14	1.92
Tug-ATB	13.31	6.19
Tug-Escort/Ship Assist	3.37	1.57
Tug-Push/Tow	3.41	1.58
Workboat	2.27	1.06

3. Spatial and Temporal Allocation of Emissions

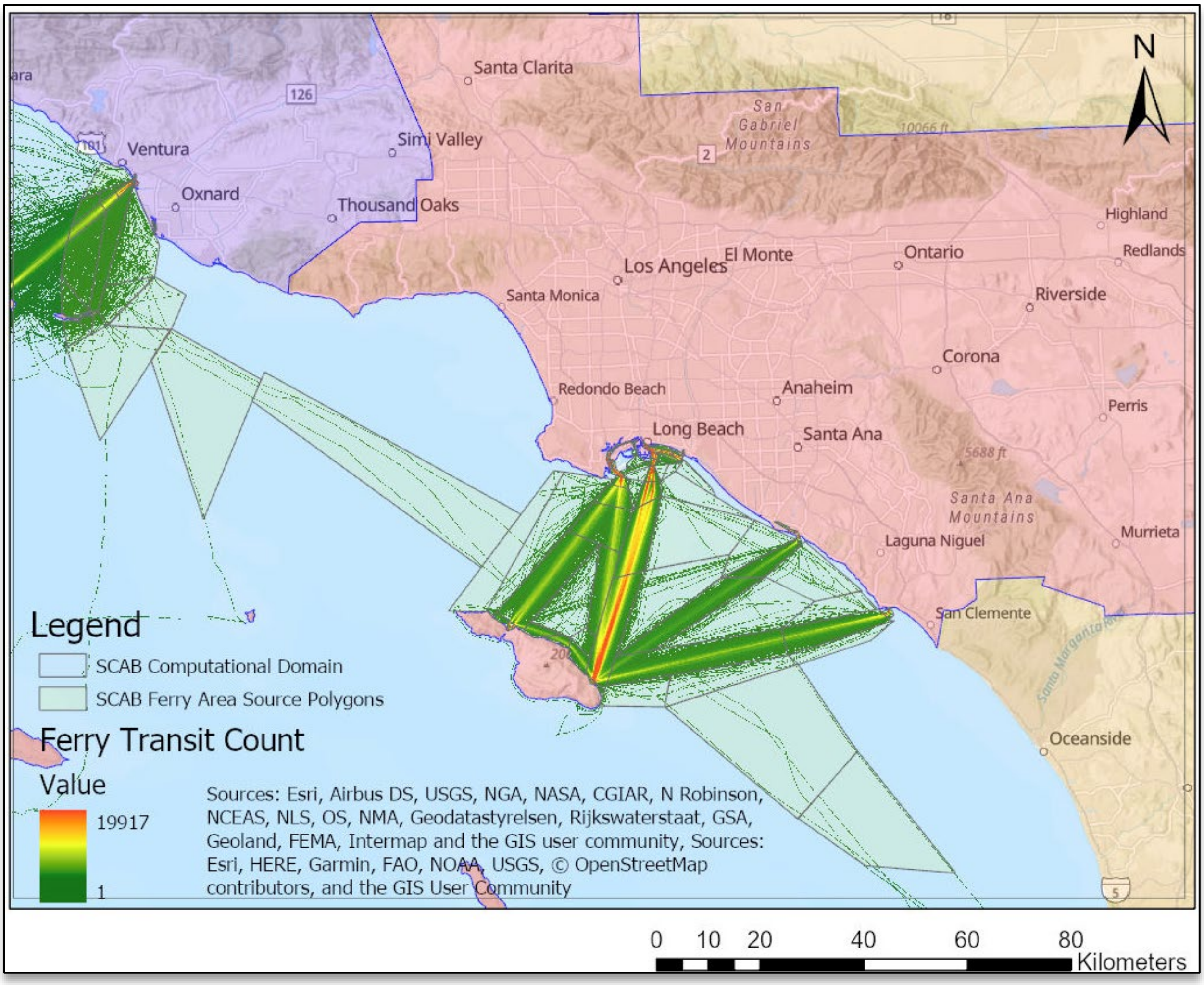
An AIS transponder is a navigation safety device that monitors and transmits the location and characteristics of many vessels in U.S. and international waters. AIS data are collected by the U.S. Coast Guard and prepared by the U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management and the U.S. Department of the Interior's Bureau of Ocean Energy Management (BOEM). AIS data include, but are not limited to, location, time, vessel type, and speed. Staff extracted the information for each CHC category in California coastal waters from the 2017 AIS data. Staff used the AIS vessel traffic data to allocate CHC emissions spatially and temporally as needed for the air dispersion model inputs.

Since barges do not navigate under their own power and are not required to carry AIS transponders, limited AIS data was available for this category. Further discussion of how barge emissions were allocated, both spatially and temporally, is presented in Section III.C.3.c below.

a) Spatial Allocation of Emissions

To spatially allocate emissions in the air dispersion model, staff determined the locations and boundaries of area source polygons for each source category by using AIS data. Staff used the AIS data along with GIS analysis tools to generate CHC traffic intensity maps. This data helped to allocate the area source polygons, define their boundaries, and weight emissions. As an example, Figure G-4 shows a map of the area source polygons defined for ferry emissions and the ferry traffic intensity or heat map from the AIS data, which the area source polygons were based upon. The area source polygons are drawn within 24 nautical miles from the SCAB shoreline and the warmer color indicates the higher traffic intensity.

Figure G-4 Spatial Allocation of Emissions and Traffic Intensity for Ferries Operating in the South Coast Air Basin



Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community, Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

To determine the level of emissions coming from each area source in each vessel category, staff used AIS vessel pass data and the CARB statewide emission inventory for each vessel category. AIS data can be used to determine the number of times all vessels of the same type pass through a given geographic area. To weigh the emissions from each area source, staff totaled up the number of vessel passes within each area source and divided that number by the total number of vessel passes for the entire state. That ratio was then multiplied by the total statewide emissions for that vessel category. This gave us the emissions from each area source for each vessel category. Equation 1 illustrates the weighting calculation for emission of each area source polygon.

$$Ei = \left(\frac{Ti}{Ts}\right) x\ Es$$

Where:

Ei = Emission of area source polygon i

Ti = Traffic intensity within area source polygon i

Ts = Statewide total traffic intensity

Es = Statewide total emission

b) Temporal Profiles of Emissions

CHC operate according to their specific vocation, resulting in emission rates that vary in time with vessel activity. As an example, ferries may adhere to published operating schedules with more activity during the day. Whereas tugboats, which provide ship assistance, may operate at all hours. Understanding when CHC operate is important for representing DPM emission rates that vary with time. Variable emission rates are accounted for in the air dispersion model.

For the CHC modeling, the type of variation that best describes CHC activity is the diurnal cycle (i.e., a pattern that repeats every 24 hours). In the CALPUFF model, this means that DPM emissions from the CHC sources occur with the same hourly pattern of variation each day. The diurnal variation is accounted for by using emission rate scaling factors, one scaling factor for each hour of the day, to proportion the emission rates according to time of day. These scaling factors, collectively termed the diurnal factor profile, change the emission rates of the modeled sources so that emission rates are higher when vessels are more active and lower when vessels are less active. Staff performed statistical analyses using the AIS data to determine the level of diurnal variance for each vessel category. A variance for 0.001 or less was considered to be insignificant and a diurnal profile was not applied to those vessel categories. In the CALPUFF model, a diurnal factor profile is applied to every vessel category's area source polygon for all days in the modeling timeframe. Staff performed statistical analyses using the AIS data and generated diurnal temporal emission profiles for those vessel categories.

As with the spatial allocation method described above, staff chose to use surrogates to define the diurnal emission profile for the barge category. Staff applied the dredge diurnal profile to the Barge Other vessel category for both SCAB and BAAB modeling.

Tables G-12 and G-13 summarize the variance in diurnal factor profiles and application decisions for each CHC category and modeling domain. Table G-14 and Table G-15 list the diurnal factor profile of each source category used in the modeling for SCAB and BAAB, respectively.

Table G-12 Diurnal Factor Profile Variance and CALPUFF Application Decisions for the South Coast Air Basin

Vessel Category	Diurnal Factor Profile Variance	Apply Diurnal Factor Profile?
Barge-ATB	0.0004	No
Barge-Bunker	N/A[14]	No
Barge-Other	N/A[15]	Yes
Barge-Towed Petrochemical	N/A[16]	No
Commercial Passenger Fishing	0.0205	Yes
Commercial Fishing	0.1223	Yes
Crew/Supply	0.0130	Yes
Dredge	0.1114	Yes
Excursion	0.0185	Yes
Ferry	0.1303	Yes
Pilot Vessel	0.0001	No
Research Vessel	0.0559	Yes
Tug-ATB	0.0004	No
Tug-Escort/Ship Assist	0.0004	No
Tug-Push/Tow	0.0048	Yes
Workboat	0.0130	Yes

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[14] For the Barge-Bunker category, knowledge of vessel operations was used to determine if a diurnal profile was needed.

[15] For the Barge-Other category, the dredge category was used as a surrogate to determine if a diurnal profile was needed.

[16] For the Barge-Towed Petrochemical category, the Barge-ATB category was used as a surrogate to determine if a diurnal profile was needed.

Table G-13 Diurnal Factor Profile Variance and CALPUFF Application Decisions for the Bay Area Air Basin

Vessel Category	Diurnal Factor Profile Variance	Apply Diurnal Factor Profile?
Barge-ATB	0.0001	No
Barge-Bunker	N/A[17]	No
Barge-Other	N/A[18]	Yes
Barge-Towed Petrochemical	N/A[19]	No
Commercial Passenger Fishing	0.3244	Yes
Commercial Fishing	0.0080	Yes
Crew/Supply	0.1981	Yes
Dredge	0.0018	Yes
Excursion	0.2758	Yes
Ferry	0.2954	Yes
Pilot Vessel	0.0028	Yes
Research Vessel	0.0144	Yes
Tug-ATB	0.0001	No
Tug-Escort/Ship Assist	0.0003	No
Tug-Push/Tow	0.0113	Yes
Work Boat	0.1160	Yes

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[17] For the Barge-Bunker category, knowledge of vessel operations was used to determine if a diurnal profile was needed.

[18] For the Barge-Other category, the dredge category was used as a surrogate to determine if a diurnal profile was needed.

[19] For the Barge-Towed Petrochemical category, the Barge-ATB category was used as a surrogate to determine if a diurnal profile was needed.

Table G-14 Diurnal Temporal Profile by CHC Vessel Category Operating in the South Coast Air Basin[20]

Hour	Barge-Other	Commercial Fishing	Commercial Passenger Fishing	Crew Supply	Dredge	Excursion	Ferry	Research Vessel	Tug - Push/Tow	Workboat
1	0.74	0.63	0.86	0.84	0.74	0.86	0.49	0.80	0.92	0.90
2	0.73	0.68	0.83	0.83	0.73	0.85	0.48	0.78	0.92	0.89
3	0.70	0.75	0.83	0.83	0.70	0.84	0.53	0.77	0.92	0.90
4	0.68	0.82	0.84	0.87	0.68	0.85	0.62	0.73	0.93	0.90
5	0.66	0.89	0.91	0.96	0.66	0.86	0.80	0.73	0.95	0.91
6	0.76	1.29	1.10	1.06	0.76	0.89	0.99	0.87	0.98	0.98
7	1.09	1.46	1.18	1.08	1.09	0.95	1.15	1.11	1.03	1.04
8	1.39	1.47	1.17	1.11	1.39	1.05	1.36	1.37	1.07	1.14
9	1.51	1.43	1.14	1.10	1.51	1.16	1.47	1.45	1.09	1.19
10	1.53	1.41	1.13	1.09	1.53	1.20	1.48	1.39	1.09	1.21
11	1.54	1.40	1.14	1.10	1.54	1.21	1.37	1.36	1.10	1.19
12	1.53	1.38	1.13	1.11	1.53	1.23	1.31	1.31	1.09	1.16
13	1.49	1.35	1.14	1.10	1.49	1.23	1.25	1.25	1.08	1.12
14	1.37	1.34	1.15	1.11	1.37	1.18	1.20	1.17	1.08	1.09
15	1.09	1.31	1.17	1.12	1.09	1.08	1.26	1.04	1.05	1.04
16	0.89	1.10	1.12	1.11	0.89	1.03	1.39	0.98	1.03	1.00

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[20] The diurnal profiles sum to 24 for each vessel category.

Hour	Barge-Other	Commercial Fishing	Commercial Passenger Fishing	Crew Supply	Dredge	Excursion	Ferry	Research Vessel	Tug - Push/Tow	Workboat
17	0.85	0.82	1.06	1.10	0.85	1.02	1.37	0.91	1.01	0.97
18	0.80	0.70	0.94	1.07	0.80	1.00	1.22	0.87	0.99	0.94
19	0.80	0.67	0.86	0.99	0.80	0.96	1.06	0.86	0.97	0.93
20	0.79	0.64	0.85	0.93	0.79	0.95	0.84	0.87	0.95	0.91
21	0.77	0.63	0.85	0.90	0.77	0.94	0.70	0.86	0.94	0.90
22	0.76	0.62	0.87	0.88	0.76	0.91	0.62	0.85	0.93	0.90
23	0.76	0.61	0.87	0.86	0.76	0.88	0.54	0.85	0.93	0.89
24	0.76	0.61	0.87	0.85	0.76	0.87	0.51	0.83	0.92	0.90

Table G-15 Diurnal Temporal Profile by CHC Vessel Category Operating in the Bay Area Air Basin[21]

Hour	Barge-Other	Commercial Fishing	Commercial Passenger Fishing	Crew Supply	Dredge	Excursion	Ferry	Pilot Vessel	Research Vessel	Tug - Push/Tow	Workboat
1	0.95	0.90	0.43	0.54	0.95	0.47	0.23	0.97	0.89	0.87	0.73
2	0.96	0.91	0.43	0.51	0.96	0.45	0.23	0.97	0.89	0.87	0.73
3	0.95	0.93	0.43	0.49	0.95	0.44	0.23	0.98	0.88	0.88	0.74
4	0.95	0.95	0.43	0.50	0.95	0.44	0.31	0.98	0.87	0.90	0.71
5	0.95	1.00	0.45	0.53	0.95	0.44	0.60	0.99	0.88	0.97	0.76
6	0.99	1.06	0.50	0.76	0.99	0.48	0.93	1.01	0.91	1.04	0.95

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[21] The diurnal profiles sum to 24 for each vessel category.

Hour	Barge-Other	Commercial Fishing	Commercial Passenger Fishing	Crew Supply	Dredge	Excursion	Ferry	Pilot Vessel	Research Vessel	Tug - Push/Tow	Workboat
7	1.04	1.10	0.75	1.27	1.04	0.52	1.16	1.04	1.03	1.10	1.06
8	1.07	1.12	1.31	1.59	1.07	0.61	1.35	1.09	1.13	1.13	1.30
9	1.07	1.12	1.60	1.65	1.07	0.80	1.47	1.08	1.14	1.13	1.48
10	1.05	1.13	1.60	1.65	1.05	1.17	1.49	1.07	1.13	1.13	1.55
11	1.06	1.13	1.78	1.66	1.06	1.52	1.50	1.05	1.14	1.13	1.50
12	1.06	1.11	1.88	1.67	1.06	1.69	1.48	1.06	1.15	1.13	1.49
13	1.05	1.08	1.76	1.62	1.05	1.70	1.49	1.06	1.17	1.12	1.56
14	1.04	1.07	1.73	1.41	1.04	1.67	1.56	1.05	1.18	1.11	1.46
15	1.02	1.03	1.73	1.12	1.02	1.67	1.60	1.03	1.17	1.09	1.23
16	1.00	0.99	1.45	0.97	1.00	1.72	1.57	1.00	1.06	1.04	0.95
17	1.00	0.96	1.31	0.91	1.00	1.73	1.55	0.97	0.98	1.01	0.78
18	0.98	0.95	1.11	0.92	0.98	1.55	1.44	0.95	0.93	0.96	0.71
19	0.98	0.92	0.87	0.83	0.98	1.29	1.22	0.94	0.94	0.94	0.72
20	0.98	0.92	0.63	0.74	0.98	1.01	0.96	0.93	0.91	0.91	0.73
21	0.97	0.91	0.49	0.70	0.97	0.84	0.68	0.94	0.91	0.90	0.69
22	0.97	0.90	0.44	0.68	0.97	0.72	0.42	0.93	0.90	0.89	0.73
23	0.97	0.89	0.44	0.66	0.97	0.59	0.30	0.93	0.89	0.88	0.72
24	0.96	0.90	0.43	0.60	0.96	0.50	0.24	0.96	0.89	0.87	0.73

c) Emission Allocation Methodology for the Barge Category

Barges are marine vessels used to transport bulk materials or equipment via water. For these health analyses, barges are subcategorized into four different operational groups: articulated tug barges (ATB), petrochemical barges, bunker barges, and general use barges. Each type of barge is typically moved by tugboats or towboats and does not have a main propulsion diesel engine. The DPM emission sources for these vessels are the onboard auxiliary diesel engines. These engines are used to pump fuel or petrochemicals off the barge, run deck equipment, and generate electricity for lights. Since barges are not self-propelled, they are not required to carry AIS transponders.[22] Because of this lack of barge-specific AIS data, surrogate data was used to estimate barge activity and define barge area sources for the four barge subgroups.

