PORT OF OAKLAND
2012 SEAPORT AIR EMISSIONS INVENTORY

PORT OF OAKLAND

Prepared by:
ENVIRON International Corporation
Novato, California
November 5, 2013

ENVIRON

Message from the Port of Oakland

Meeting our Commitment to Clean Air and Reporting Back to the Community:

The Port of Oakland is pleased to present the *2012 Seaport Air Emissions Inventory*. We suggest that you give close attention to Chapter 8, *Comparison of 2005 and 2012 Emissions Inventories*, which highlights the emissions reductions from key seaport sources since 2005.

In March 2008, the Port of Oakland committed to achieving an 85% reduction in seaport-related diesel health risk by 2020 from a 2005 baseline. The following year in April 2009, the Port approved its Maritime Air Quality Improvement Plan (MAQIP), developed by a diverse task force of Port business partners, community stakeholders, and partnering agencies, to provide the roadmap to achieve its goal. We also agreed to report back to the community on our progress. At the 2012 midpoint of our goal timeline, we have already achieved a 70% reduction in diesel particulate matter emissions, even though we're handling 3% more cargo today than in 2005.

A key tool we use to track implementation of the MAQIP is the seaport emissions inventory. As a baseline, the Port prepared a comprehensive inventory of pollutant emissions from Port-related ships, harbor craft, cargo handling equipment, trucks, and locomotives in 2005. As new emissions control technologies are introduced in response to regulations and other initiatives undertaken by the Port, our business partners, or other groups, we can track the resulting emissions reductions with respect to the MAQIP goals through quantitative updates to the baseline emissions inventory.

Based on our 2012 inventory results, we have made significant strides toward our 2020 goal. This success is thanks to our MAQIP and the many partners who have helped along the way. The Port looks forward to continue working with its partners to further reduce emissions and meet its 2020 clean air commitment.

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GLOSSARY

Adjustment factors: Used to adjust emissions or engine load or other situations for non-standard conditions.

Assist mode: Period when a tugboat is engaged in assisting a ship to/from the harbor and to/from its berth.

Auxiliary engine: Used to drive on-board electrical generators to provide electric power or to operate equipment on board the vessel.

Auxiliary power: Typically electric power generated via the auxiliary engine.

Barge: A flat-bottomed craft built mainly for water transport of heavy goods and, in this report, dredge spoils. Most barges are not self-propelled and need to be moved by tugboats towing or towboats pushing them.

Bollard pull class: A power measure of the tug's capacity to push or pull ships.

Brake-specific fuel consumption (BSFC): This is the measure of the engines efficiency in terms of the fuel consumption rate (weight of fuel burned per hour) divided by the engine load or output (e.g. kilowatts). For marine engines a different term, standard fuel oil consumption (SFOC), is sometimes used to describe the identical efficiency measure.

Cargo handling equipment: Equipment used to transfer cargo or containers. Cargo handling equipment is used to move containers from one mode of transportation to another, or from a storage area to a truck chassis, for example. Typical cargo handling equipment at the Port of Oakland include yard trucks, RTG cranes, top and side picks, forklifts, and other general industrial equipment.

Clamshell dredge: Hangs from an onboard crane, or is carried by a hydraulic arm, or is mounted like on a dragline and grabs dredge material.

CO: carbon monoxide.

Cutter head dredge: Also known as a suction dredge, this dredge uses a suction tube with a cutter head at the suction inlet, to loosen the earth and transport it to the suction mouth. The cutter can also be used for hard surface materials like gravel or rock. The dredged soil is usually sucked up by a wear resistant centrifugal pump and discharged through a pipe line or to a barge. From Wikipedia.

Cruise modes: The vessel mode while traveling in the open ocean or in an area without speed restrictions.

Dead weight tonnage (DWT): Dead Weight Tonnage (DWT) is the weight of the ship, all her stores and fuel, pumps and boilers, crews quarters with crew and the cargo. In other words, how much water the vessel displaces when loaded.

Deep draft marine vessel: Deep draft vessels are larger vessels typically with draft in excess of 14 feet measured at the highest waterline and the bottom of the vessel. Other works describe this type of vessel as only Ocean-Going Vessels (OGV), but deep draft is used in this report to distinguish and avoid confusion between these larger vessels and smaller ocean-going tugs, supply vessels, and fishing vessels that could also be considered "ocean-going vessels".

DPM: Diesel particulate matter

Dredging: An excavation activity or operation carried out underwater typically for the purpose of the removal of materials from the bottom of channels and berths to allow vessels with deep drafts.

Emission estimation: Method by which the quantity of a particular pollutant emission is estimated.

Emission factor: The average emission rate of a given pollutant for a given source, relative to a unit of activity. For example, grams per kilowatt of actual power or grams per hour of engine operation.

Emissions inventory: A listing of all the pollutant emissions included in the study.

g/kW-hr: This is the unit for reporting emission or fuel consumption factors, and means the grams per kilowatt-hour of work performed. Work and energy are used synonymously in this context.

HC: hydrocarbon emissions

Hotelling: On-board activities while a ship is in port and at its berth or anchored nearby.

Hydrolyze: To add water to a chemical compound.

Hydrated sulfuric acid: sulfuric acid to which water had been added.

Installed power: The engine power available on the vessel. The term most often refers only to the propulsion power available on the vessel, but could incorporate auxiliary engine power as well.

Intermodal site: Location where cargo is transferred from one form of transportation to another, for example between an ocean-going vessel and a railroad car.

Knot: A nautical unit of speed meaning one nautical mile per hour and is equal to about 1.15 statute miles per hour.

Lift: Lifting a container (box) onto a vessel, truck, or rail car.

Link: A defined portion of a vessel's, train's, or truck's travel. For example a link was established extending from the November Buoy out in the ocean to the location where the pilot boards the vessel. A series of links defines all of the movements within a defined area or a trip.

Load: The actual power output of the vessel's engines or generator. The load is typically the rated maximum power of the engine multiplied by the load factor if not measured directly.

Load factor: Average engine load expressed as a fraction or percentage of rated power.

Maximum power: A power rating usually provided by the engine manufacturer that states the maximum continuous power available for an engine.

Medium speed engine: A 4-stroke engine used for auxiliary power and rarely, for propulsion. Medium speed engines typically have rated speeds of greater than 250 revolutions per minute.

Mode: Defines a specific set of activities, for example, a tug's transit mode includes travel time to/from a port berth while escorting a vessel.

NO_x: nitrogen oxides. Includes all different nitrogen oxide compounds.

Ocean-going vessels (OGV): Vessels equipped for travel across the open oceans. These do not include the vessels used exclusively in the harbor, which are covered in this report under commercial harbor craft. And in this report OGV are restricted to the deep draft vessels that carry containers.

Off-Road activity: Activity that occurs off of established roadways. Activity within a marine terminal yard is considered off-road activity.

On-road activity: Activity that occurs on established roadways.

Operation mode: the current mode of operation for a ship – cruise, RSV, maneuver, or berth.

Pilot Buoy: used to mark a maritime administrative area to allow boats and ships to navigate safely.

PM_{10}: particulate matter emissions less than 10 micrometers in diameter.

$PM_{2.5}$: particulate matter emissions less than 2.5 micrometers in diameter

Port of Call (POC): A specified port where a ship docks.

Port berth: A location in a port or harbor used specifically for mooring vessels.

Propulsion engine: Shipboard engine used to propel the ship.

Propulsion power demand: Power used to drive the propeller and the ship.

Rated power: A guideline set by the manufacturer as a maximum power that the engine can produce continuously.

Reefer plug: Plug allowing a refrigerator container to plug into an outlet connected to the ship's power generation.

ROG: reactive organic gas; all hydrocarbon compounds that can assist in producing ozone (smog). Includes HC plus aldehyde and alcohol compounds minus methane.

Roll on/roll off vessels: Ships designed to carry wheeled cargo such as automobiles, trailers, or railway carriages that drive or are pulled onto the vessels.

RSZ: Reduced speed zone.

RTG Crane: Rubber tired gantry (RTG) crane is sometimes but rarely called a straddle crane because the crane ‘straddles’ a row of containers stored in the terminal yard as it drives up and down the row.

Shoaling: Shoaling is term used in this report to describe subsidence of the shore or other filling of the navigation channel near shore.

SO_2: Sulfur dioxide.

SO_x: Oxides of sulfur. Interchangeable term with sulfur dioxide but include some other minor forms of sulfur oxides.

Spatial allocation: Areas on a map allocating a specific set of activities.

Spatial scope: A specified area on a map that defines the area covered in study.

Slow speed engine: Typically a 2-stroke engine or an engine that run below 250 rpm’s.