(1) Articulated Tug Barge (ATB) and Petrochemical Barge

ATB and petrochemical barges transport fuel and petrochemicals for oil refineries 24 hours a day, 7 days a week, and 365 days a year. Because these categories have the same vocation, and operate similarly, they were modeled using the same model inputs, with differentiation between the two types of barges occurring during the post-processing stage after the model runs.

The ATB tugboat AIS data and area sources were used as a surrogate for this barge subgroup because ATB tugboats are the prime movers for the ATBs. The source of emissions from ATBs and petrochemical barges are the auxiliary pump engines, which are started and hour or two before the barge reaches the marine terminal. Because of this, ATB and petrochemical barge DPM emissions are not expected to occur everywhere the ATB tugboats operate, so a subset of the ATB tugboat AIS data and area sources were selected based on where barge auxiliary engines are expected to be operating and emitting DPM.

(2) Bunker Barge

Bunker barges are used for fueling ocean going vessels either at berth or at anchor. Fuel bunkering occurs 24 hours a day, 7 days a week, and 365 days a year.

The tugboat-push/tow AIS data and area sources were used as a surrogate for bunker barges because these barges are designed to be towed or pushed by tugboats. Similar to ATBs and petrochemical barges, bunker barge emissions are not expected to occur everywhere the tugboat-push/tow vessels operate, so a subset of the tugboat-push/tow AIS data and area sources were selected based on where bunker barge auxiliary engines are expected to be operating and emitting DPM.

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[22] Code of Federal Regulations, Title 33 § 164.46 Automatic Identification System, pg. 666, July 1, 2015, last accessed May 10, 2021, *https://www.govinfo.gov/content/pkg/CFR-2015-title33-vol2/pdf/CFR-2015-title33-vol2-sec164-46.pdf*.

(3) General Use Barge

General use barges are multipurpose barges, commonly providing transportation for bulk, large volume, or oversized cargos, and construction support.

The dredge AIS data and area sources were used as a surrogate for general use barges because dredging is an example of an operation that relies on general use barge support, both as a mount for heavy equipment and as a means to transport sediment produced by the dredging operation. General use barge DPM emissions are not expected to occur everywhere dredges operate, so a subset of the dredge AIS data and area sources were selected based on where barge auxiliary engines are expected to be operating and emitting DPM.

4. Meteorological Data

The CALMET meteorological model is a key component of the CALPUFF modeling system. Its primary purpose is to prepare meteorological input data for CALPUFF model. Execution of the CALMET meteorological model requires preprocessing meteorological and geophysical input data, and the determination of appropriate control file settings. Since the modeling domains span overwater and overland, staff also defined the coastline data. Table G-16 lists these CALMET input data sources. The outputs of CALMET are hourly gridded fields of micrometeorological parameters and three dimensional fields of wind flow and temperature distribution.

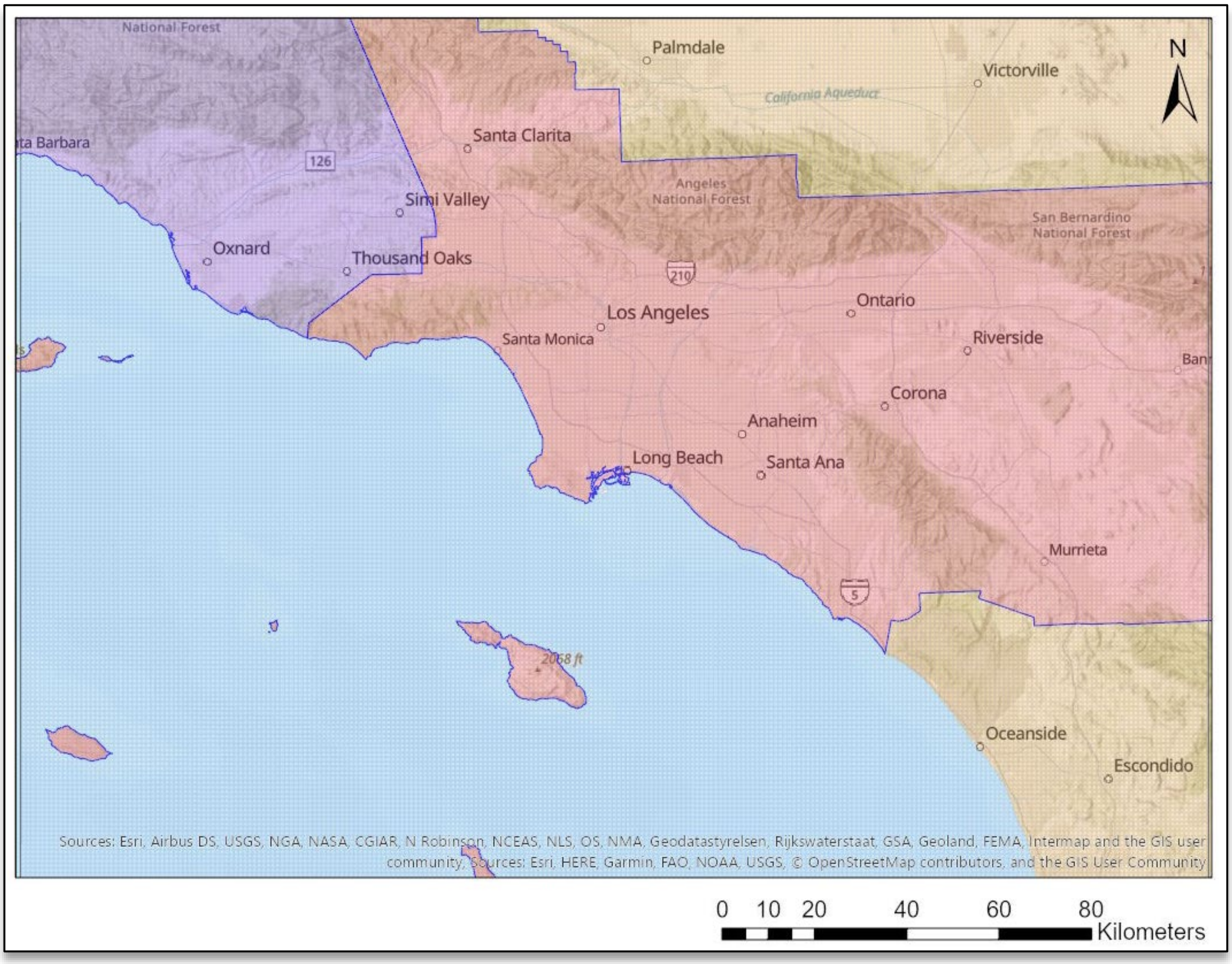
Table G-16 CALMET Meteorological and Geophysical Input Data Sources

Input Data	Source
Surface	Prognostic data from Weather Research and Forecasting (WRF) Modeling
Upper Air	Prognostic data from WRF Modeling
Overwater	Prognostic data from WRF Modeling
Precipitation	Prognostic data from WRF Modeling
Terrain	Gridded terrain elevations were derived from the Digital Elevation Models (DEM) produced by the United States Geological Survey (USGS): DEM 1-Deg (USA -90m)
Land Use	USGS Land Use and Land Cover (LULC) grids encoded in the Character Composite Theme Grid (CTG) format: USGS CTG (US 200m)
Coastline	Global self-consistent hierarchical high-resolution shoreline (GSHHS)

The meteorological gridded domain defines the area over which land use, winds, and other meteorological variables are defined. For this HRA, the factors that determined the size of each meteorological domain include the coverage of: all vessel travel routes within 24 nautical miles from the shoreline of each modeled air basin, port and marine terminal locations, travel routes through inland waterways, the surrounding land, and the area with expected cancer risk level of one chance per million or greater.
Figure G-5 shows the meteorological domain of SCAB. The size of the domain is

257 km by 186 km. Figure G-6 depicts the meteorological domain of BAAB. The size of the domain is 230 km by 265 km.

Figure G-5 Meteorological Domain of the South Coast Air Basin



Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community, Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

Figure G-6 Meteorological Domain of the Bay Area Air Basin

Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community. Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

The selection of meteorological grid cell size reflects a compromise between the need to define meteorological and geophysical variations on a very small scale, and the computational time and resources necessary to do so. Given the complex terrain (sea, land, rolling mountains), non-uniform land use characteristics, and water surfaces large enough to cause strong local-scale flows, we selected a grid cell size of 1 km by 1 km for the meteorological modeling.

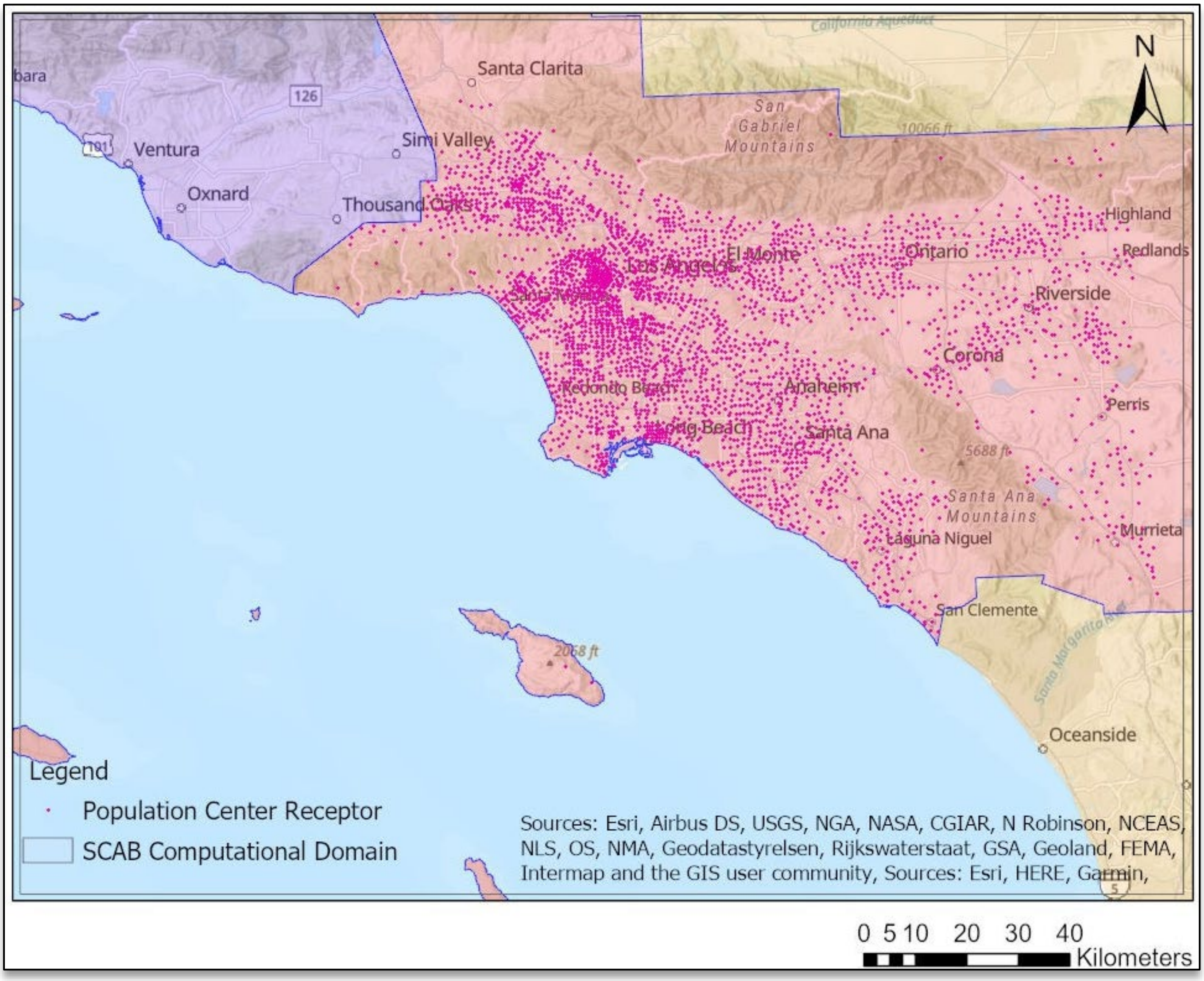
The vertical structure of the meteorological grid was defined by 10 layers in the CALMET model. The layer heights were set at 20, 60, 80, 100, 300, 600, 1000, 1500, 2200, and 3000 meters above ground level.

CALMET and CALPUFF were set to run for the 2017 calendar year. A one-year period is necessary to enable estimation of the annual average concentrations which are required in a health impact assessment.

5. Model Domain and Receptor Network

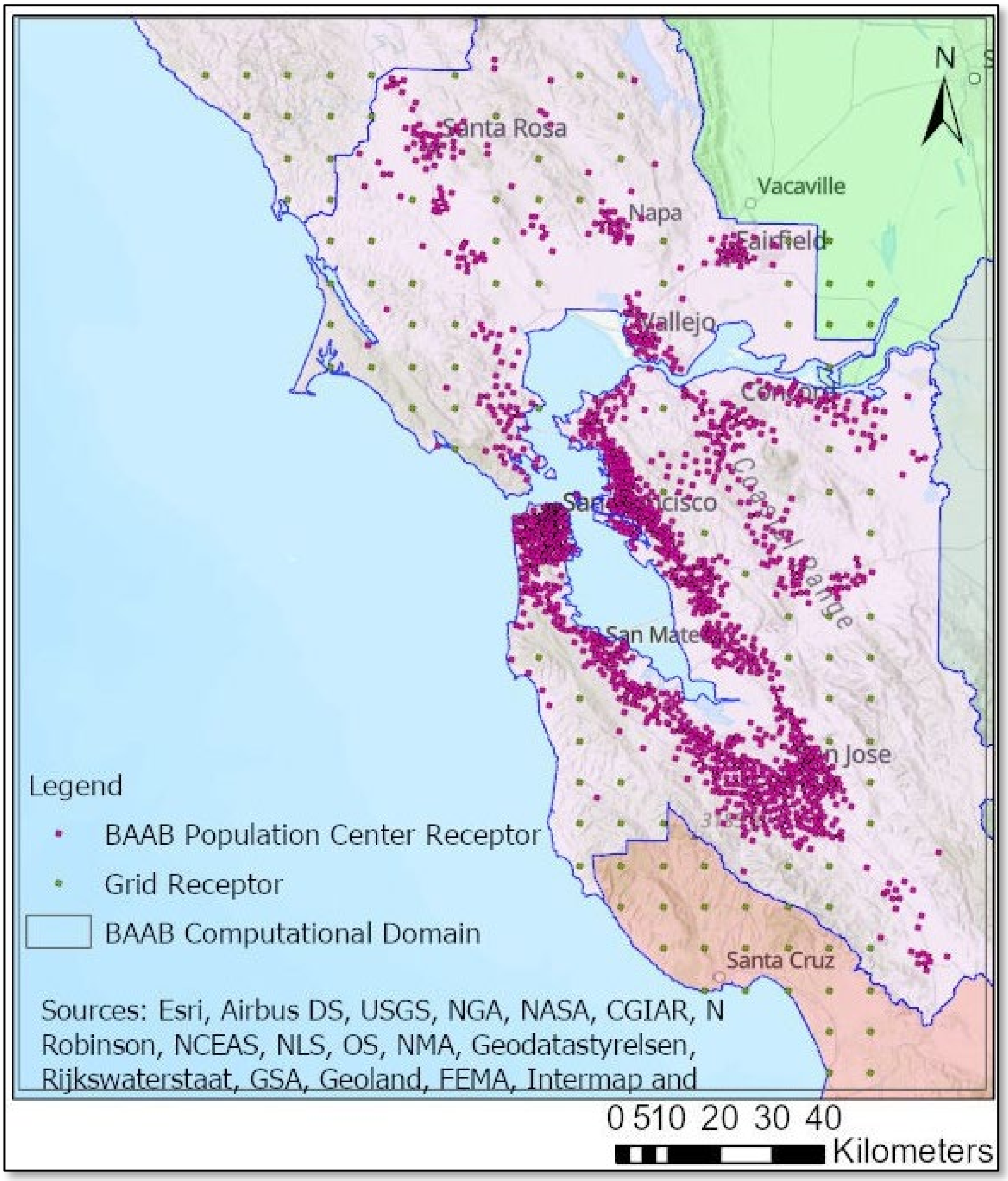
In this HRA, the receptors were defined using the population centers of census tracts within the modeling domain and air basin respectively. The population centers of census tracts are from the 2010 U.S. Census Bureau data (2020 census data was not available when the health analyses were conducted). For BAAB modeling, the densities of the census tract receptors, in some portions of the modeling domain, was insufficient to generate smooth isopleths of cancer risks. To compensate for this, staff added extra grid receptors to cover the areas that had too few census tract receptors. The grid spacing of the grid receptors is 8 km by 8 km. The elevation of each receptor within each modeling domain was determined from the USGS topographic data. Figure G-7 shows the modeling domain and census tract population center receptors within SCAB. Figure G-8 displays the modeling domain and, both the census tract receptors and the grid receptors within BAAB.