Standard fuel oil consumption (SFOC): See brake specific fuel consumption (BSFC).

Steam boiler: Boiler used to create steam or hot water using external combustion.

Steam turbines: A mechanical device that extracts thermal energy from pressurized steam, and converts it into useful mechanical work.

Tender: a utility vessel used to service another type of vessel, for example, servicing a clamshell dredge.

TEU: Twenty foot equivalent unit.

Time in mode: The amount of time a vessel remains in a specified mode, for example the amount of time a ship spends in the reduced speed zone.

Tons: Represents short tons (2,000 lbs) unless otherwise noted.

Tonnes: Metric tons (1,000 kg)

Transit mode: The time a tug spends traveling to/from its berth to the pick-up location.

Tug class: A tugboat's Bollard pull class designation.

Two-stroke engine: Engine designed so that it completes the four processes of internal combustion (intake, compression, power, exhaust) in only two strokes of the piston.

EXECUTIVE SUMMARY

The Port of Oakland oversees the Oakland seaport and Oakland International Airport. The Port's jurisdiction includes 20 miles of waterfront from the Bay Bridge through Oakland International Airport. The Oakland seaport is the fifth busiest container port in the U.S.; Oakland International Airport is the second largest San Francisco Bay Area airport offering over 300 daily passenger and cargo flights; and the Port's real estate includes commercial developments such as Jack London Square and hundreds of acres of public parks and conservation areas. The Port of Oakland was established in 1927 and is an independent department of the City of Oakland.

The Port of Oakland (Port) 2012 Seaport Air Emissions Inventory (Emissions Inventory) identifies and quantifies air emissions from the Port's maritime activities, organized by the major source categories:

- Deep-Draft Ocean-Going Vessels (OGV)
- Commercial Harbor Craft (dredging and assist tugs)
- Cargo Handling Equipment (CHE)
- Trucks (container movements)
- Locomotives
- Other Offroad Equipment

The Port of Oakland voluntarily chose to prepare an air emissions inventory for its seaport operations for calendar year 2005 and decided to periodically update the Port's activity and emission estimates in the coming years. The Port's 2005 emissions inventory was completed in 2008 (ENVIRON, 2008) and is available on the Port's website (http://www.portofoakland.com/environm/publicat.asp). This calendar year 2012 emissions inventory highlights the Port's commitment to continue to improve understanding of the nature, location and magnitude of emissions from its maritime-related operations. The Port is committed to conducting its operations in the most sustainable and environmentally sensitive manner possible.

The purpose of this inventory is to better understand the emissions from typical Port activities so the Port can better address its impact on air quality. The inventory:

- Updates changes in Port activity and emissions for the 2012 calendar year.
- Continues to evaluate air pollution control regulations as they are phased in.
- Informs local, state and federal regulatory decision-makers in their effort to reduce air emissions from Port-related sources and improve air quality.
- Provides air quality background information to be used in future environmental documents.
- Provides a technical basis for setting priorities and evaluating the cost-effectiveness and potential benefits of air pollutant control measures as the Port evaluates the progress of its Maritime Air Quality Improvement Plan for the seaport.

An emissions inventory is best understood as an estimate of the quantity of pollutants that a group of sources produce in a given area, over a prescribed period of time. Emissions inventories should be used with care and in conjunction with other information and tools to evaluate and assess air quality problems.

The inventory provides estimates for emissions of five “criteria” air pollutants, reported as tons per year. The pollutants are:

- Reactive organic gases (ROG)
- Carbon monoxide (CO)
- Nitrogen oxides (NOx)
- Particulate matter (including diesel) (PM)
- Sulfur oxides (SOx)

Particulate matter emissions estimated in this report are primarily diesel particulate matter (DPM). DPM has been designated a toxic air contaminant by the California Air Resources Board (ARB). A fraction of particulate matter emissions come from boilers and LPG-powered engines, and thus are not classified as DPM. Total particulate is divided into two size ranges: PM_{10} (particles with aerodynamic diameter 10 microns or less) and $PM_{2.5}$ (particles with aerodynamic diameter 2.5 microns or less).

In addition, three greenhouse gas (GHG) components (carbon dioxide [CO_2], methane [CH_4], and nitrous oxide [N_2O]) were estimated. These components were combined in a CO_2 equivalent (CO_2e) estimate using the relative global warming potential of each component.

Introduction, Scope and Coordination

This is an inventory of the air emissions generated by maritime activities conducted by the Port of Oakland tenants and by Port construction activity in the seaport. On the water side, the spatial domain of the inventory includes Port-related marine vessel transit from dockside out through the Golden Gate Bridge, to the first outer buoys beyond the Pilot Buoy, approximately 30 miles away from the Port. On the landside, the spatial scope of the inventory includes seven marine terminals, one rail yard, and the road traffic between those facilities and the nearest freeway interchanges. The Port area was defined approximately by the boundaries of I-80, I-880, and Howard Terminal (Berths 67 and 68) adjacent to Jack London Square. Within this defined geographic domain, three areas were specifically excluded: the privately-owned Schnitzer Steel terminal and Union Pacific rail yard, and the former Oakland Army Base located between Maritime Street and I-880, where redevelopment didn’t begin until 2013. These areas were not controlled or operated by the Port of Oakland in 2005, and were therefore not included in the emissions inventory for that year. As this 2012 inventory update is used to examine the trends of air pollutant emissions over time, the same domain and area exclusions were maintained to allow a clear understanding of the changes in emissions over time. Nevertheless, new estimation methods or other factors may affect the inventory in some cases.

We have noted such changes where appropriate throughout this report. Figures 1-1, 2-1 and 2-2 in the body of the report illustrate the spatial scope of the inventory.

With the exception of possible roll-on and roll-off activity, the Port of Oakland operated exclusively as a container port in 2012. All but two of the 1,812 calls were by deep-draft vessels designed as container ships, and one of those was converted to transport containers. On the land side, Port terminals operated as a collection of intermodal sites where cargo handling equipment transferred containers to and from vessels to truck or rail transportation.

ENVIRON International prepared the first ever 2005 seaport emissions inventory, and this 2012 emissions inventory update for the Port. ENVIRON assembled the emissions inventory by analyzing the time-in-mode, load or speed, and engine characteristics of the marine vessels and other equipment used to transport container cargo. The time-in-mode characteristic allowed for the emissions inventory to be defined by location. Input data from previous studies and literature reviews or ARB input data or models were used when more precise estimates of emission factors or load factor could not be generated.

Technical Approach to Major Source Categories

Emissions were estimated for the five source categories as described below; a summary of the emission results are presented in Table ES-1.

Ocean-going Marine Vessels. Ocean-going vessel emissions were estimated in each operating mode: cruising in the open ocean, cruising in the reduced speed zone (RSZ) inside the Bay, maneuvering (low speed operation between the Bay Bridge and Port berths in the Inner or Outer Harbors), and hotelling (vessels at berth being loaded and offloaded and at anchor in the Bay). Separate mode estimates are important for distinguishing the location of emissions, especially the proximity to on-shore areas like West Oakland. Emissions sources included the vessels' main propulsion engines, auxiliary engines, and small auxiliary boilers. Except for the boilers, all emission sources in ocean-going vessels are diesel engines.

Harbor Craft. Smaller marine vessels are included in a category described as "Commercial Harbor Craft". Vessels in this category are associated with Port maritime operations and consist primarily of assist tugs and a few small boats that support maintenance dredging. On average almost two tugs assist vessels during the maneuvering mode as they enter and leave the Port. While eight tug companies provide assist services, one is a subsidiary of another and one pair of firms has a joint operating agreement, while the three other companies comprised only 0.6% of the activity. Information from several data sources was used to characterize the three primary tug fleets and installed equipment. The inventory includes tug emissions estimates in two operating modes: 1) vessel assist and, 2) transit to and from the tug's home location and the vessel assist point located near the port. Emissions sources include tug main propulsion and auxiliary diesel engines.

The inventory also addresses emissions from operation and maintenance dredging, which occurs annually to maintain safe depths in Federal channels and at Port berths. Reported maintenance dredging activity was much higher in 2012 compared to 2005 since some maintenance dredging material was incorporated in the channel and berth deepening project in 2005. Emissions were estimated from dredges, dredge tenders, survey boats, and tugs that push barges containing dredged material to disposal or reuse areas. Dredging equipment is typically powered by diesel engines, though in 2005 some maintenance dredged material was removed by an electric-powered dredge as part of the deepening project.

Cargo Handling Equipment. ENVIRON collected specific activity information for cargo handling equipment used in the Port of Oakland in 2012 to move containers within maritime and rail yards. ENVIRON determined annual emissions for each piece of equipment according to engine characteristics (model year, rated power, and equipment type) and equipment operation (hours of operation and fuel consumption rates). Yard trucks (sometimes called hostlers), side picks and top picks were the most prevalent types of equipment. Other equipment included rubber tired gantry cranes, forklifts, and tractors. Most of the equipment was powered by diesel engines and many units had been retrofitted with emissions control devices or repowered to comply with regulations. Some of the cargo handling units were fueled by liquid petroleum gas (LPG) or gasoline. Equipment that solely uses electric power was not included.

Trucking. Maritime operations create a demand for a significant number of truck trips, including short trips within the Port moving containers from marine terminals to other locations. Trucks arrive at the Port terminals primarily via freeway interchanges or rail yards, and leave through the same general exits. Even if trucks arrive via surface streets, the trips mostly pass through the same intersections that define the primary freeway interchanges. The spatial scope of the truck emissions inventory was therefore defined to include truck routes from the marine terminals to each of three freeway interchanges and the two rail yards. To insure consistency with the 2005 inventory, this inventory does not include emissions from Port trucks operating on freeways.

ENVIRON's general approach to estimate truck emissions was to determine truck travel by estimating the number of truck trips to and from the marine terminals, the trip mileage to and from the terminals, and the average link and trip speed. To estimate the number of truck trips, the Port of Oakland conducted an in-depth survey with the terminal operators to determine the gate counts by configuration of each truck (tractor only or tractor with a trailer) at the entrance and exit to the terminals. ENVIRON then estimated truck trips from truck gate count data and container lift data provided by the port.

Emissions from trucks depend on the age distribution and emission control devices of the transport trucks as well as site-specific conditions. State regulations, Port incentives and a Port ban on non-compliant trucks have led truck owners to use new technology trucks or retrofit relatively new trucks to meet emission standards. In contrast, the 2005 seaport emission inventory noted that Port trucks tended to be older than average in that calendar year.

ENVIRON estimated emissions for four truck operating modes: idling at terminal queues, in-terminal idling, in-terminal driving, and over-the-road driving to and from the rail yard and freeway exits. ENVIRON used the most recent version of ARB's EMFAC model to estimate emission rates for the various modes.

Locomotive. The Oakland International Gateway (OIG) rail yard is a Port of Oakland terminal operated under a lease by Burlington Northern Santa Fe (BNSF) railway. BNSF uses the OIG as a near dock transfer point for Port of Oakland maritime traffic and only Port containers are handled at the yard. Locomotives and trains enter the general port area from the north via the Union Pacific (UP) lines, and leave in the same direction via tracks going north through Richmond and onto BNSF lines out of the Bay Area. The Union Pacific rail yard (UP Railport) that sits adjacent to the Port terminals serves as an intermodal yard for freight movements through the port, but it is not included in the Port's emissions inventory because it is independently operated and may handle non-Port cargo. UP has in the past provided the ARB with an independent analysis of the emissions from its Oakland facility.

Because different locomotive and engine models have different emission characteristics, it was important to characterize the types and models of the locomotives that arrive/depart and are serviced at OIG. ENVIRON determined the locomotive fleet fractions and number of different locomotive types and models using train arrival and departure data provided by BNSF. One switching engine is usually assigned to the OIG yard at any one time, with very similar engine models used for this purpose.

Emissions Inventory Results

Results of this Port of Oakland 2012 Seaport Emissions Inventory update, the 2005 Inventory and the percent changes between these inventories, are summarized in Table ES-1. Note that the 2005 inventory did not distinguish between PM_{10} and $PM_{2.5}$; only total PM and DPM emissions were reported. For emission sources found at the Port, total PM can be considered to be the same as PM_{10}.

Table ES-1. Port of Oakland 2012 and 2005 air emissions inventory comparison.

2012 Inventory	ROG	CO	NO_x	PM_{10}	$PM_{2.5}$	DPM	SO_x
Ocean-going vessels	176	232	2,591	66.9	62.1	57.4	289
Harbor craft	25	95	235	9.3	9.0	9.3	0
CHE	35	207	413	8.0	7.4	7.9	1
Truck	13	49	135	3.0	2.3	2.0	0
Locomotive	1	2	19	0.5	0.4	0.5	0
Other Offroad Equipment	1	4	4	0.3	0.3	0.3	0
Total	**250**	**589**	**3,398**	**88**	**81**	**77**	**290**
2005 Inventory	**ROG**	**CO**	**NO_x**	**PM**	**$PM_{2.5}$**	**DPM**	**SO_x**
Ocean-going vessels	117	235	2,484	220	N/A	208	1,413
Harbor craft	22	83	345	13	N/A	13	2.85
CHE	53	408	766	22	N/A	21	7
Truck	49	149	334	16	N/A	15	2.2
Locomotive	7	11	76	2	N/A	2	2
Total	**248**	**886**	**4,005**	**272**	N/A	**261**	**1,427**
% Change from 2005	**ROG**	**CO**	**NO_x**	**PM**	**$PM_{2.5}$**	**DPM**	**SO_x**
Ocean-going vessels	50%[a]	-1%	4%[b]	-70%	N/A	-72%	-80%
Harbor craft	11%[c]	14%[c]	-32%	-30%	N/A	-30%	-94%
CHE	-33%	-49%	-46%	-63%	N/A	-63%	-92%
Truck	-74%	-67%	-60%	-81%	N/A	-88%	-90%
Locomotive	-83%	-81%	-75%	-77%	N/A	-77%	-100%
Total	**1%**	**-33%**	**-15%**	**-68%**	N/A	**-70%**	**-80%**

[a]OGV ROG increase due to change in emissions factor (see Sec. 8.2)
[b]OGV NO_x increase due to lower fraction of calls by steamships in 2012 (see Sec. 8.2).
[c]Harbor craft ROG and CO increase due to increased dredging activity included in inventory (see Sec. 8.3).

As shown in Table ES-1, the comparisons of 2012 with 2005 emissions show a general reduction in emissions, mostly due to the use of more modern engines, retrofits and cleaner fuels. Notably, the DPM and SO_x emissions are substantially lower in 2012 for all source categories. Changes to emission factors for ROG resulted in increases in estimated OGV and harbor craft ROG emissions. A small increase in the OGV NO_x emissions between 2005 and 2012is a result of relatively more OGVs with diesel engines and fewer steamship calls in 2012 which is only slightly offset by minor reductions of NO_x from incorporation of newer engines in the fleet and the use of cleaner fuels. Also shown in this table, ocean-going vessels constitute the largest source category for all pollutants, producing nearly 75% of estimated particulate matter emissions and the major portion of other pollutants within the scope of this emissions inventory. Table ES-2 shows a more detailed assessment of ocean going vessel emissions by mode of operation.

It is important to keep in mind that location of emissions is often as significant as the total quantity: the greater the distance between the emission source and the affected area, the lower the pollutant concentration and resulting exposures in the affected area. Thus, emissions generated close to community receptors will have a greater effect on human health risk on a per ton basis. In other words, the impact of the various source categories on West Oakland air quality is not directly proportional to the magnitude of their total emissions. For example, the particulate matter emissions from ocean-going vessels in cruising mode, which occurs outside the Golden Gate, will have less impact on sensitive receptors in Oakland on a per-ton basis than emissions that occur closer to shore during the maneuvering or hotelling modes.

Table ES-2. OGV emissions summary by mode, using ARB-specified activity emission factors – tons in 2012.

2012 Inventory	ROG	CO	NO_x	PM_{10}	$PM_{2.5}$	DPM	SO_x
OGV – Cruise	30	42	618	14.0	13.0	12.0	65
OGV – RSZ	38	52	626	15.3	14.2	12.7	70
OGV – Maneuver	72	61	512	13.6	12.6	12.4	34
OGV – Berth	36	75	825	23.7	22.0	20.1	119
OGV – Anchorage	0	1	11	0.3	0.3	0.3	2
OGV subtotal	**176**	**232**	**2,591**	**66.9**	**62.1**	**57.4**	**289**

Trucks, harbor craft, and cargo handling equipment together produced nearly 25% of the estimated Port-related DPM emissions in 2012. Locomotives from the OIG rail yard and other off-road equipment used for construction and maintenance work contributed a small fraction of the total emissions.

Development of the greenhouse gas emission inventory followed the same approach used to estimate criteria pollutants and used the same domain and activity as for the criteria pollutant inventory. GHG emissions are expressed in units of carbon dioxide equivalent (CO_2e) global warming potential where methane (CH_4) has 21 times and nitrous oxide (N_2O) 310 times the global warming potential of CO_2. The GHG emissions for each source category are shown in Table ES-3.

Table ES-3. Summary GHG emission inventory by source category (tpy).