Figure G-7 Modeling Domain and Receptors within the South Coast Air Basin



Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community, Sources: Esri, HERE, Garmin,

Figure G-8 Modeling Domain and Receptors within the Bay Area Air Basin



6. CALPUFF Modeling Options

CALPUFF modeling options specify parameters and algorithms for representing physical processes that are important for predicting air concentrations. Besides the key parameters discussed previously, Table G-17 lists additional CALPUFF modeling options used in this analysis. Default settings are not listed.

Table G-17 CALPUFF Modeling Options

Modeling Options	Values or Descriptions
Wet and dry deposition processes	Not included
Plume Element Modeling Method	Puff
Horizontal puff size beyond which Heffter equations are used to determine sigma-y and sigma-z	550 m
Dispersion Option	Pasquill-Gifford dispersion coefficients for rural areas and McElroy-Pooler coefficients for urban areas
Puff Splitting	No
Heffter equation for sigma-z	Not used
Complex Terrain Sub-grid for Isolated Hills	No

7. Scaling of the Modeled Results

The health analyses evaluate multiple emission inventory years for both the Current Regulation and the Proposed Amendments. To reduce computer run time, staff ran the air dispersion analysis once for each CHC category, in each air basin, using baseline emissions from 2023, then scaled from these modeled results for the years 2023 through 2038. This section provides a description of the procedures staff used to scale the modeled results.

Staff used CALPUFF to estimate the annual average concentrations at the receptors described above for each individual vessel category operating within SCAB and BAAB. Staff approximated pollutant concentrations at each receptor for each year under the Current and Proposed Regulations by scaling concentration results to the change in emissions for each vessel category. Equation 2 below shows how to scale the DPM ground-level concentration for a vessel category at a receptor point (x,y) for a specific inventory year.

$$C(x,y)_n = \left(\frac{E_n}{E_m}\right) C(x,y)_m$$

Where:

C(x,y)n = Vessel category ground-level DPM concentration at receptor (x,y) of inventory year n

En = Vessel category DPM emission of inventory year n

Em = Vessel category DPM emission of inventory year m (a baseline emission)

C(x,y)m = Vessel category ground-level DPM concentration at receptor (x,y) of inventory year m

After scaling ground-level concentrations for each source category, staff summed the ground-level concentrations at each receptor point to yield the total DPM ground-level concentration from all CHC source categories.

The mortality and illness analysis is based on PM2.5 emission values. To estimate PM2.5 concentrations from DPM emission sources, staff multiplied the total DPM concentrations at each receptor by a conversion factor to yield the total PM2.5 concentrations from all CHC categories. Staff used a scaling factor of 0.956, based on CARB's latest DPM speciation profile[23] to convert DPM to PM2.5.

D. Risk Exposure Scenarios

To compare the health impacts from the Current Regulation to the Proposed Amendments, staff evaluated the 70-year population-wide cancer risk and noncancer chronic risk. Staff calculated the health impacts using the methodology consistent with the OEHHA Guidance Manual. The health impacts were evaluated for the years 2023 and 2038, which are the years of full implementation for the Current Regulation and the Proposed Amendments respectively. 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 potential cancer risk. Potential cancer risk is calculated by converting an annual average concentration to a dose and then comparing it to a pollutant-specific cancer potency factor.

Staff evaluated potential cancer risk for a 70-year population-wide exposure, which is used for sources with large emission footprints (e.g., CHC operations, ports, refineries, rail yards, etc.). A 70-year population-wide exposure is critical to provide an illustration of the potential impacts CHC may have on a regional level. 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 tract population data to estimate the number of people within a given area.

For this exposure scenario, staff applied the CARB and the California Air Pollution Control Officers Association (CAPCOA) risk management policy (RMP) for inhalation based cancer risk.[24] The policy recommends using the 95th percentile breathing rates for age bins less than 2 years old and the 80th percentile breathing rates for age bins greater than or equal to 2 years old.

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[23] California Air Resources Board, Speciation Profiles Used in CARB Modeling PMSIZE, April 30, 2021, last accessed July 20, 2021, *https://ww2.arb.ca.gov/speciation-profiles-used-carb-modeling.*

[24] California Air Resources Board and California Air Pollution Control Officers Association, Risk Management Guidance for Stationary Sources of Air Toxics, July 23, 2015, last accessed June 4, 2021, *https://www.arb.ca.gov/toxics/rma/rmgssat.pdf*.

Because people have different breathing rates and different levels of sensitivity to carcinogens at different ages, cancer risk is calculated by age ranges or bins (i.e., third trimester, 0<2, 2<9, 2<16, 16<30, or 16-70). After the risk is calculated for each applicable age bin, the results are summed for the exposure duration of interest (e.g., 70 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 2 years of age and use a factor of 3 for age bins between 2 and 16.

The following are exposure parameters used for the 70-year population-wide cancer risk scenario:

- Exposure duration: 24 hours per day, 350 days per year, and 70 years.
- Age bin exposure duration distribution (70 years total):
    - 3rd trimester = 0.25 years,
    - 0<2 = 2 years,
    - 2<16 = 14 years, and
    - 16-70 = 54 years.
- Breathing rate: RMP (95th percentile daily breathing rates for age bins less than two years and 80th percentile daily breathing rates for age bins greater than two years).
- FAH: not applied (all age bins use one).
- Pathway evaluated: inhalation only.

2. Exposure Scenarios for Noncancer Chronic Risk

The chronic health hazard index is calculated by dividing the 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 µg/m^3 with the only target organ system identified as the respiratory system.

E. Summary of Health Risk Assessment Results

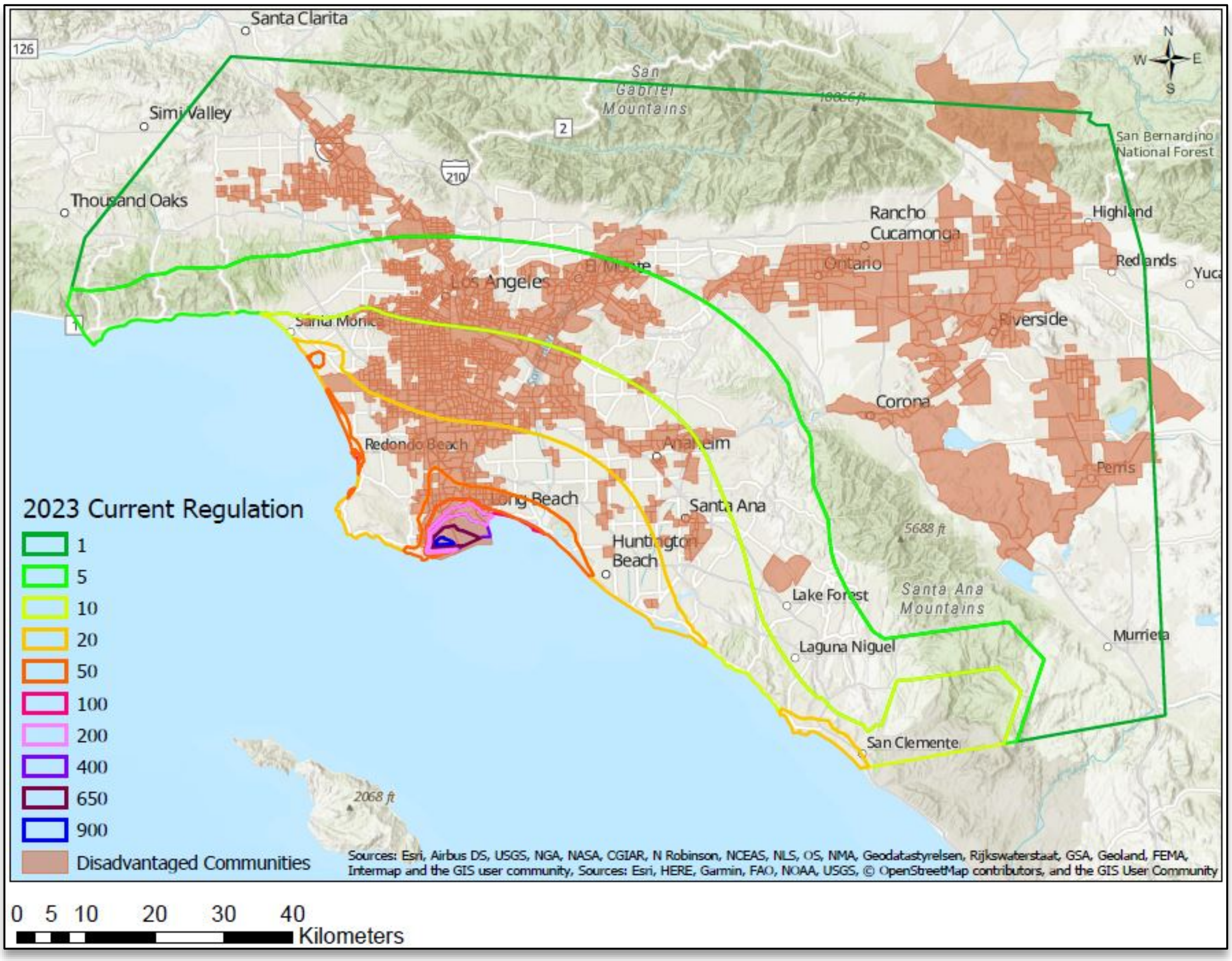
To illustrate the effectiveness of the Proposed Amendments in reducing health risks to populations living within each air basin, staff provided figures which display the risk isopleths for the Current Regulation for the years 2023 and 2038 and the Proposed Amendments for the year 2038. Tables are also provided which estimate the number of people exposed to various risk levels.

1. South Coast Air Basin Potential Cancer Risk Results

For the South Coast Air Basin, staff evaluated the potential population-wide cancer risks to the surrounding communities under the Current Regulation and the Proposed

Amendments. Figure G-9 through Figure G-11 present the predicted cancer risk isopleths (i.e., lines that connect points with the same values) for DPM emissions from CHC operating within SCAB. Disadvantaged communities within the modeling domain and SCAB are also shown. Figure G-9 shows the predicted cancer risk isopleths for the year 2023 after full implementation of the Current Regulation. Figure G-10 shows the predicted cancer risk isopleths for the year 2038 under the Current Regulation. Figure G-11 shows the predicted cancer risk isopleths for the year 2038 after full implementation of the Proposed Amendments. Figures G-12 through G-14 present the area of highest predicted cancer risk isopleths for DPM emissions from CHC operating within SCAB. Figure G-12 shows the area of highest predicted cancer risk isopleths for the year 2023 after full implementation of the Current Regulation. Figure G-13 shows the area of highest predicted cancer risk isopleths for the year 2038 under the Current Regulation. Figure G-14 shows the area of highest predicted cancer risk isopleths for the year 2038 after full implementation of the Proposed Amendments. These figures illustrate how the area within the risk isopleths would be reduced as the Proposed Amendments are implemented. The populations impacted within the risk isopleths are shown in Tables G-18 and G-19.

Figure G-9 2023 Impacts from CHC Under the Current Regulation South Coast Air Basin Potential Cancer Risk Isopleths (chances per million)[25]



Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community, Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

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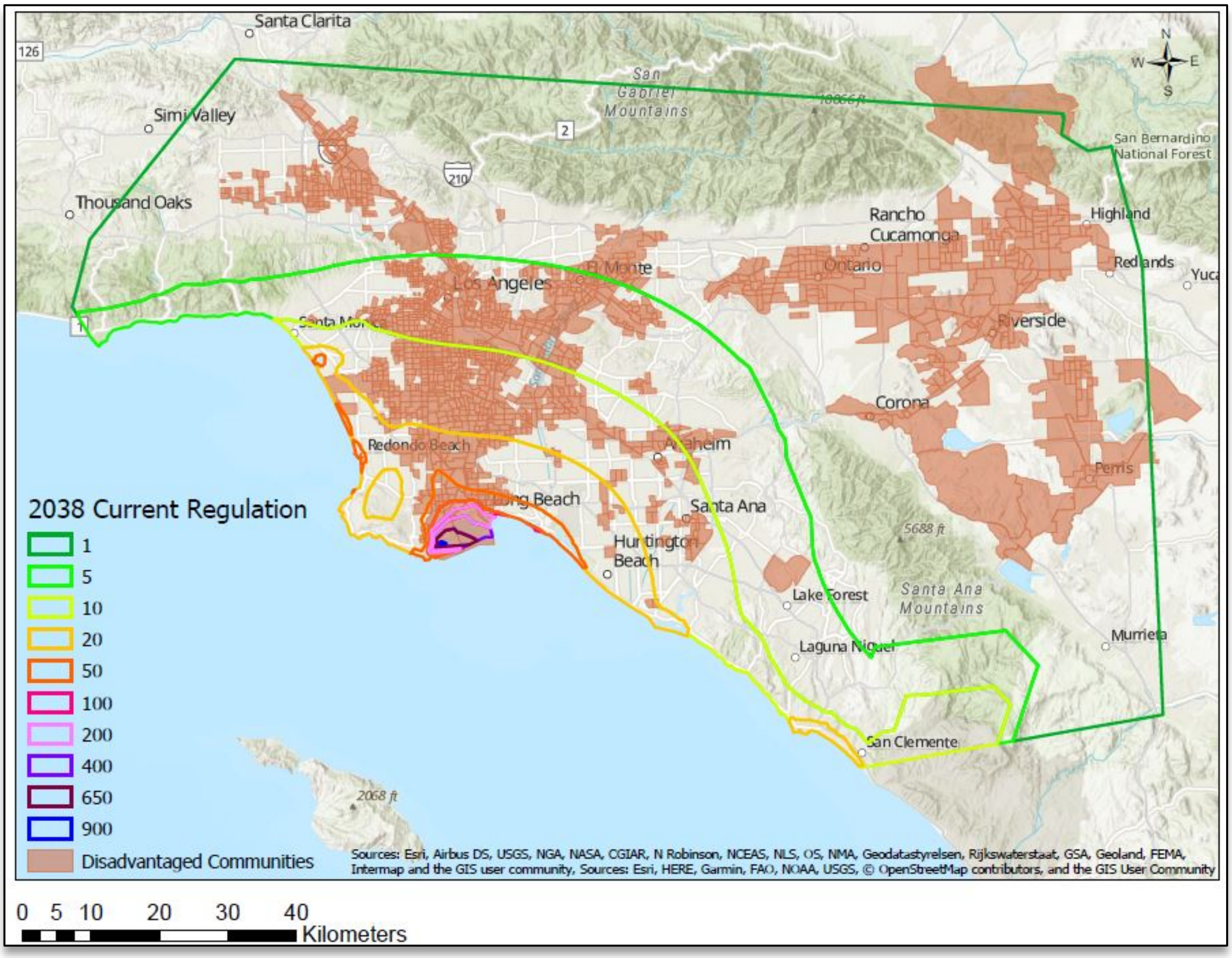
[25] Assumed exposure duration of 70 years using the RMP method (95th/80th percentile DBR). FAH equals one for all age bins.

Figure G-10 2038 Impacts from CHC Under the Current Regulation South Coast Air Basin Potential Cancer Risk Isopleths (chances per million)[26]



Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community, Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

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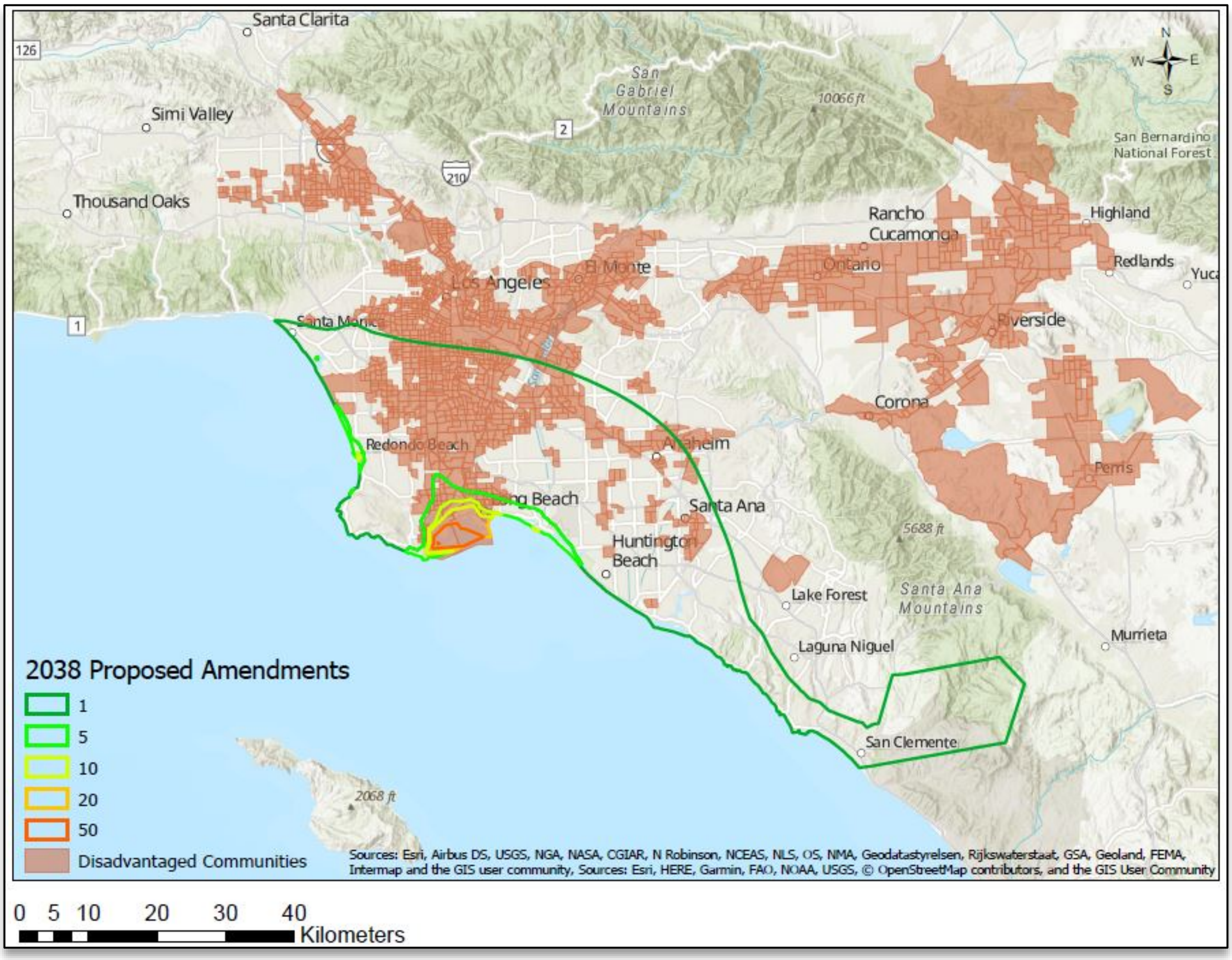
[26] Assumed exposure duration of 70 years using the RMP method (95th/80th percentile DBR). FAH equals one for all age bins.

Figure G-11 2038 Impacts from CHC Under the Proposed Amendments South Coast Air Basin Potential Cancer Risk Isopleths (chances per million)[27]



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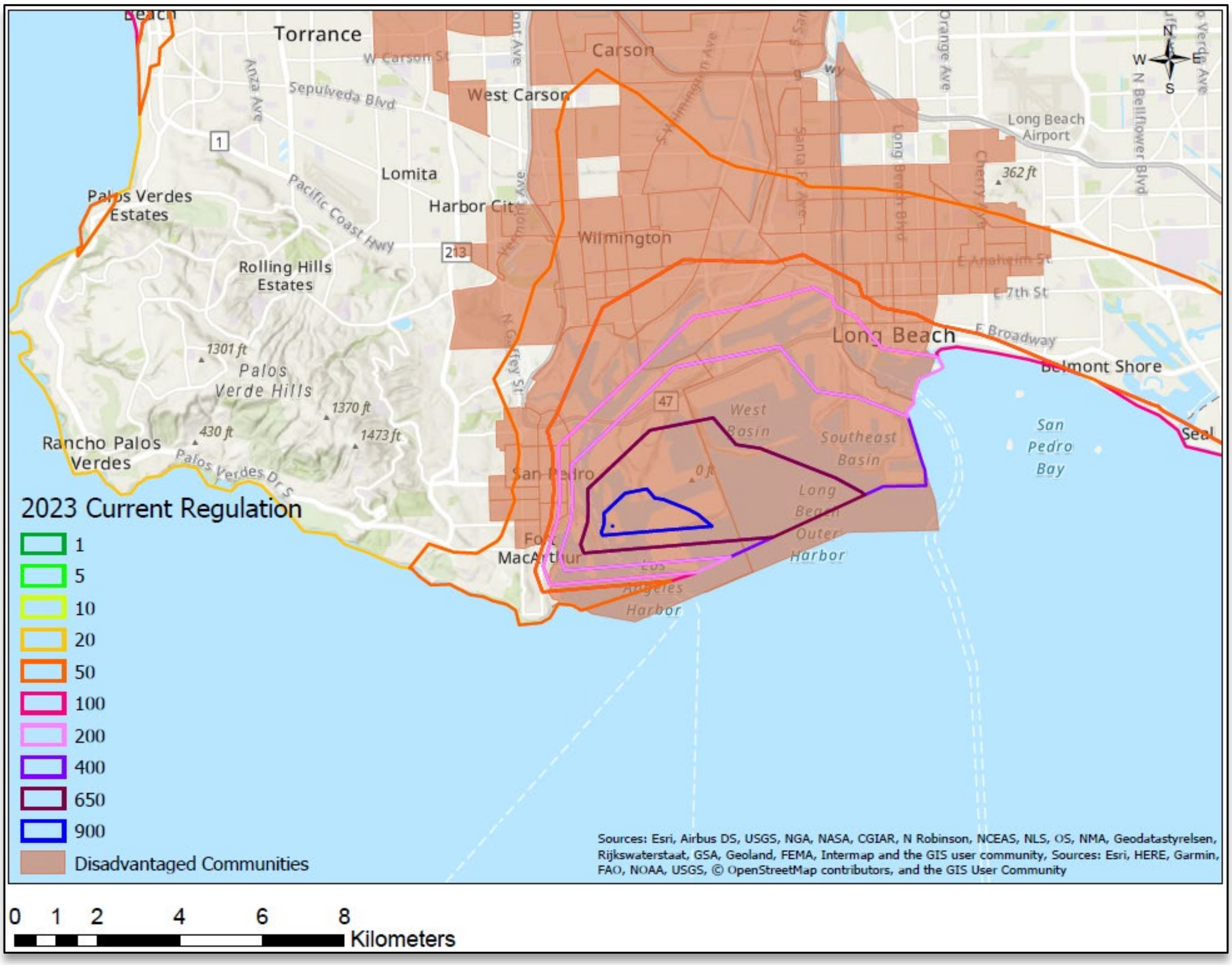
[27] Assumed exposure duration of 70 years using the RMP method (95th/80th percentile DBR). FAH equals one for all age bins.

Figure G-12 2023 Area of Highest Impacts from CHC Under the Current Regulation for the South Coast Air Basin Potential Cancer Risk Isopleths (chances per million)[28]



Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community, Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

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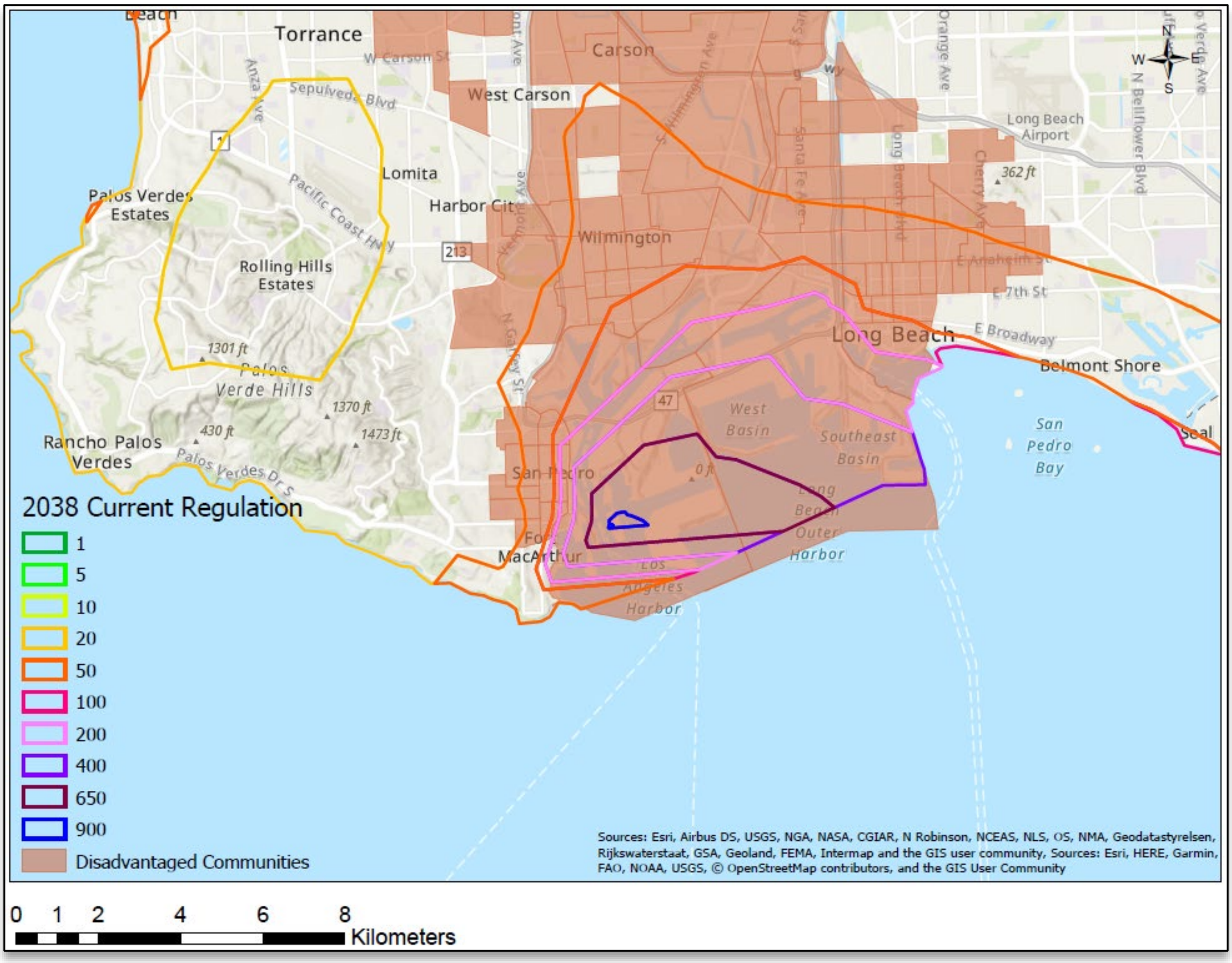
[28] Assumed exposure duration of 70 years using the RMP method (95th/80th percentile DBR). FAH equals one for all age bins.

Figure G-13 2038 Area of Highest Impacts from CHC Under the Current Regulation for the South Coast Air Basin Potential Cancer Risk Isopleths (chances per million)[29]



Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community, Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

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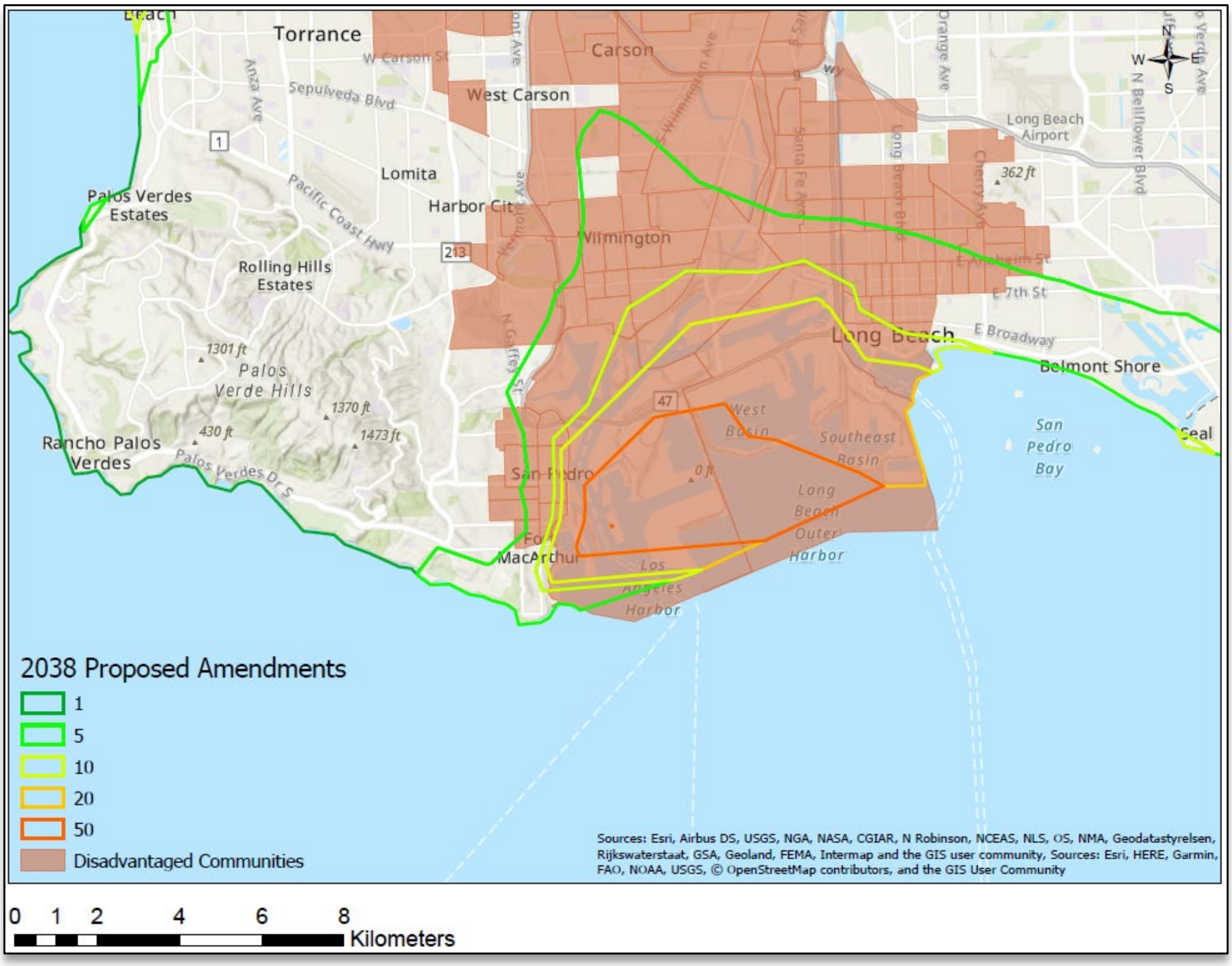
[29] Assumed exposure duration of 70 years using the RMP method (95th/80th percentile DBR). FAH equals one for all age bins.