2012 Inventory	CO_2	CH_4	N_2O	CO_2e
Ocean-going vessels	133,005	14	3	134,332
Harbor craft	20,134	4	1	20,377
CHE	38,556	5	0	38,667
Trucks	27,942	1	1	28,198
Locomotives	926	0	0	935
Other Offroad Equipment	368	0	0	370
Total	**220,930**	**24**	**5**	**222,880**

1 INTRODUCTION

1.1 Purpose and Background

The Port of Oakland (Port) has prepared this 2012 Seaport Air Emissions Inventory (emissions inventory) for the purpose of identifying and quantifying the air quality impacts from the maritime operations of the Port and its tenants. This emissions inventory updates the 2005 Seaport Air Emissions Inventory (ENVIRON, 2008) within the major categories of maritime equipment:

- Deep-Draft Ocean-Going Vessels (OGV)
- Harbor Craft (dredging and assist tugs)
- Cargo Handling Equipment (CHE)
- Trucks (container movements)
- Locomotives
- Other Off-Road Equipment

The Port voluntarily chose to prepare the original and periodic updates air emissions inventory of its seaport to help in air quality planning and to meet its commitment to develop and implement a criteria pollutant reduction program. Because annual emissions from operations vary over time due to changes in cargo volume and to the phasing in of regulations and other factors that control emissions, this study provides an updated inventory for 2012 for comparison with the calendar year 2005 baseline study year.

This emissions inventory highlights the Port's commitment to improve understanding of the nature, location and magnitude of emissions from its maritime-related operations. An emissions inventory is best understood as an estimate of the quantity of pollutants that a group of sources produce in a given area, over a prescribed period of time. Emissions inventories should be used with care and in conjunction with other information and tools to evaluate and assess air quality problems.

1.2 Considerations When Using Emissions Inventories

Emissions inventories are used for multiple purposes: to analyze air quality, to develop pollutant control strategies or plans, and to track and communicate progress toward air quality goals. Emissions inventories are essential tools, but they have some inherent shortcomings that are often overlooked and lead to misconceptions about their use and value. The term "inventory" is something of a misnomer because it implies greater precision in "counting" emissions than is really the case. An emissions inventory is better understood as an estimate of the quantity of pollutants that a group of sources produce in a given area, over a prescribed period of time. The methods of making estimates are usually very technical in nature, a characteristic that makes the limitations of emissions inventories less transparent to the general public.

The accuracy of emissions estimates varies due to a number of factors. Even a well-conducted, detailed and carefully constructed inventory, such as this one, does not have access to direct emissions measurements from the specific, individual sources being studied. As a result, it is necessary to rely on surrogate information to characterize sources, describe source activities, and specify pollutant emission rates.

Emissions estimation methodologies are continuously in flux, changing and evolving over time as better and more accurate information becomes available. Historically, emissions inventory updates have revealed previously overlooked information about sources and source activity that has substantially changed overall emissions estimates. For example, because of new information made available, such as provided in the 2005 Seaport Air Emission Inventory, the California Air Resources Board (ARB) updated the ocean-going vessel auxiliary boiler activity rates. As a result, emissions inventories conducted even a few years apart may not be directly comparable.

Another important consideration in interpreting emissions inventories is the somewhat counter-intuitive fact that there can be a poor correlation between the magnitude of emissions and an air quality impact. The importance of a given ton of emissions may differ from another ton because of the location at which it is emitted, because of the meteorological conditions that affect its dispersion, and in some cases because of the chemical reactions that occur in the atmosphere. Emissions inventories should be used with care and in conjunction with other information and tools to evaluate and assess air quality problems.

1.3 Important Features of the Port of Oakland Seaport Air Emissions Inventory

Some features of the Port emissions inventory that should be kept in mind throughout this report are described below.

1.3.1 Scope

The inventory estimates emissions from the Port's tenants' and other maritime operations that occurred in the calendar year 2012 using the same geographic scope as the 2005 inventory. It is not intended to represent emissions in other years, or emissions outside the geographic domains identified for each major source category, as described below in "Technical Approach". Tenants for which emissions were estimated include shipping lines, marine terminal operators, and the rail yard operator. Non-tenant maritime operations for which emissions were estimated include trucks, dredges, tugs, and other assist vessels.

1.3.2 Sources

The inventory focuses on the largest sources of air emissions from maritime operations, which, except for ship boilers and various gasoline and compressed gas fueled off-road equipment, are all powered by diesel engines. The source categories include ocean-going vessels, harbor craft assisting those vessels, vessels performing or assisting in dredging, cargo handling equipment at marine terminals and the one Port rail yard, and locomotives and trucks engaged in transport of maritime cargo containers. The inventory does not address other sources, such as gasoline-powered, light-duty vehicles, that operated at the Port.

1.4 Criteria Air Pollutants

The inventory provides estimates for emissions of five "criteria" air pollutants described here, reported as tons per year.[1]

Reactive Organic Gases	Generally colorless gases that are emitted during combustion or through evaporation. They react with other chemicals in the ambient air to form ozone or particulate matter, both of which can have adverse health effects at higher concentrations
Carbon Monoxide	Colorless gas that is a product of incomplete combustion. Has an adverse health effect at higher concentrations.
Nitrogen Oxides	Nitrogen oxides include nitric oxide and nitrogen dioxide. Nitrogen dioxide is a light brown gas formed during combustion from reactions with nitrogen in the fuel or the combustion air. Nitrogen dioxide has adverse health effects at higher concentrations. Both nitrogen dioxide and nitric oxide participate in the formation of ozone and particulate matter in the ambient air.
Particulate Matter	Solid or liquid particles that form from a variety of chemical reactions during the combustion process. Solid particulate may also be emitted from activities that involve abrasion or friction, such as brake and tire wear. Have adverse health effects at higher concentrations. Particulates are divided into those less than 10 microns, PM_{10}, and those less than 2.5 microns, $PM_{2.5}$ aerodynamic diameter. Diesel particulate matter (DPM) is defined as particulates from diesel engine exhaust.
Sulfur Oxides	Sulfur bearing gases, primarily SO_2, that form during combustion of a fuel that contains sulfur. Has adverse health effects at higher concentrations and participates in the formation of sulfate particulate matter in the ambient air.

1.4.1 Particulate Matter

The particulate matter estimated in this report is primarily diesel particulate matter (DPM), which is defined as a toxic air contaminant by the ARB. Some ocean-going vessels use boilers to supply steam power for propulsion engines, and all vessels operate auxiliary boilers for hot water on board. In addition, some particulate emissions were from non-diesel gasoline or LPG fueled cargo handling equipment, as noted in Section 4. The particulate emissions were estimated from emission factors as PM_{10}; $PM_{2.5}$ was calculated as a fraction of PM_{10} which varied by source category.

1.5 Greenhouse Gases

The greenhouse gas emission inventory includes estimates of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions from each source category. Fuel combustion is the source of CO_2, while CH_4 results from incomplete combustion and N_2O is generated during the high temperature combustion. A combined carbon dioxide equivalent (CO_2e) estimate was prepared by adding 21 times the CH_4 and 310 times N_2O emissions to the CO_2 emissions to account for the greater greenhouse gas potential of these two emissions. (IPCC, 1995).

[1] The term "criteria" pollutant is applied to pollutants for which an ambient air quality standard has been set, or which are chemical precursors to pollutants for which an ambient air quality standard has been set.

1.6 Technical Approach

This report outlines the maritime emissions inventory from mobile sources at the Port of Oakland in 2005 and includes the input data and methodology used in estimating emissions. The emissions inventory includes the following major source categories:

- Deep-Draft Ocean-Going Vessels (OGV)
- Commercial Harbor Craft (dredging and assist tugs)
- Cargo Handling Equipment (CHE)
- Trucks (container movements)
- Locomotives

This is an inventory of the air emissions generated by maritime activities conducted by the Port of Oakland's tenants. On the water side, the spatial domain of the inventory includes Port-related marine vessel transit from dockside out through the Golden Gate Bridge, to the first outer buoys beyond the Sea Buoy approximately 30 miles away from the Port. On the landside, the spatial scope of the inventory includes seven marine terminals, one rail yard, and the road traffic between those facilities and the nearest freeway interchanges. The Port area was defined approximately by the boundaries of I-80, I-880, and the Howard Terminal (Berths 67 and 68) adjacent to Jack London Square. Within this defined geographic domain, three areas were specifically excluded: the Schnitzer Steel terminal, the Union Pacific rail yard, and the former Oakland Army Base located between Maritime Street and I-880. These areas were not controlled or operated by the Port of Oakland in 2005, and are therefore not included in this update. Figures 1-1 and 2-1 illustrate the spatial scope of the inventory.

Figure 1-1. Port of Oakland maritime facilities – 2012.

The inventory was prepared by ENVIRON International Corporation (ENVIRON) by analyzing all maritime activity in 2012 including the time in different modes of operation, the load or speed, and the engine characteristics of all equipment and vessels used in the Port's maritime operations. To obtain this data, Port, State, and terminal and rail operator records were used, along with special studies that are described in the appendices. Previous studies and literature reviews, and ARB input data or model estimates were used when more precise estimates could not be generated during the period of this study.

ENVIRON and the Port worked with ARB and the BAAQMD in preparing this inventory. The emissions estimates in this report use ARB inputs and methodologies, and both the ARB and BAAQMD have received this inventory and provided comment, which the authors have addressed as detailed in Appendix A.

1.7 Report Organization

This emissions inventory report is organized into an Executive Summary, seven sections, and the appendices.

- The Executive Summary briefly describes the methodologies used to estimate air emissions for all Port activities, and includes a summary of the results (Tables ES-1, ES-2 and ES-3).

- Section 1 contains this introduction to the report.
- Section 2 describes deep-draft ocean-going marine vessels.
- Section 3 describes operation and maintenance dredging activity and assist tugs.
- Section 4 describes cargo handling equipment.
- Section 5 describes the Port of Oakland on-road truck activity associated with container movements.
- Section 6 describes locomotive emissions.
- Section 7 describes other off-road equipment emissions.
- Section 8 contains the summary and results of the report and a comparison with the 2005 seaport emission inventory.
- Section 9 provides the references used in developing the emissions inventory.
- A glossary defines the technical terms used in the report.

2 DEEP-DRAFT OCEAN-GOING VESSELS (OGV)

2.1 Deep-Draft Ocean-Going Vessel Activity and Inventory

This section documents the emission estimation methods and results for large deep-draft ocean-going vessels (OGV) calling at Port of Oakland terminals in 2012. ENVIRON followed the latest California Air Resources Board (ARB) emission estimation methodology for ocean-going vessels (ARB, 2011a).

OGV use propulsion engines for transiting, auxiliary engines for onboard electrical power and small boilers to meet steam and hot water needs. Each vessel has unique characteristics of design speed, engine type and power that affect the estimate of time and engine load for each vessel call.

Of the 1,812 deep draft vessel calls to the Port of Oakland in 2012, all were container ships except for two bulk carrier calls, one of which called at Berth 33 (which is not a container berth) and the other was an older vessel, perhaps originally designed as a bulk or general cargo vessel, and labeled as such in the vessel database used for this work. There was one additional call at the Port by an oil tanker barge; emissions from this call are included with the harbor craft emissions described in Chapter 3.

Ship size can be defined by three different methods:

- Dead weight tonnage (DWT),
- Container capacity in twenty-foot equivalent units (TEU), or
- Length.

Each of these size measurements may affect one emission source or another. Table 2-1 describes general ship characteristics using three size measurements for vessels calling at the Port of Oakland in 2012. Some of the ships calling in 2012 are significantly larger than in previous years including vessels exceeding 1100 feet and with carrying capacity up to 12,000 TEU.

Table 2-1. Ocean-Going Vessels – 2012 Port of Oakland vessel calls by three different ship size measures.

Dead Weight Tonnage	Calls	TEU	Calls	Length	Calls
<20,000	24	<2000	91	<750 feet	306
<40,000	405	<3000	346	750 – 1100	1,398
<60,000	681	<4000	484	>1100	108
<80,000	1,424	<5000	979		
<100,000	1,590	<6000	1,296		
<120,000	1,765	<7000	1,541		
		<9000	1,704		
		<11000	1,782		
All	1,812	All	1,812	All	1,812

Vessels call at both regular and irregular frequencies. Many vessels follow regular routes between ports in Hawaii, New Zealand, the South Pacific or Asia, and the Port of Oakland, while others make infrequent calls. Vessels calling between 4 and 10 times in 2012, accounted for more than 70% of total calls, and more than 10% of calls were from vessels calling 11 or more times during 2012. Table 2-2 lists the distribution of Port of Oakland call counts by individual ships in 2012.

Table 2-2. Ocean-Going Vessel - Port of Oakland vessel call counts in 2012.

Number of Calls in 2012	Ship Count	Subtotal Calls	Cumulative Calls
1	49	49	49
2	51	102	151
3	38	114	265
4	38	152	417
5	33	165	582
6	32	192	774
7	32	224	998
8	26	208	1,206
9	23	207	1,413
10	16	160	1,573
11	6	66	1,639
12	1	12	1,651
13	1	13	1,664
14	1	14	1,678
15	0	0	1,678
16	0	0	1,678
17	0	0	1,678
18	1	18	1,696
19	1	19	1,715
20	0	0	1,715
21	1	21	1,736
22	0	0	1,736
23	0	0	1,736
24	0	0	1,736
25	2	50	1,786
26	1	26	1,812

The age distribution of the vessels calling at the Port in 2012 is shown in Table 2-3. Many were relatively new with 70% built since 2000, but there were several frequently calling vessels older than 30 years. The median age of vessels calling the Port in 2012 was 9 years. The age distribution is important because the international emission standards limit NO_x emissions from marine engines: Tier 1 emission standards started with model year 2000 vessels, Tier 2 started with model year 2011. Tier 3 standards will take effect with model year 2016.

Steamships (ships powered by propulsion boilers) are among the oldest vessels calling at the Port. Steamships that were not originally designed for operation on marine distillate fuel or natural gas are exempt from the North American ECA fuel sulfur requirements as per

International Maritime Organization resolution MEPC.202(62) until at least 2020.[2] Propulsion boilers are also exempt from the ARB fuel sulfur requirements. Auxiliary boilers, however, are not exempt from the ARB fuel requirements. NO_x emission limits described here apply only to diesel engines and do not affect steamship propulsion boilers which have low NO_x emission rates.

Table 2-3. Ocean-Going Vessels – Port of Oakland vessel age distribution in 2012.

Model Year	Count of Calls	Individual % of Calls	Cumulative Calls
2012	0	0.0%	0
2011	13	0.7%	13
2010	103	5.7%	116
2009	89	4.9%	205
2008	71	3.9%	276
2007	115	6.3%	391
2006	206	11.4%	597
2005	157	8.7%	754
2004	135	7.5%	889
2003	102	5.6%	991
2002	107	5.9%	1,098
2001	126	7.0%	1,224
2000	77	4.2%	1,301
1999	13	0.7%	1,314
1998	13	0.7%	1,327
1997	77	4.2%	1,404
1996	52	2.9%	1,456
1995	71	3.9%	1,527
1994	47	2.6%	1,574
1993	26	1.4%	1,600
1992	16	0.9%	1,616
1991	8	0.4%	1,624
1990	14	0.8%	1,638
1989	1	0.1%	1,639
1988	11	0.6%	1,650
1987	0	0.0%	1,650
1986	0	0.0%	1,650
1985	0	0.0%	1,650
1984	0	0.0%	1,650
1983	3	0.2%	1,653
1982	0	0.0%	1,653
1981	43	2.4%	1,696
1980	46	2.5%	1,742
1979	0	0.0%	1,742
1978	1	0.1%	1,743
1977	46	2.5%	1,789
1976	0	0.0%	1,789
1975	0	0.0%	1,789
1974	0	0.0%	1,789

[2] http://www.imo.org/blast/blastDataHelper.asp?data_id=30761&filename=202%2862%29.pdf

Model Year	Count of Calls	Individual % of Calls	Cumulative Calls
1973	22	1.2%	1,811
1972	0	0.0%	1,811
1971	1	0.1%	1,812

Source: San Francisco Marine Exchange, 2013 and Fairplay, 2009

ENVIRON excluded from this inventory vessels calling at the privately owned Schnitzer Steel operation, which lies within the boundaries of the Port of Oakland terminals and generally sees bulk carriers calling for scrap steel. Vessel calls at Schnitzer Steel are not included because the Schnitzer facility is not owned or controlled by the Port of Oakland.

The spatial domain of this inventory includes vessel transit activity between the outer buoys that lie beyond the Sea Buoy outside the Golden Gate and berths at the Port as shown in Figures 2-1 and 2-2. This domain is the same as was used in the 2005 emission inventory (ENVIRON, 2008) although a slightly shorter route was used for all inbound vessels based on recent traffic route samples obtained from the Coast Guard's Vessel Traffic Service and interviews with the San Francisco Bar Pilots.

Based on discussions with the Marine Exchange (2013), and San Francisco (SF) Bar Pilots (2013), a schematic of the transit activity for vessels calling at the Port of Oakland in 2012 can be described as shown in Table 2-4. Entries in Table 2-4 correspond to the schematic link descriptions shown in Figures 2-1 and 2-2. Links listed in Table 2-4 are used to specify activity applicable to each portion of the vessel's transit.