Figure G-14 2038 Area of Highest Impacts from CHC Under the Proposed Amendments for the South Coast Air Basin Potential Cancer Risk Isopleths (chances per million)[30]



Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community, Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

Using the U.S. Census Bureau's data from the 2010 census (2020 census data was not available when the health analyses were conducted),[31] staff estimated the population within the isopleth boundaries. Table G-18 shows the estimated affected general population that fall within the potential cancer risk levels of 1-5, 6-10, 11-20, 21-50, 51-100, 101-200, 201-900, and 901-988 chances per million. Table G-19 shows the estimated affected general population in disadvantaged communities that fall within the potential cancer risk levels of 1-5, 6-10, 11-20, 21-50, 51-100, 101-200, 201-900, and 901-988 chances per million.

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[30] Assumed exposure duration of 70 years using the RMP method (95th/80th percentile DBR). FAH equals one for all age bins.

[31] United States Census Bureau, Centers of Population 2010, last accessed July 17, 2021, *https://www2.census.gov/geo/docs/reference/cenpop2010/tract/CenPop2010_Mean_TR06.txt*.

Table G-18 South Coast Air Basin's Estimated Population Impacts by Potential Cancer Risk Level[32,33,34]

Risk Level[35]	Current Regulation – 2023	Current Regulation – 2038	Proposed Amendments – 2038
901-1030	1,260	1,260	--
201-900	60	60	--
101-200	29,520	14,910	--
51-100	362,250	317,260	1,260
21-50	1,907,450	1,379,880	60
11-20	3,661,200	3,531,710	8,440
6-10	3,472,680	3,678,390	275,210
1-5	5,573,420	6,076,660	4,936,150
Total	15,007,840	15,000,130	5,221,120

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[32] The total population within the SCAB modeling domain is 15,011,548. This population is based on 2010 U.S. Census Bureau data.

[33] Population values are rounded to the nearest ten.

[34] Assumed exposure duration of 70 years using the RMP method (95th/80th percentile DBR). FAH equals one for all age bins.

[35] Risk levels are presented in chances per million.

Table G-19 South Coast Air Basin's Estimated Population Impacts in Disadvantaged Communities by Potential Cancer Risk Level[36,37,38]

Risk Level[39]	Current Regulation – 2023	Current Regulation – 2038	Proposed Amendments – 2038
901-1030	1,260	1,260	--
201-900	60	60	--
101-200	16,440	11,680	--
51-100	204,570	177,110	1,260
21-50	473,980	308,000	60
11-20	1,916,950	1,748,760	5,210
6-10	1,306,720	1,548,250	144,740
1-5	2,061,550	2,186,410	2,077,570
Total	5,981,530	5,981,530	2,228,840

In 2038 without the Proposed Amendments, in the South Coast Air Basin, about 15 million people, including 6 million people who live in disadvantaged communities (DACs), are estimated to be exposed to a potential cancer risk of greater than one chance per million from exposure to DPM. As shown in Tables G-18 and G-19, the Proposed Amendments would provide significant benefits by reducing the number of people exposed to each impacted risk level. Under the Proposed Amendments compared to the Current Regulation in 2038:

- The population weighted-average cancer risk would be reduced from 10 chances per million to one chance per million,
- The potential cancer risk levels greater than 100 chances per million would be eliminated,
- More than 9.7 million people would have their potential cancer risk reduced to less than one chance per million, of which about 3.8 million live in disadvantaged communities, and

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[36] The total population within the SCAB modeling domain is 15,011,548. This population is based on 2010 U.S. Census Bureau data.

[37] Population values are rounded to the nearest ten.

[38] Assumed exposure duration of 70 years using the RMP method (95th/80th percentile DBR). FAH equals one for all age bins.

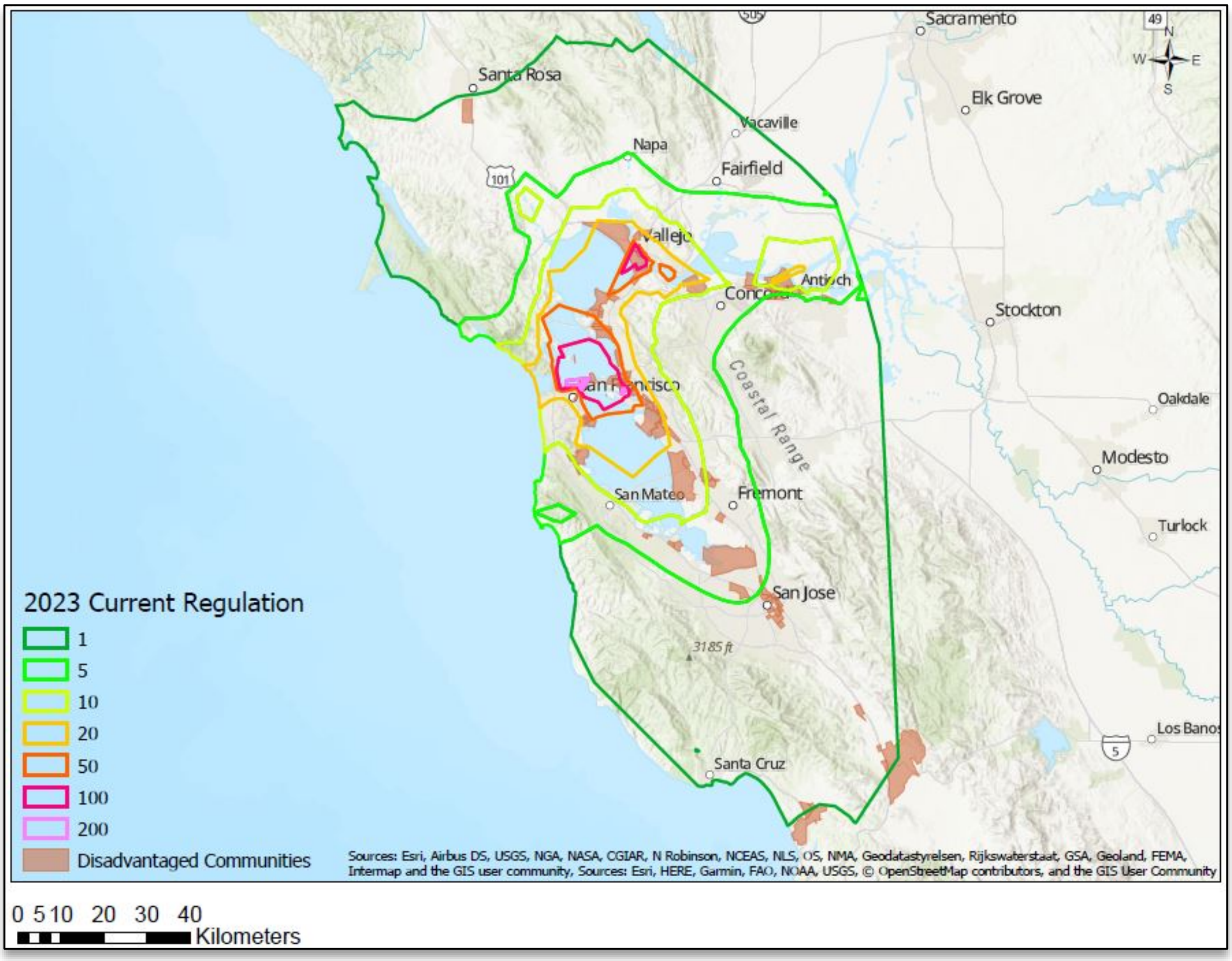
[39] Risk levels are presented in chances per million.

- More than 5.2 million fewer people will be exposed to a cancer risk greater than 10 chances per million, of which about 2.2 million live in disadvantaged communities.

2. San Francisco Bay Area Air Basin Potential Cancer Risk Results

For BAAB, staff evaluated the potential population-wide cancer risk to the surrounding communities under the Current Regulation and the Proposed Amendments. Figures G-15 through G-17 present the predicted cancer risk isopleths for DPM emissions from CHC operating within BAAB. Disadvantaged communities within the modeling domain and BAAB are also shown. Figure G-15 shows the predicted cancer risk isopleths for the year 2023 after full implementation of the Current Regulation. Figure G-16 shows the predicted cancer risk isopleths for the year 2038 under the Current Regulation. Figure G-17 shows the predicted cancer risk isopleths for the year 2038 after full implementation of the Proposed Amendments. Figures G-18 through G-20 present the area of highest predicted cancer risk isopleths for DPM emissions from CHC operating within BAAB. Figure G-18 shows the area of highest predicted cancer risk isopleths for the year 2023 after full implementation of the Current Regulation. Figure G-19 shows the area of highest predicted cancer risk isopleths for the year 2038 under the Current Regulation. Figure G-20 shows the area of highest predicted cancer risk isopleths for the year 2038 after full implementation of the Proposed Amendments. These figures illustrate how the area within the risk isopleths would be reduce as the Proposed Amendments are implemented. The populations impacted within the risk isopleths are shown in Tables G-20 and G-21.

Figure G-15 2023 Impacts from CHC Under the Current Regulation San Francisco Bay Area Air Basin Potential Cancer Risk Isopleths (chances per million)[40]



Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community, Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

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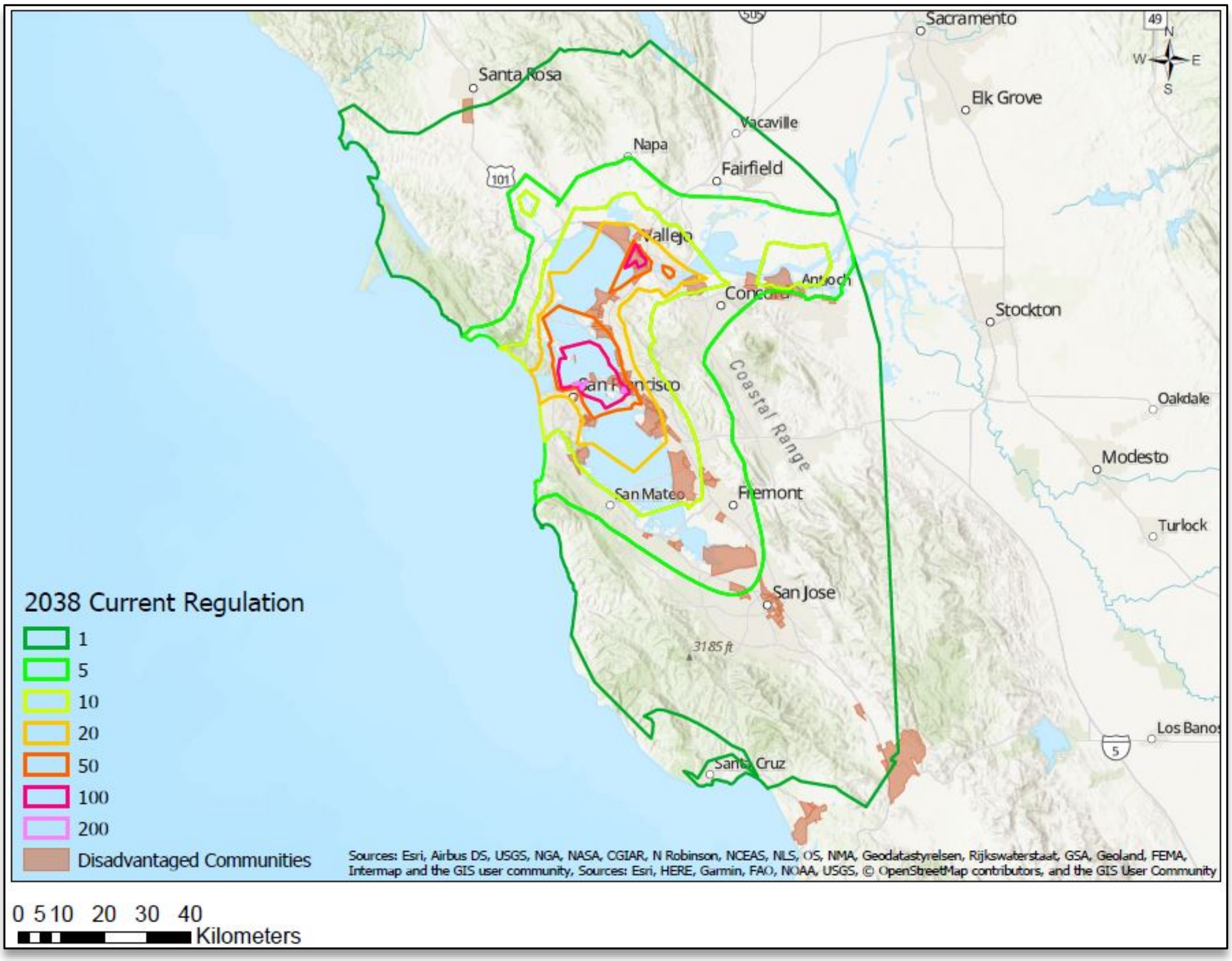
[40] Assumed exposure duration of 70 years using the RMP method (95th/80th percentile DBR). FAH equals one for all age bins.

Figure G-16 2038 Impacts from CHC Under the Current Regulation San Francisco Bay Area Air Basin Potential Cancer Risk Isopleths (chances per million)[41]



Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community, Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

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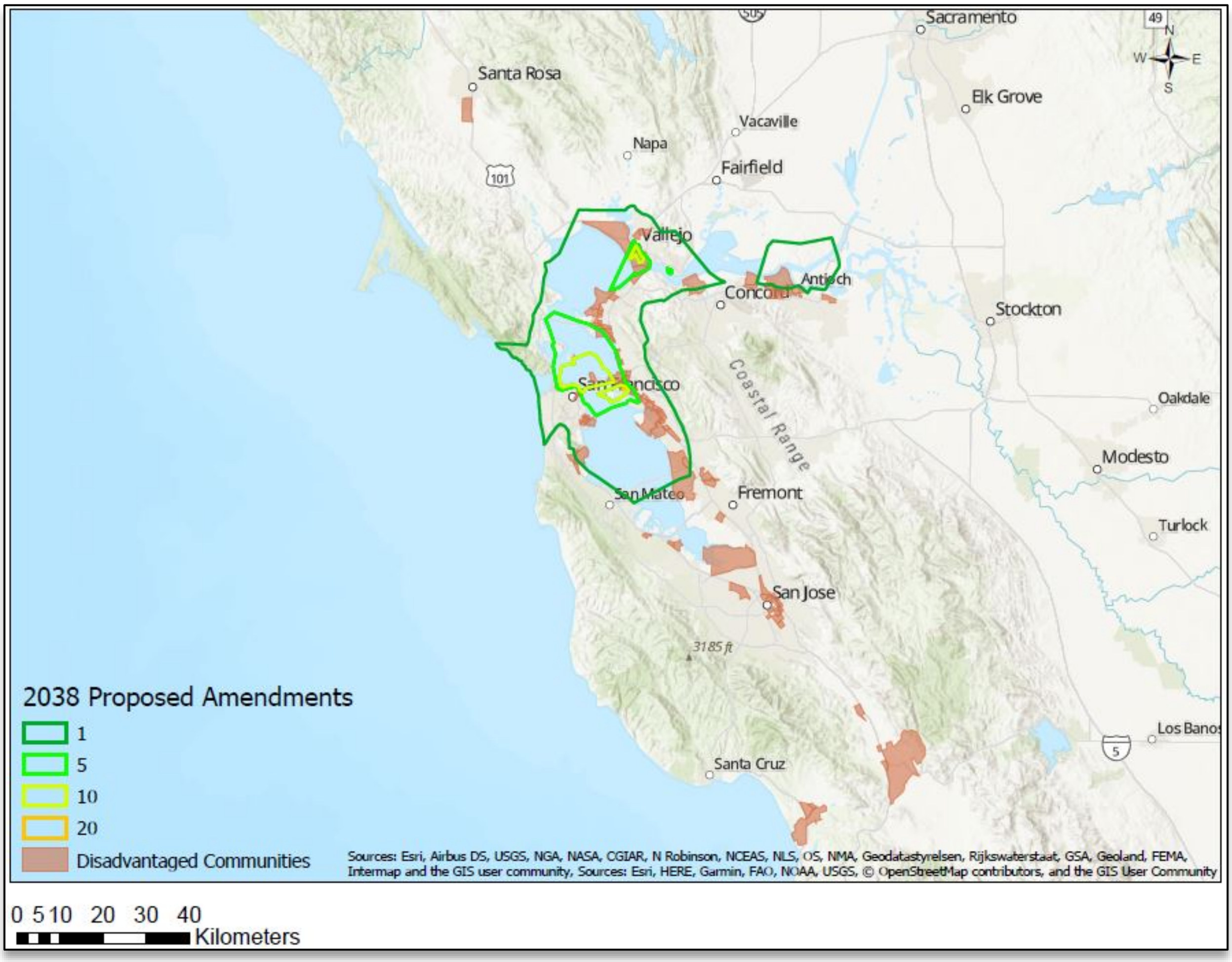
[41] Assumed exposure duration of 70 years using the RMP method (95th/80th percentile DBR). FAH equals one for all age bins.