Generally, vessel activity is classified into four modes of operation: cruise, reduced speed zone (RSZ), maneuvering, and hotelling as follows:

- Cruise mode occurs in the open ocean where there are fewer navigational challenges and where ships typically operate at their design speed.
- RSZ mode occurs where ships are required to slow down and stay within prescribed lanes as shown on Figure 2-1 and 2-2. For ships arriving in the SF Bay, the RSZ mode occurs after a SF bar pilot boards and takes command of the vessel at the Sea Buoy until the vessel slows to a very low maneuvering speed near the Port defined for the purposes of this inventory as starting at the Bay Bridge. The RSZ mode for departing ships is the inverse of that for arriving ships.
- Maneuvering mode is defined as occurring between the Bay Bridge and the berth.
- Lastly, the hotelling or 'at berth' mode occurs when the vessel is stopped at berth or lying at anchor south of the Bay Bridge.

Two additional modes were added to account for any time spent at anchorage in the South Bay before or after calling at the Port and for vessel shifts to or from anchorage or between berths at the Port. Vessel emissions were calculated for each operating mode by multiplying the engine operating time for the mode by the engines' rated power, the engine load factor and the appropriate emission factor. The number of vessel calls multiplied by the time per call spent in each of the four operational modes constitutes the total time in mode.

Time in mode and load for propulsion engines was calculated based on vessel speed and the distance (length) of each transit mode. The SF Bar Pilots (2013) estimated the RSZ average speed and typical maneuvering mode times as listed in Table 2-4. An average RSZ mode speed of 13.5 kts was chosen to account for an average compliance margin relative to the legal requirement to “Not exceed a speed of 15 knots through the water” in the regulated navigation areas (RNAs) included in Coast Guard, 2009 regulations. ENVIRON determined the cruise speed from the Fairplay (2009) design speed for each vessel. ENVIRON determined the time in mode from the speed and distance along each link to estimate the propulsion and auxiliary engine activity for cruise and RSZ modes. The Port of Oakland Wharfingers (2013) provided berthing time information for nearly all calls, and estimates were verified and supplemented using the Marine Exchange date and time stamps for entry (at the Golden Gate) adjusted for transit time to the port and ‘last line off’ records for each call.

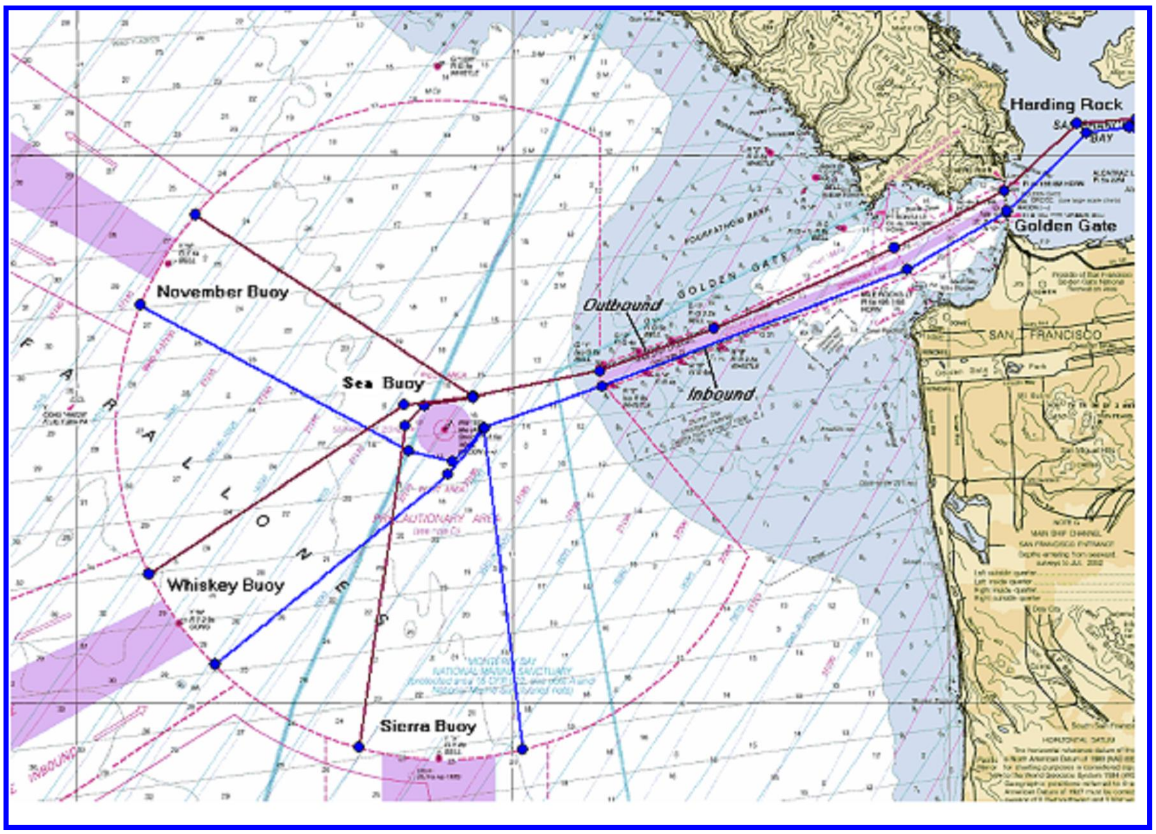

Figure 2-1. Link descriptions outside of the Golden Gate.

There are two potential transit routes between the Golden Gate and Bay bridges shown in Figure 2-2. Ships follow one or the other depending on a number of factors including weather and scheduling of public events on the Bay. The SF Bar Pilots (2013) indicated that the primary in-bound transit route between the Golden Gate and Bay Bridges is south of Alcatraz unless the vessel is drawing more than 45 feet in which case it should use the deep water route north of Harding Rock. Only one vessel call to the Port exceeded 45 foot draft and this vessel was reported by the Marine Exchange to have a 54 foot draft, but according to Fairplay, this vessel was design for a maximum 46 foot draft, so the draft reported for this call was considered erroneous. The northern route may also occasionally be used by other vessels under unusual weather conditions or if public events interfere with the southern route. Because insufficient data was available to describe each call's specific route, the typical (and shorter) route south of Alcatraz was assumed for all inbound transits. The outbound transit uses the deep water route north of Harding Rock if the vessel draft exceeds 28 feet, and the route may not be available due to traffic concerns. Because almost all ships outbound from Oakland draw more than 28 feet and the route south of Alcatraz is rarely available for outbound transit, all vessels were assumed to use the route north of Harding Rock for outbound transit. Alternative inbound and outbound transit routes are shown and described in Figure 2-2 and Table 2-4, but these alternatives were not used in the emission estimation.

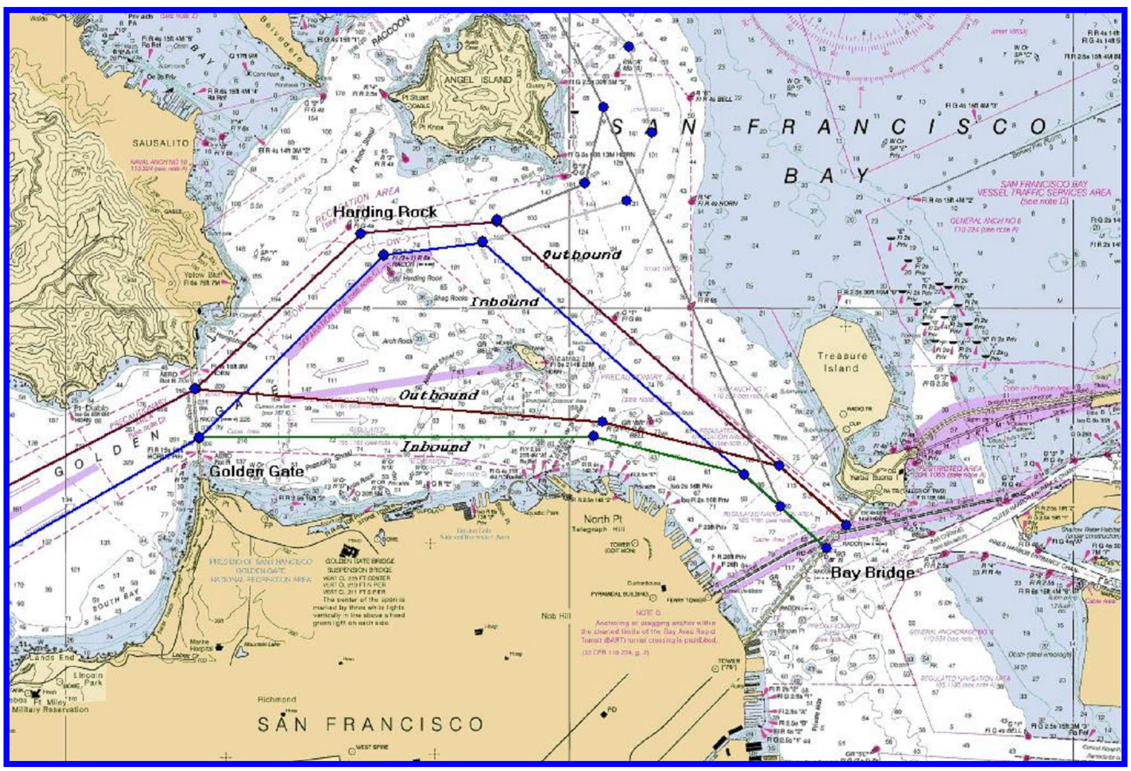

Figure 2-2. Transit link descriptions in San Francisco Bay (direct route primarily used inbound and less direct route outbound).

Vessels are assumed to be in maneuvering mode while moving between the Bay Bridge and the berths. This mode consists of a short low speed transit, turn at the berth or in the turning basin, and propulsion engine start and stop at the berth with tug assist. Based on the SF Bar Pilots' (2013) best judgment, the maneuvering time is longer for the Inner Harbor berths and for larger vessels, defined here as two types of longer vessels, one greater than 750 foot and another greater than 1100 feet in length. The larger ships require more time to turn and can only turn in prescribed areas, such as the Inner Harbor and Outer Harbor turning basins. Therefore, as shown in Table 2-4, the SF Bar Pilots (2013) estimated the maneuvering time for larger ships to be longer than for smaller ships. Also, maneuvering time is shorter for the Outer Harbor terminal calls than the Inner Harbor terminal calls because of the shorter distance from the Bay Bridge and proximity of the Outer Harbor turning basin to the Outer Harbor berths.

Table 2-4. Ocean Going Vessels – Transit link descriptions.

Transit into Port				
Direction	**Link Start**	**Link End**	**Distance (nautical miles)**	**Speed (knots)**
In – From Asia or Northern Ports	North Buoy	Pilot Boards	7.4	Cruise
In – From Hawaii and points west	West Buoy	Pilot Boards	6.7	Cruise
In – From Southern Ports	South Buoy	Pilot Boards	6.0	Cruise
In – All	Pilot Boards	Sea Buoy	1.5[2]	9
In – All	Sea Buoy	Golden Gate	8.7	13.5
In – All (alternative route) [1]	Golden Gate[1]	Harding Rock	2.0	13.5
In – All (alternative route) [1]	Harding Rock[1]	Bay Bridge	4.5	13.5
In – All [1]	Golden Gate	Bay Bridge	5.3	13.5
Maneuvering Modes				
Direction	**Link Start**	**Link End**	**Time (hrs)**	**Load**
In/Out – Inner Harbor Terminals (<= 750 foot Ships)	Bay Bridge	Dock	0.833 / 0.833	2%
In/Out – Inner Harbor Terminals (>1100 or >750 foot Ships – Turning Basin)	Bay Bridge	Dock	2.09 or 1.42 / 0.833	2%
In/Out – Outer Harbor Terminals (<= 750 foot Ships)	Bay Bridge	Dock	0.75 / 0.75	2%
In/Out – Outer Harbor Terminals (>750 feet Ships – Turning Basin)	Bay Bridge	Dock	1.33 / 0.75	2%
Shifts (small number of calls have shifts from one terminal to another)	Oakland	Oakland	0.75	2%
Transit Out of Port				
Direction	**Link Start**	**Link End**	**Distance (nautical miles)**	**Speed (knots)**
Out – All [1]	Bay Bridge[1]	Harding Rock	4.8	13.5
Out – All [1]	Harding Rock[1]	Golden Gate	1.8	13.5
Out – All (alternative route) [1]	Bay Bridge[1]	Golden Gate	5.5	13.5
Out – All	Golden Gate	Sea Buoy	8.9	13.5
Out – All	Sea Buoy	Pilot Departs	1.5[2]	9
Out – To Asia or Northern Ports	Pilot Departs	North Buoy	6.1	Cruise
Out – To Hawaii	Pilot Departs	West Buoy	6.8	Cruise
Out – To Southern Ports	Pilot Departs	South Buoy	7.3	Cruise

[1] SF Bar Pilots (2013) reported that ships with drafts greater than 45 feet must use the Deep Water Traffic Lane north of the Harding Rock Buoy, though other ships under certain conditions (such as occurrence of special events) may also take northern route. For transit out of the Bay, ships with drafts greater than 28 feet must use the Deep Water Traffic Lane.

[2] Assumes 10 minutes at 9 knots for the pilot to board and depart safely. Distance in this mode was subtracted from the cruise mode. Distances were measured from east of Sea Buoy.

ENVIRON estimated total activity along each link using the number of vessel movements along each link for the 2012 vessel calls. The purpose of defining these links was to provide emissions that were accurately spatially allocated and to estimate the time in mode based on vessel speed and the distance along each link. Determining the total vessel movements for most segments is straightforward because each call required transiting along a set route as described in Table 2-4. Vessel movements between the Sea Buoy and the South, West and North outer buoys as shown in Figure 2-1 were determined on the basis of the vessel's previous or next port of call as listed in the San Francisco Marine Exchange data. Table 2-5 lists the resulting number of inbound and outbound transits in each direction outside of the Sea Buoy for vessel calls to the Port in 2012. Maneuvering mode movements inside the Bay Bridge were determined based on which berth the vessel called and the vessel length as described above.

Table 2-5. Ocean-Going Vessels – Port direction from the San Francisco Bay.

Last or Next Port of Call	Direction	Trips In or (Out)
US northern continental ports including Alaska, Canada, and all Asian ports	N	309 (1324)
US Hawaii, Guam, New Zealand, Fiji, Tahiti	W	108 (105)
US Southern continental ports, Mexico, Panama, Chile and other South American ports, and Caribbean and European ports through the Panama canal	S	1395 (383)

ENVIRON determined emissions for each link using the equation below, accounting for the engine rated power, typical load factor, and time at that load. The rated power is the maximum power that the engine can produce. The load factor is the fraction of the actual to the rated power that the engine operates for a given mode. ENVIRON determined emissions separately for propulsion and auxiliary engines, and for boilers, using emission factors from ARB (2011).

Emissions per vessel/mode = (Rated Power) x (Load Factor) x (Time) x (Emission Factor)

Emissions total = Σ{All vessel calls and modes}

ENVIRON calculated the time in each link from the link length and estimated speed. The load factor was calculated on the basis of the vessel's maximum speed and the actual vessel speed in each mode as described in Section 2.2.

2.2 Input Data and Use

The basic input data for calculating emissions from OGVs include the number of vessel calls in 2012, vessel installed power and speed, and estimates of load and time during each operation mode.

1) Vessel Port Calls
2) Vessel Type
3) Vessel Characteristics
    a) Cruise speed (knots)

b) Auxiliary Power (kW)
4) Engine Characteristics
   a) Rated Power
   b) Engine Type (slow 2-stroke, medium 4-stroke, or steam)
5) Model Year
6) Berthing Time (with and without adjustment for shorepower use specific to each call)
7) Anchorage Vessel Calls and Time
8) Route between Sea Buoy and Outer buoys (north, west, or south)

2.3 Vessel Calls

Data on vessel calls to the Port of Oakland in 2012 were provided by the San Francisco Marine Exchange, and the Port Wharfinger (2013) provided date and time stamps for each visit at the Port's berths. The Wharfinger data was recorded at the dock and included the dock arrival and departure times, thereby allowing the berth hotelling time by vessel call to be calculated. The Marine Exchange data also identified those vessel calls for which the ship went to the anchorage area before or after calling to the Port. For those vessels that go to an anchorage area before calling the Port, the Marine Exchange data included the arrival time at the Golden Gate to which an estimate of the travel time (0.68 hours) from the Golden Gate to the anchorage was added and the time the vessel left anchorage, and by difference the time anchored was estimated. For vessels going to anchor after calling the Port, the time the vessel left the berth plus 0.75 hours for shifting to anchor and the time the vessel left anchorage were used to estimate the time at anchor.

2.3.1 Propulsion Power and Load

Propulsion power and vessel speed were derived from the Fairplay (2009) database, which reports design features for each vessel. To obtain estimates of maximum power and speed, Lloyds main engine power and Lloyds vessel design speed were used directly, consistent with ARB's methodology (ARB, 2011a). The vessel design speed was assumed to be the cruise speed.