Figure G-17 2038 Impacts from CHC Under the Proposed Amendments San Francisco Bay Area Air Basin Potential Cancer Risk Isopleths (chances per million)[42]



Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community, Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

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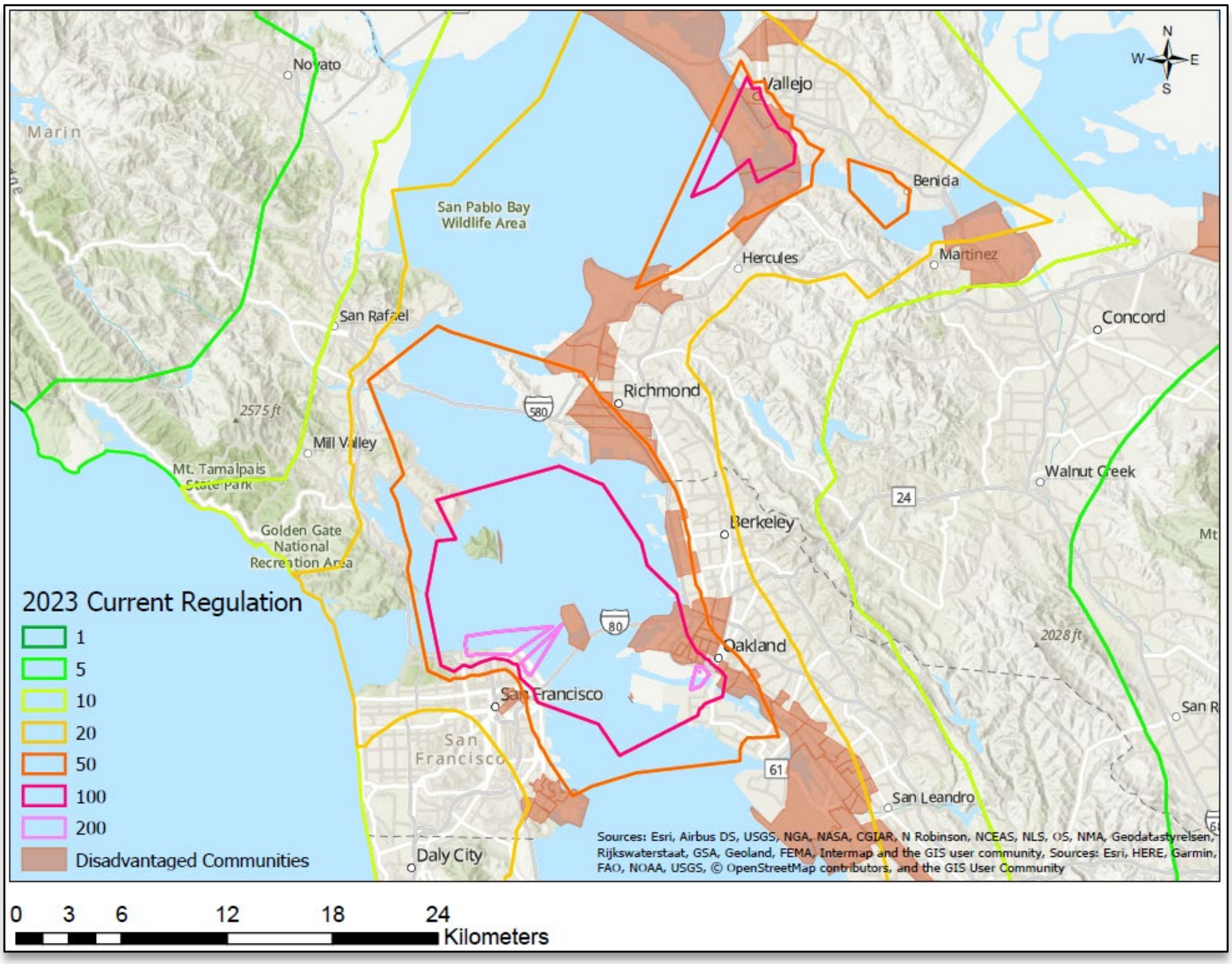
[42] Assumed exposure duration of 70 years using the RMP method (95th/80th percentile DBR). FAH equals one for all age bins.

Figure G-18 2023 Area of Highest Impacts from CHC Under the Current Regulation for the San Francisco Bay Area Air Basin Potential Cancer Risk Isopleths (chances per million)[43]



Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community, Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

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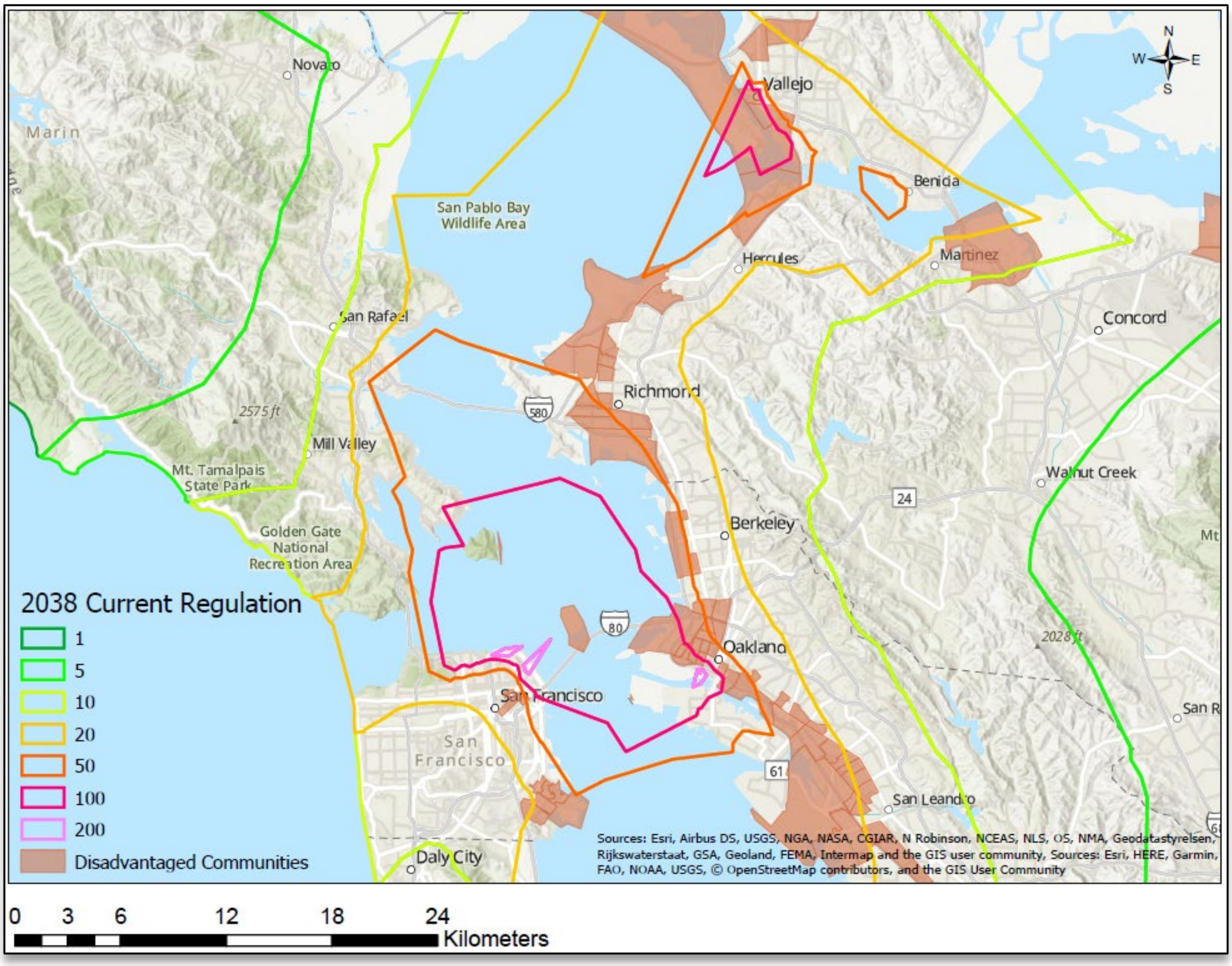
[43] Assumed exposure duration of 70 years using the RMP method (95th/80th percentile DBR). FAH equals one for all age bins.

Figure G-19 2038 Area of Highest Impacts from CHC Under the Current Regulation for the San Francisco Bay Area Air Basin Potential Cancer Risk Isopleths (chances per million)[44]



Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community, Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

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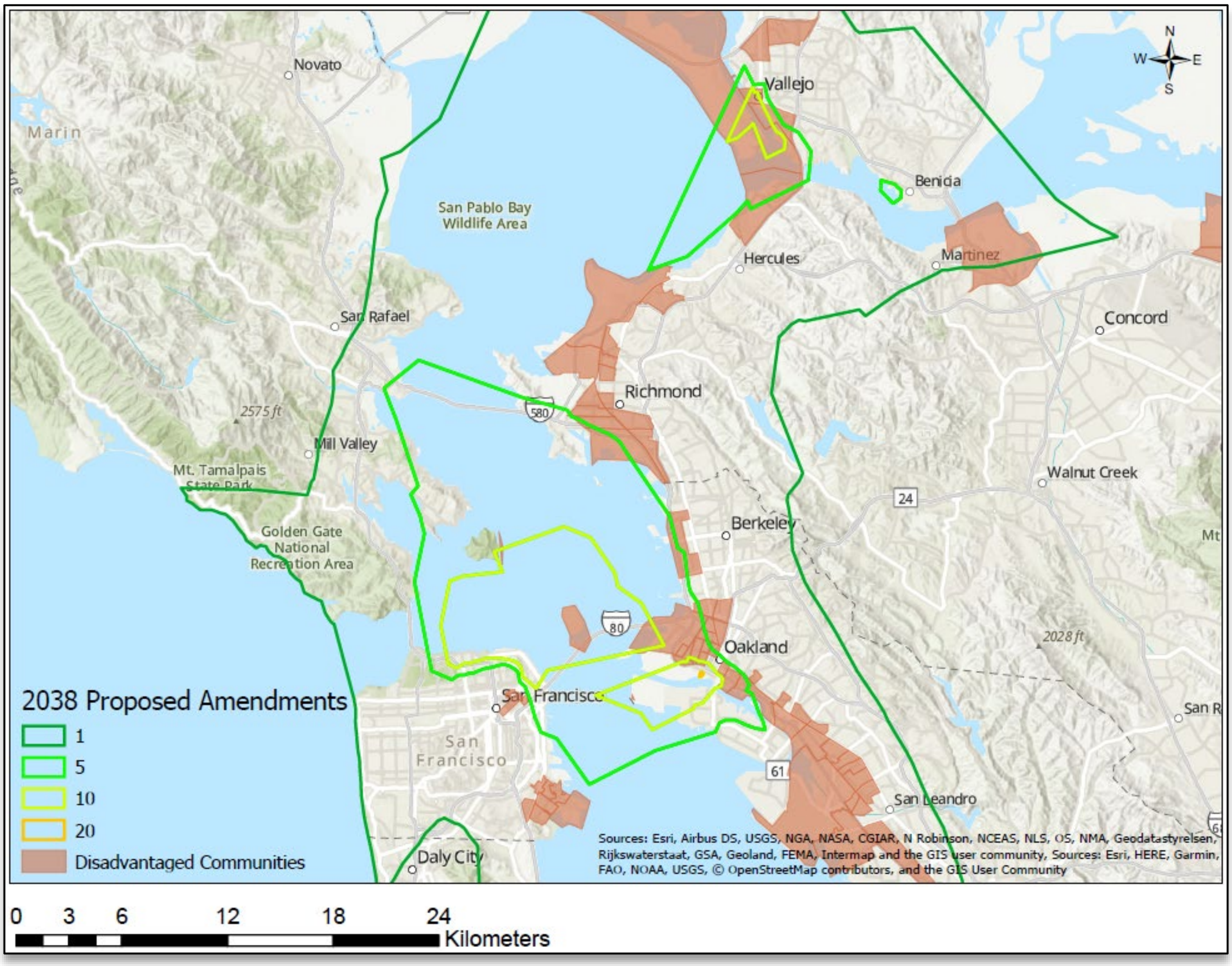
[44] Assumed exposure duration of 70 years using the RMP method (95th/80th percentile DBR). FAH equals one for all age bins.

Figure G-20 2038 Area of Highest Impacts from CHC Under the Proposed Amendments for the San Francisco Bay Area Air Basin Potential Cancer Risk Isopleths (chances per million)[45]



Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community, Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

Using the U.S. Census Bureau's data from the 2010 census (2020 census data was not available when the health analyses were conducted), staff estimated the population within the isopleth boundaries. Table G-20 shows the estimated affected general population that fall within the potential cancer risk levels of 1-5, 6-10, 11-20, 21-50, 51-100, 101-200, and 201-263 chances per million. Table G-21 shows the estimated affected general population in disadvantaged communities that fall within the potential cancer risk levels of 1-5, 6-10, 11-20, 21-50, 51-100, 101-200, and 201-263 chances per million.

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[45] Assumed exposure duration of 70 years using the RMP method (95th/80th percentile DBR). FAH equals one for all age bins.

Table G-20 San Francisco Bay Area Air Basin's Estimated Population Impacts by Potential Cancer Risk Level[46,47,48]

Risk Level[49]	Current Regulation – 2023	Current Regulation – 2038	Proposed Amendments – 2038
201-268	9,400	6,500	--
101-200	50,620	47,130	--
51-100	202,520	179,180	--
21-50	1,003,510	895,880	70
11-20	1,213,460	1,168,490	33,990
6-10	1,766,540	1,721,970	114,670
1-5	2,517,110	2,677,850	1,932,230
Total	6,763,160	6,697,000	2,080,960

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[46] The total population within the BAAB modeling domain is 6,968,762. This population is based on 2010 U.S. Census Bureau data.

[47] Population values are rounded to the nearest ten.

[48] Assumed exposure duration of 70 years using the RMP method (95th/80th percentile DBR). FAH equals one for all age bins.

[49] Risk levels are presented in chances per million.

Table G-21 San Francisco Bay Area Air Basin's Estimated Population Impacts in Disadvantaged Communities by Potential Cancer Risk Level[50,51,52]

Risk Level[53]	Current Regulation – 2023	Current Regulation – 2038	Proposed Amendments – 2038
201-268	--	--	--
101-200	17,660	17,660	--
51-100	58,100	48,510	--
21-50	166,570	166,850	--
11-20	48,250	53,640	9,600
6-10	88,910	72,780	25,630
1-5	94,750	104,280	247,820
Total	474,240	463,720	283,050

In 2038 without the Proposed amendments, in the San Francisco Bay Area Air Basin, about 7 million people, including 0.5 million people who live in DACs, are estimated to be exposed to a potential cancer risk of greater than one chance per million from exposure to DPM. As shown in Tables G-20 and G-21, the Proposed Amendments would provide significant benefits by reducing the number of people exposed to each impacted risk level. Under the Proposed Amendments compared to a baseline of the Current Regulation in 2038:

- The population weighted-average cancer risk would be reduced from 12 chances per million to 1 chance per million,
- The potential cancer risk levels greater than 50 chances per million would be eliminated,
- The potential cancer risk levels greater than 20 chances per million would be eliminated in disadvantaged communities,
- More than 4.6 million people would have their potential cancer risk reduced to less than one chance per million, of which about 0.2 million live in disadvantaged communities, and

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[50] The total population within the BAAB modeling domain is 6,968,762. This population is based on 2010 U.S. Census Bureau data.

[51] Population values are rounded to the nearest ten.

[52] Assumed exposure duration of 70 years using the RMP method (95th/80th percentile DBR). FAH equals one for all age bins.

[53] Risk levels are presented in chances per million.

- More than 2.2 million fewer people will be exposed to a cancer risk greater than 10 chances per million, of which about 0.3 million live in disadvantaged communities.

3. Noncancer Chronic Health Impacts

Staff evaluated the noncancer chronic hazard index (HI) of the DPM modeled concentrations in SCAB and BAAB. The HI is a ratio of annual average concentrations of DPM to the chronic inhalation REL. OEHHA has adopted a chronic REL of 5 $\mu g/m^3$. CARB staff used the highest modeled annual average concentration in SCAB and BAAB and determined the HI at those two receptors is 0.23 and 0.06, 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

An 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 toxicities of TACs are 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 TAC,[6] 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 understanding of fluid dynamics, uncertainties are associated with the models.

The U.S. EPA modeling guidance accepts the use of CALPUFF as a dispersion model of emissions involving complex terrain and complex winds as well as for longer modeling distances greater than 50 km.

3. Uncertainty Associated with the Model Inputs

The model inputs include emission rates, spatial and temporal emission allocation, 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. However, it is difficult to quantify the associated uncertainties.

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. Staff estimated CHC emissions based on the best available information regarding past, current, and projected future engine specifications and activities.

The CHC emission source characteristics also have several sources of uncertainty including: stack height, stack temperature, stack exit velocity, and stack orientation. These characteristics vary from vessel to vessel.

IV. Regional PM2.5 Mortality and Illness Analysis for California Air Basins

In this section, CARB staff have quantified a portion of the health benefits (cardiopulmonary mortality, hospitalizations, and emergency room (ER) visits) expected from achieving the emission reductions required by the Proposed Amendments. Emissions from CHC operations in California contribute to high levels of criteria air pollutants and TACs, which lead to adverse health effects including respiratory and cardiac illnesses, hospitalizations, and deaths, as well as lung cancer. Thus, shifting toward cleaner CHC will lead to substantial public health benefits. In addition, this section also discusses the existing scientific literature looking at the health effects from air pollution and specifically from ship and port operations. Altogether, the Proposed Amendments would provide substantial improvements to public health, especially to the communities disproportionately impacted by marine operations.

A. CARB's Estimation of the Health Benefits from the Proposed Amendments

1. Methodology for the Mortality and Illness Analysis

CARB staff evaluated a limited number of statewide noncancer health impacts associated with exposure to PM2.5 and NOx emissions from CHC. NOx includes nitrogen dioxide, a potent lung irritant, which can aggravate lung diseases such as asthma when inhaled.[54] The health impacts from NOx quantifiable by CARB staff occur from the conversion of NOx into fine particles of ammonium nitrate (i.e., secondary PM2.5) through atmospheric chemical processes. PM2.5 formed in this manner is termed secondary PM2.5. Both directly emitted (primary) PM2.5 and secondary PM2.5 from on-road and off-road mobile sources such as CHC are associated with adverse health outcomes, such as cardiopulmonary mortality, hospitalizations for cardiovascular and respiratory illnesses, and emergency room visits for asthma. As a result, reductions in PM2.5 and NOx emissions are associated with improvements in these adverse health outcomes.

CARB staff used two methods to estimate the health benefits of the Proposed Amendments. A description of both methods is located on CARB's webpage.[55] For SCAB and BAAB, the health benefits of primary PM2.5 emission reductions were estimated using air dispersion results of primary PM2.5 concentrations from the HRA (Section III). For all other air basins, where air quality results from air dispersion modeling results were unavailable, CARB staff used the incidence-per-ton (IPT) methodology to quantify the health benefits of primary PM2.5 emission reductions. And for all air basins, the health benefits of reducing NOx emissions leading to secondary PM2.5 formation were estimated using the IPT methodology. Unlike the HRA, the PM mortality and illness analysis presents the statewide health benefits in dollar amounts.

a) Health Outcomes for the South Coast and San Francisco Bay Area Air Basin

The air dispersion analysis performed in the HRA covered large enough domains to represent SCAB and BAAB. The reductions in PM2.5 concentrations estimated by the air dispersion analysis were used to estimate the health benefits for these two air basins. The estimates were calculated using a concentration-response function (CRF). A CRF is an equation that relates concentrations of air pollutants, such as PM2.5, to health outcomes. Besides PM2.5 concentrations, the inputs to the CRF are population data, baseline incidence rates for the health outcome of interest, and a risk coefficient

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[54] U.S. EPA, Integrated Science Assessment for Oxides of Nitrogen – Health Criteria, January 2016, last accessed July 16, 2021, *http://ofmpub.epa.gov/eims/eimscomm.getfile?p_download_id=526855*.

[55] California Air Resources Board, CARB's Methodology for Estimating the Health Effects of Air Pollution, last accessed July 20, 2021, *https://ww2.arb.ca.gov/resources/documents/carbs-methodology-estimating-health-effects-air-pollution*.

derived from studies analyzing the relationship between PM2.5 exposures and the health outcome of interest.

Population data for each year of the analysis are estimated by taking 2010 U.S. Census Bureau data and projecting it to the years in question using county population projections from the California Department of Finance.[56,57] 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. Incidence data were taken from the CDC Wonder database and the U.S. EPA's Environmental Benefits Mapping and Analysis Program (BenMAP).[58,59]

CARB uses a subset of risk coefficients from studies used by the U.S. EPA as described in their 2010 Quantitative Health Risk Assessment for Particulate Matter.[60] CARB uses the cardiopulmonary mortality risk coefficient for the 1999-2000 time period from Krewski et al., 2009; the cardiovascular and respiratory hospitalizations risk coefficients from Bell et al., 2008; and the emergency room visits for asthma risk coefficients from Ito et al., 2007.[61,62,63]

b) 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

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[56] U.S. Census Bureau, American Community Survey 2016 5-Year Estimates, July 6, 2021, last accessed July 20, 2021, *https://data.census.gov/cedsci/table?q=american%20community%20survey%202016&g=0400000US06.140000&tid=ACSST5Y2016.S0101*.

[57] California Department of Finance, Projections P-2B County Population by Age, last accessed April 4, 2018, *https://www.dof.ca.gov/Forecasting/Demographics/Projections/*.

[58] U.S. Centers for Disease Control and Prevention, CDC WONDER, last accessed August 29, 2018, *https://wonder.cdc.gov/*.

[59] U.S. EPA, Benefits Mapping and Analysis Program (BenMAP) Downloads: BenMAP-Community Edition v1.5, last accessed July 20, 2021, *https://www.epa.gov/benmap/benmap-downloads*.

[60] U.S. EPA, Quantitative Health Risk Assessment for Particulate Matter, June 2010, last accessed July 16, 2021, *https://www3.epa.gov/ttn/naaqs/standards/pm/data/PM_RA_FINAL_June_2010.pdf*.

[61] Krewski et al., Extended Follow-Up and Spatial Analysis of the American Cancer Society Study Linking Particulate Air Pollution and Mortality, May 2009, last accessed July 20, 2021, *https://ephtracking.cdc.gov/docs/RR140-Krewski.pdf*.

[62] Bell et al., Seasonal and Regional Short-term Effects of Fine Particles on Hospital Admissions in 202 US Counties 1999-2005, October 14, 2008, last accessed July 20, 2021, *https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2732959/pdf/kwn252.pdf*.

[63] Ito et al., Characterization of PM2.5, gaseous pollutants, and meteorological interactions in the context of time-series health effects models, December 14, 2007, last accessed July 20, 2021, *https://www.nature.com/articles/7500627.pdf*.

is based on a methodology developed by U.S. EPA.[64,65,66] 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 ambient concentrations and dividing by the emissions of PM2.5 or a precursor. The calculation is performed separately for each air basin using the following equation:

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

Multiplying the emission reductions from the Proposed Amendments in an air basin by the IPT factor then yields an estimate of the reduction in health outcomes achieved by the Proposed Amendments. 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 the two types of PM2.5: primary PM2.5 and secondary PM2.5 of ammonium nitrate aerosol formed from precursors.

2. Estimated Health Benefits from the Proposed Amendments

If California moves to cleaner CHC as required under the Proposed Amendments, CARB expects there to be substantial health benefits through the reduction of primary PM2.5 and NOx emissions. Tables G-22 through G-24 show the estimated avoided incidence of mortality and morbidity by California air basin, summed over the 2023-2038 time period. CARB estimates approximately 531 fewer cardiopulmonary deaths, 236 fewer asthma ER visits, and 161 fewer hospitalizations for respiratory and cardiovascular illnesses (Table G-24). The largest estimated health benefits correspond to regions in California with the most CHC activity: SCAB and BAAB.

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[64] Fann, et al., The influence of location, source, and emission type in estimates of the human health benefits of reducing a ton of air pollution, June 9, 2009, last accessed July 20, 2021, *https://link.springer.com/content/pdf/10.1007/s11869-009-0044-0.pdf*.

[65] Fann, et al., Characterizing the PM2.5-related health benefits of emission reductions for 17 industrial, area and mobile emission sectors across the U.S., Environment International 49 (2012):141-151, *https://doi.org/10.1016/j.envint.2012.08.017.*

[66] Fann, et al., Assessing Human Health PM2.5 and Ozone Impacts from U.S. Oil and Natural Gas Sector Emissions in 2025, August 7, 2018, last accessed July 20, 2021, *https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6718951/pdf/nihms-1047155.pdf*.

Table G-22 Proposed Amendments: Estimated Cumulative Reductions in Health Outcomes from Primary PM2.5 Emissions from 2023 to 2038[67]

Air Basin	Cardiopulmonary Mortality	Hospitalizations for Cardiovascular Illness	Hospitalizations for Respiratory Illness	Emergency Room Visits for Asthma
Lake Tahoe	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
North Central Coast	1 (1 - 1)	0 (0 - 0)	0 (0 - 0)	1 (0 - 1)
North Coast	2 (2 - 3)	0 (0 - 0)	0 (0 - 0)	1 (0 - 1)
Sacramento Valley	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
San Diego County	16 (13 - 20)	2 (0 - 4)	3 (1 - 5)	7 (4 - 9)
San Francisco Bay	79 (62 - 97)	9 (0 - 17)	10 (2 - 18)	30 (19 - 40)
San Joaquin Valley	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
South Central Coast	8 (6 - 10)	1 (0 - 2)	1 (0 - 2)	3 (2 - 5)
South Coast	126 (98 - 155)	14 (0 - 28)	17 (4 - 30)	41 (26 - 57)
STATEWIDE	233 (182 - 286)	27 (0 - 52)	32 (7 - 56)	82 (52 - 113)

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[67] The values in parentheses represent the 95 percent confidence intervals of the central estimate. Totals may not add due to rounding. Air basins with zero impacts are not shown, and these are: Great Basin Valleys, Lake County, Mojave Desert, Mountain Counties, Northeast Plateau, and Salton Sea.

Table G-23 Proposed Amendments: Estimated Cumulative Reductions in Health Outcomes from NOx Emissions from 2023 to 2038[68]

Air Basin	Cardiopulmonary Mortality	Hospitalizations for Cardiovascular Illness	Hospitalizations for Respiratory Illness	Emergency Room Visits for Asthma
Lake Tahoe	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
North Central Coast	1 (1 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 1)
North Coast	1 (1 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
Sacramento Valley	0 (0 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
San Diego County	19 (15 - 23)	3 (0 - 5)	3 (1 - 5)	8 (5 - 11)
San Francisco Bay	88 (69 - 108)	13 (0 - 26)	16 (4 - 28)	49 (31 - 67)
San Joaquin Valley	1 (1 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
South Central Coast	20 (16 - 24)	3 (0 - 6)	4 (1 - 6)	9 (6 - 12)
South Coast	169 (132 - 206)	27 (0 - 54)	33 (8 - 58)	87 (55 - 119)
STATEWIDE	298 (233 - 365)	47 (0 - 92)	56 (13 - 98)	154 (97 - 210)

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[68] The values in parentheses represent the 95 percent confidence intervals of the central estimate. Totals may not add due to rounding. Air basins with zero impacts are not shown, and these are: Great Basin Valleys, Lake County, Mojave Desert, Mountain Counties, Northeast Plateau, and Salton Sea.

Table G-24 Proposed Amendments: Estimated Total Cumulative Reductions (from Primary PM2.5 and NOx Emissions) in Health Outcomes from 2023 to 2038[69]

Air Basin	Cardiopulmonary Mortality	Hospitalizations for Cardiovascular Illness	Hospitalizations for Respiratory Illness	Emergency Room Visits for Asthma
Lake Tahoe	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
North Central Coast	2 (1 - 2)	0 (0 - 1)	0 (0 - 1)	1 (1 - 2)
North Coast	3 (2 - 3)	0 (0 - 1)	0 (0 - 1)	1 (1 - 1)
Sacramento Valley	1 (1 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
San Diego County	35 (28 - 43)	5 (0 - 9)	6 (1 - 10)	15 (9 - 20)
San Francisco Bay	167 (130 - 205)	22 (0 - 43)	26 (6 - 47)	78 (50 - 107)
San Joaquin Valley	1 (1 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
South Central Coast	28 (22 - 34)	4 (0 - 8)	5 (1 - 8)	12 (8 - 17)
South Coast	295 (230 - 360)	42 (0 - 82)	50 (12 - 88)	128 (81 - 176)
STATEWIDE	531 (415 - 651)	73 (0 - 144)	88 (21 - 155)	236 (149 - 323)

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[69] The values in parentheses represent the 95 percent confidence intervals of the central estimate. Totals may not add due to rounding. Air basins with zero impacts are not shown, and these are: Great Basin Valleys, Lake County, Mojave Desert, Mountain Counties, Northeast Plateau, and Salton Sea.

3. Monetization of Health Outcomes

CARB staff monetized the health outcomes by multiplying incidence by a standard value derived from economic studies.[70] This valuation per incident is provided in Table G-25. The valuation for avoided premature mortality is based on willingness to pay.[71] 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,[72] 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).[73]

Table G-25 Valuation per Incident Avoided Health Outcomes ($2019)

Avoided Health Outcome	Valuation Per Incident
Deaths	$9,864,695
Hospital Admissions for Cardiovascular Illness	$58,288
Hospital Admissions for Respiratory Illness	$50,841
Emergency Room Visits	$834

Statewide valuation of health benefits were calculated by multiplying the avoided health outcomes by valuation per incident. The total statewide valuation due to avoided health outcomes between 2023 and 2038 totaled $5.25 billion. These values are summarized in Table G-26. The spatial distribution of these benefits follows the distribution of emission reductions and avoided adverse health outcomes; therefore,

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[70] U.S. EPA, Appendix B: Mortality Risk Valuation Estimates, Guidelines for Preparing Economic Analyses, December 2010, last accessed July 6, 2021, *https://www.epa.gov/sites/production/files/2017-09/documents/ee-0568-22.pdf*.

[71] U.S. EPA Science Advisory Board, An SAB Report on EPA's White Paper Valuing the Benefits of Fatal Cancer Risk Reduction, July 27, 2000, last accessed July 21, 2021, *https://yosemite.epa.gov/sab%5CSABPRODUCT.NSF/41334524148BCCD6852571A700516498/$File/eeacf013.pdf*.

[72] U.S. EPA, Mortality Risk Valuation – What does it mean to place a value on life?, last accessed June 4, 2021, *https://www.epa.gov/environmental-economics/mortality-risk-valuation#means*.

[73] Thayer et al., The Economic Value of Respiratory and Cardiovascular Hospitalizations, May 31, 2003, last accessed July 21, 2021, *https://ww2.arb.ca.gov/sites/default/files/classic//research/apr/past/99-329.pdf*.

most cost savings associated with avoided health outcomes for individuals would occur in SCAB and BAAB.

Table G-26 Statewide Valuation from Avoided Adverse Health Outcomes Between 2023 and 2038 for the Proposed Amendments

Avoided Health Outcome	Statewide Valuation
Avoided Premature Deaths	$5,242,800,000
Avoided Hospitalizations	$8,700,000
Avoided Emergency Room Visits	$197,000
Total Valuation	$5,251,697,000 ($5.25 billion)

4. Uncertainties Associated with the Mortality and Illness Analysis

Although the estimated health outcomes presented in this report are based on a well-established methodology, they are subject to uncertainty. Uncertainty is reflected in the 95 percent confidence intervals included with the central estimates in Tables G-22 through G-24. These confidence intervals take into account uncertainties in translating air quality changes into health outcomes. Other sources of uncertainty include the following:

- The relationship between changes in pollutant concentrations and changes in pollutant or precursor emissions is assumed to be proportional, although this is an approximation.
- Air quality data is subject to natural variability from meteorological conditions, local activity, etc.
- Emissions are reported at an air basin resolution, and do not capture local variations.
- Future population estimates are subject to uncertainty. The further into the future they are projected, the more uncertain they become.
- Baseline incidence rates can experience year-to-year variation.

5. Potential Future Evaluation of Additional Health Benefits

While CARB’s PM2.5 mortality and illness valuation has been, and continues to be, a useful method for valuing the health benefits of regulations, it only represents a portion of those benefits. The full health benefits of the Proposed Amendments are underestimated because not all the adverse health outcomes from PM2.5 and additional pollutants (e.g., TACs) are evaluated and monetized. Also, CARB’s current evaluation methodology does not take into account all PM2.5 precursor emissions. An expansion of the emissions inputs and an assessment for other health outcomes, including, but not limited to, additional cardiovascular and respiratory illnesses, nonfatal/fatal cancers, nervous system diseases, and lost workdays would provide a more complete picture of the benefits from reduced exposure to air pollution. In fact, in 2021, EPA issued a Technical Support Document (TSD) for their Cross-State Air Pollution Rule that provided both health functions and health valuation for lung cancer incidence, Alzheimer's disease, and Parkinson's disease, among other health endpoints related to PM2.5 exposures.[74]

While CARB's mortality and illness valuation is just for PM2.5, there are other pollutants that can cause health issues. For instance, NOx reacts with other compounds to form ozone, which can then cause respiratory problems. Updated health impact functions and valuation for ozone are also provided in the aforementioned Cross-State Air Pollution Rule TSD provided by the U.S. EPA.[74] Additionally, TACs emitted from diesel engines can lead to cancers. As described in Section III, CARB staff has conducted an assessment of the cancer risk from DPM, a TAC, from specific California ports, although this is not quantified as a monetized impact.

Expanding CARB's health evaluation and valuation methodology to include any of the above additional strategies would allow the public to reach a better understanding of the benefits from reducing air pollution by moving toward cleaner combustion and zero-emission technologies. Importantly, this understanding is valuable to the successful implementation of various emission reduction strategies, including moving toward cleaner CHC to protect public health.

The scientific literature has demonstrated the broad impacts of exposures to pollution and specifically living near marine vessel and port/harbor activity, which include but go beyond the outcomes CARB staff has quantified in Tables G-22 through G-24 and are thus summarized in the next section.

B. Diesel Pollution Impacts Human Health

Diesel-powered mobile sources, including CHC, emit a complex mixture of air pollutants, including DPM and gases. The gaseous pollutants include volatile organic compounds (VOCs) and NOx, which can lead to the formation of ozone (O3) and the secondary formation of particulate matter (PM).[75]

1. Air Toxic Impacts

DPM is a TAC composed of over 40 known cancer-causing substances and PM.[75] Examples of these carcinogenic chemicals include polycyclic aromatic hydrocarbons (PAHs), benzene, formaldehyde, acetaldehyde, acrolein, and 1,3-butadiene.[75] CARB

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[74] U.S. EPA, Technical Support Document (TSD) for the Final Revised Cross-State Air Pollution Rule Update for the 2008 Ozone Season NAAQS: Estimating PM2.5- and Ozone-Attributable Health Benefits, March 2021, last accessed July 21, 2021, *https://www.epa.gov/sites/default/files/2021-03/documents/estimating_pm2.5-_and_ozone-attributable_health_benefits_tsd_march_2021.pdf*.

[75] California Air Resources Board, Overview: Diesel Exhaust & Health, last accessed July 21, 2021, *https://ww2.arb.ca.gov/resources/overview-diesel-exhaust-and-health*.

listed DPM as a TAC in 1998, due largely to its association with lung cancer.[75] Since CARB's listing, additional studies on the cancer-causing potential of diesel exhaust were published, which led the International Agency for Research on Cancer (IARC, a division of the World Health Organization) to classify diesel engine exhaust as "carcinogenic to humans" in 2012.[75,76] In California, about 70 percent of known cancer risks from TACs are from diesel engine emissions.[75,77]

2. Particle Pollution Impact

The majority of DPM particles are PM2.5.[78,79] Due to their small size, PM2.5 in air can reach the lower respiratory tract and potentially pass into the bloodstream to affect other organs.[78,80] By this means, PM2.5 air pollution leads not only to increased cancer risk, but it also causes respiratory and cardiovascular diseases and even premature death; adverse health outcomes from PM2.5 include asthma, chronic heart disease, and heart attack.[78,80,81,82] Moreover, PM2.5 air pollution can result in respiratory, cardiac, and mortality effects over short time periods of exposure such as hours, days, or weeks.[82] Exposures to PM2.5 may also lead to myriad other health outcomes, including metabolic, nervous system, reproductive, and developmental effects.[82] For example, adverse health conditions with possible links to airborne PM2.5 include high blood pressure, insulin resistance, and other risk factors for Type II Diabetes, as well as psychological/cognitive problems.[82] PM2.5 may especially impact women and children via health effects such as pre-term birth, reduced birth weight, and abnormal lung and cardiovascular development.[82]

In addition to its ability to increase risk for diseases, PM2.5 is also well known to exacerbate underlying illnesses such as asthma, bronchitis, and heart disease.[82] As a result, the health impacts of PM2.5 are typically studied not only using cancer diagnoses and the rates of onset for lung and cardiovascular diseases, but also via metrics on respiratory symptoms (e.g., cough, wheeze, asthma medication usage), measures of abnormal lung and heart functioning (e.g., reduced lung volume, irregular

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[76] International Agency for Research on Cancer, Press Release N° 213, IARC: Diesel Engine Exhaust Carcinogenic, June 12, 2012, last accessed July 21, 2021, *https://www.iarc.who.int/wp-content/uploads/2018/07/pr213_E.pdf.*

[77] Propper, et al., Ambient and Emission Trends of Toxic Air Contaminants in California, September 4, 2015, last accessed July 21, 2021, *https://pubs.acs.org/doi/pdf/10.1021/acs.est.5b02766*.

[78] California Air Resources Board, Inhalable Particulate Matter and Health (PM2.5 and PM10), last accessed July 21, 2021, *https://ww2.arb.ca.gov/resources/inhalable-particulate-matter-and-health*.

[79] U.S. EPA, Particulate Matter (PM) Basics, last accessed July 21, 2021, *https://www.epa.gov/pm-pollution/particulate-matter-pm-basics*.

[80] U.S. EPA, Health and Environmental Effects of Particulate Matter (PM), last accessed July 21, 2021, *https://www.epa.gov/pm-pollution/health-and-environmental-effects-particulate-matter-pm*.

[81] World Health Organization, Review of evidence on health aspects of air pollution - REVIHAAP Project: Technical Report, 2013, last accessed July 21, 2021, *https://www.euro.who.int/__data/assets/pdf_file/0004/193108/REVIHAAP-Final-technical-report-final-version.pdf*.

[82] U.S. EPA, Integrated Science Assessment (ISA) for Particulate Matter, December 2019, last accessed July 21, 2021, *https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=347534*.

heartbeat), plus rates of hospitalizations, ER visits, and restricted activity days associated with worsening of chronic lung and heart diseases.

3. Ozone Pollution Impacts

As a gaseous pollutant from diesel-powered CHCs, NOx can react with other compounds to form ozone, which is the main component of smog. Based on the extent of evidence from scientific studies, U.S. EPA has determined that short-term exposure from ozone is causally linked to adverse respiratory effects.[83] Ozone can cause irritation and damage lung tissue, worsen asthma and chronic illnesses including chronic obstructive pulmonary disease (COPD) and reduced lung function. For instance, a study conducted in the San Joaquin Valley showed that increased ozone pollution led to increased risk for asthma ER visits, especially for children and Black residents.[84] Metabolic functions are also likely to be affected by short-term ozone pollution, such as those leading to increased risk for complications and hospitalizations in diabetic individuals.[83] And, similar to PM2.5, other potential health effects from ozone exposure include impacts on the cardiovascular, nervous, and reproductive systems, and even increased risk of mortality.[83]

C. Marine Operations Impact Vulnerable Populations and Health Disparities

In addition to the multitude of studies showing the impacts of DPM, PM2.5, and ozone air pollution, there are also several studies that have specifically looked at the effects of marine air pollution sources. For example, one study looking at marine pollution across the U.S. showed that the marine vessels with Category 1 and 2 engines (which categorizes most CHC) sources have greater air pollution impacts on states in the western U.S. including California.[85] In addition, another study showed that health impacts from marine vessels powered by Category 1 and 2 engines are not expected to decrease as much as other mobile sectors with existing regulations and programs.[86] While more research would improve our understanding, the current available research underscores the potential health effects resulting from marine operations, especially in vulnerable communities, thereby demonstrating the need for the Proposed Amendments. Communities adjacent to ports and harbors are exposed to high levels

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[83] U.S. EPA. Integrated Science Assessment (ISA) for Ozone and Related Photochemical Oxidants, April 2020, last accessed July 21, 2021, *http://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=348522*.

[84] Gharibi, et al., Ozone pollution and asthma emergency department visits in the Central Valley, California, USA, during June to September of 2015: a time-stratified case-crossover analysis, Journal of Asthma 56, 10 (2019):1037-1048, doi: 10.1080/02770903.2018.1523930.

[85] Wolfe, et al., Monetized health benefits attributable to mobile source emission reductions across the United States in 2025, September 21, 2018, last accessed July 21, 2021, *https://www.sciencedirect.com/science/article/pii/S0048969718337239?via%3Dihub*.

[86] Davidson et al., The recent and future health burden of the U.S. mobile sector apportioned by source, July 6, 2020, last accessed July 22, 2021, *https://iopscience.iop.org/article/10.1088/1748-9326/ab83a8/pdf*.

of air pollution, including ozone, PM, and DPM especially from mobile sources such as vehicles and ships.[86,87,88,89,90]

Children living in these communities are particularly vulnerable to pollution impacts from marine sources. One study showed that ship emissions alone within California's Los Angeles-Long Beach port complex were estimated to account for substantial numbers of respiratory health problems among children living nearby.[89] For example, among children with asthma, 21 percent of bronchitis episodes in Long Beach can be attributed solely to air pollution from marine vessels.[89] Meteorological patterns can even carry marine vessel pollution many miles to inland communities, such that even 8 percent of bronchitis episodes among asthmatic children in Riverside could be attributed to ship emissions.[89] Similarly, in Long Beach, ship emissions account for 1 percent of all emergency room usage, clinic visits, and hospital admissions for asthma among children.[89] These estimates demonstrate that emissions from ships can be an important contributor to air pollution impacts on health especially among children.

Additionally, marine emissions may have large impacts on exposure inequality. Recent research demonstrates that marine pollution exposures disproportionately impact people of color in California, especially the Asian and Black populations.[2] Marine pollution exposures experienced by Asian and Black residents were estimated to be 32 and 27 percent higher, respectively, compared to the average exposures attributed to marine emissions in the State.[2] Similarly, a separate nationwide study found that both Hispanic and non-Hispanic Black populations, as well as low-income households, bear a greater burden of air pollution exposures from living in harbor areas.[90] For example, low-income households can be as much as five times more likely to live within U.S. harbor areas in which there are substantially greater risks for cancer from air pollution.[90]

Many of the public and private port and terminal facilities in California are located next to and near disadvantaged communities which experience inequities in air pollution exposures and health impacts. In California, pursuant to State Bill (SB) 535, CalEPA has defined DACs as communities that rank within the top 25 percent scoring communities in CalEnviroScreen.[1] There are 21 CalEnviroScreen indicators used in scoring each community including socioeconomic factor indicators, sensitive population indicators,

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[87] California Air Resources Board, Diesel Particulate Matter Exposure Assessment Study for the Ports of Los Angeles and Long Beach, 2006, last accessed July 22, 2021, *https://ww2.arb.ca.gov/sites/default/files/classic/regact/marine2005/portstudy0406.pdf*.

[88] Marshall et al., Prioritizing Environmental Justice and Equality: Diesel Emissions in Southern California, *Environmental Science & Technology* 48, 7 (2014): 4063-4068, doi: 10.1021/es405167f.

[89] Perez et al., Global Goods Movement and the Local Burden of Childhood Asthma in Southern California, November 2009, last accessed July 22, 2021, *https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2774197/pdf/S622.pdf*.

[90] Rosenbaum et al., Analysis of diesel particulate matter health risk disparities in selected US harbor areas, December 2011, last accessed July 22, 2021, *https://ajph.aphapublications.org/doi/pdf/10.2105/AJPH.2011.300190*.

environmental effect indicators, and exposure indicators. Research showed that DACs are exposed to seven percent higher air pollution from marine sources than the state average.[2] This comparison was based on the average exposure for the population living in all DACs in CA, regardless of their proximity to marine emissions. Therefore, it is expected that some of the DACs surrounding ports and harbors might be impacted even more due to their close proximity to marine emissions. For example, a modeling simulation for SCAB showed that the highest concentrations of diesel PM occurred around the Ports of Los Angeles and Long Beach.[3] Meanwhile, the neighboring communities surrounding the ports also had the highest cancer risks from air pollution in this basin.[3] CARB's own modeling, conducted is support of this regulation, shows the same pattern of concentrations.

D. Additional Potential Toxics Valuation Metrics for Future Regulations

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*[91] (methylene chloride rulemaking) introduced methods 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.

The methylene chloride rulemaking sets a precedent for considering other health benefits and for using a variety of valuation methods, including 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 these metrics, along with the current PM mortality and illness analysis, would allow CARB to perform more comprehensive cost-benefit analyses for future regulations.

E. Conclusion

CHC operations result in emissions of gaseous and particulate criteria pollutants and TACs that are known to cause serious health impacts. As shown in Tables G-22 through G-24, CARB's estimation of possible health benefits finds that shifting to lower-emitting CHCs would result in substantial health and economic benefits to areas around the State, due to reduced cardiovascular/respiratory hospitalizations, asthma ER visits, and cardiopulmonary mortality. In addition, studies conducted in port communities underscore the serious health effects from living near these pollution sources. Residents living in communities that are more heavily impacted by pollution

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[91] U.S. EPA, Final Rule – Economic Analysis of Regulation of Methylene Chloride, Paint and Coating Remover under TSCA Section 6(a), March 11, 2019, last accessed July 22, 2021, *https://www.regulations.gov/document/EPA-HQ-OPPT-2016-0231-0990*.

exposures such as ports experience increased vulnerability to adverse health effects from a combination of factors, including proximity to pollution sources and other health and socioeconomic conditions. For these residents, actions to transition to cleaner combustion and zero-emission and advanced technologies are critically important.