The load factors for the propulsion power over any given link were determined from the classic Stokes Law cubic relationship for speed and load. The proportional relationship of load to the vessel speed can be expressed as in the following equation where the 100% load factor would correspond to the vessel operating at its maximum speed.

$$\text{Load Factor} = (\text{Vessel Speed} / \text{Vessel Maximum Speed})^3$$

The design speed of the vessel was estimated to be 0.937 of the maximum speed. Thus the load factor at the cruise speed is 0.823. For other transiting modes the load was calculated directly from the equation shown above and is unique to each vessels reported design speed.

2.3.2 Auxiliary Power and Load

As described in ENVIRON (2008), the auxiliary power was primarily derived from auxiliary generator capacity taken from the Lloyds database and supplemented by other available data and estimates. ENVIRON has used of the load factors shown in Table 2-6 to describe the vessel activity in the Port of Oakland. These load factors were taken from ARB (2011).

Table 2-6. Ocean Going Vessels – Auxiliary engine load factors assumptions.

Ship-Type	Cruise	Reduced Speed Zone (RSZ)	Maneuvering	Hotel
Container Ship	13%	13%	50%	18%
Bulk Carrier/General Cargo	17%	17%	45%	10%

Source: ARB, 2011a.

For each vessel call, the time when the auxiliary engine was running was estimated and used in the emission calculations. For those calls without shoreside power used, the time at berth was used to determine the hotelling time. The benefit of the shoreside power usage was included in the calculation of hotelling emissions by subtracting the time when shorepower was used from the berthing time. There were six calls totaling 27.2 hours of shorepower use representing about 0.1% reduction in berthing time.

2.4 Emission Factors

Emission factors depend on the type of engine and fuel used in the vessel for propulsion or auxiliary engines. Three types of engines were used for propulsion power on ships; slow speed engines (2-stroke and typically lower than 250 rpm), medium speed engines (4-stroke), and steam boilers coupled with steam turbines. ENVIRON determined from Fairplay data (Fairplay, 2009) that the primary propulsion engines used on vessels calling at the Port of Oakland were slow speed engines (1,713 vessel calls), steam boilers (96 calls), and medium speed engines (3 calls). Emission factors for these engines are shown in Table 2-7 (ARB 2011). In the ARB reference (http://www.arb.ca.gov/regact/2011/ogv11/ogv11isor.pdf), it was noted that 0.3% sulfur fuel represents an average in-use fuel sulfur level, and the PM emission factor was estimated as the average of the 0.5% and 0.1% sulfur emission factor.

Table 2-7. Ocean Going Vessels – Emission factors (g/kW-hr) for Precontrol, Tier I, and Tier II engines as noted.

Engine Type	Fuel Type	ROG	CO	NO_x	PM_{10}	$PM_{2.5}$
Slow Speed	Marine Distillate (0.1% S)	0.78	1.10	17.0	0.25	0.23
Slow Speed	Marine Distillate (0.5% S) [Marine Distillate (0.3% S)]	0.78	1.10	17.0 14.4 Tier II	0.375 [0.3125]	0.345 [0.2875]
Slow Speed	Heavy Fuel Oil	0.69	1.38	18.1	1.50	1.46
Medium Speed	Marine Distillate (0.1% S)	0.65	1.10	13.2	0.25	0.23
Medium Speed	Marine Distillate (0.5% S) [Marine Distillate (0.3% S)]	0.65	1.10	13.2 10.9 Tier II	0.375 [0.3125]	0.345 [0.2875]
Medium Speed	Heavy Fuel Oil	0.57	1.10	14.0	1.50	1.46
Steam	Residual Oil	0.1	0.2	2.1	1.50	1.46
Auxiliary	Marine Distillate (0.1% S)	0.78	1.10	13.9	0.25	0.23
Auxiliary	Marine Distillate (0.5% S) [Marine Distillate (0.3% S)]	0.78	1.10	13.9 11.54 Tier I 9.2 Tier II	0.375 [0.3125]	0.345 [0.2875]
Auxiliary	Residual Oil	0.57	1.10	14.7	1.5	1.46

Source: ARB (2011a).

NO_x emissions from marine engines are regulated by model year with Tier I beginning with the 2000 model year, Tier II for model year 2011 and Tier III with model year 2016 (for vessels operating in the North American Emission Control Area). Minimum marine engine emission standards for foreign flagged vessels are specified in MARPOL Annex 13 which defines the model year as, “Ships constructed means ships the keels of which are laid or which are at a similar stage of construction.” Though not all of the ships have ‘keel laid’ as an entry in the Fairplay database, all ships have a date of delivery listed. This date was used together with the average time from the keel laid to delivery date for container ships calling the Port (where both dates were provided) of 158 days to estimate the model year of the vessel. Tier I and II2 NO_x emission rates were derived from ARB (2011).

Emission rates assuming 0.3% fuel sulfur content were used based on ARB’s expectation of vessel operator’s response to the California fuel sulfur requirements. (ARB 2011 http://www.arb.ca.gov/regact/2011/ogv11/ogv11.htm) Steamships, which are not required to use low sulfur fuels, were assumed to use residual oil in the main propulsion boilers.

2.4.1 Low Load Adjustment Factors

Emission factors for OGV engines were derived from data collected at high operational loads. Adjustment factors are applied to obtain emission factors applicable to operation at very low loads where the engine does not operate as efficiently. As recommended by ARB (see ENVIRON, 2008), ENVIRON applied low load adjustment factors for propulsion engines consistent with those used in the calendar year 2008 Port of Los Angeles emission inventory (Starcrest, 2009) for HC, CO, NO_x and SO_x. These adjustment factors are listed in Table 2-8. Low load adjustment factors for PM listed in Table 2-8 are from ARB (2006a).

Table 2-8. Ocean Going Vessels – Low load adjustment factors for propulsion engines.

Load %	HC	CO	NO_x	SO_x	PM
1	N/A	N/A	N/A	N/A	9.82
2	21.18	9.68	4.63	1.00	5.60
3	11.68	6.46	2.92	1.00	4.03
4	7.71	4.86	2.21	1.00	3.19
5	5.61	3.89	1.83	1.00	2.66
6	4.35	3.25	1.60	1.00	2.29
7	3.52	2.79	1.45	1.00	2.02
8	2.95	2.45	1.35	1.00	1.82
9	2.52	2.18	1.27	1.00	1.65
10	2.18	1.96	1.22	1.00	1.52
11	1.96	1.79	1.17	1.00	1.40
12	1.76	1.64	1.14	1.00	1.31
13	1.60	1.52	1.11	1.00	1.22
14	1.47	1.41	1.08	1.00	1.15
15	1.36	1.32	1.06	1.00	1.09
16	1.26	1.24	1.05	1.00	1.03
17	1.18	1.17	1.03	1.00	1.00
18	1.11	1.11	1.02	1.00	1.00
19	1.05	1.05	1.01	1.00	1.00
20	1.00	1	1.00	1.00	1.00

Source: Table 3.8 from Starcrest, 2009 except PM values from ARB (2006a).

The low load adjustments in Table 2-8 were applied to propulsion engines when in the RSZ and maneuvering modes. Low load adjustment factors only affect propulsion engine emissions because no single auxiliary engine operates below 20% load at any time. Typically each vessel usually has a set of three or more auxiliary engines to provide auxiliary power, so individual engines are shut-down when the load decreases leaving the remaining working engines operating above 20% load.

A 2% average propulsion engine load was assumed for the maneuvering mode (accounting for activity between the Bay Bridge and berth). For the RSZ mode (between the Bay Bridge and the Sea Buoy), a load factor was calculated specifically for each vessel as the cube root of the ratio of the assumed RSZ mode speed (13.5 knots) to the maximum speed of the vessel. Of all vessels calling at Oakland, the maximum speed of the fastest vessel was estimated to be 28.4 knots. For slower vessels, the RSZ load factor was higher than the 11% load calculated for the fastest vessel.

2.5 Boiler Emissions

In-use boiler power estimates of 506 kW for container ships and 109 kW for bulk cargo vessels were assumed based on ARB (2011). Boiler emission factors shown in Table 2-9 were used; these are consistent with emission factors used in ARB (2011).

Table 2-9. Auxiliary boiler emission rates (g/kW-hr).

Fuel Type	ROG	CO	NO_x	PM_{10}	SO_x	CO_2	CH_4	N_2O
Residual	0.11	0.20	2.1	0.80	16.50	970	0.032	0.013
0.5% Sulfur	0.11	0.20	1.995	0.20	2.99	921.5	0.032	0.013
0.1% Sulfur	0.11	0.20	1.995	0.133	0.58	921.5	0.032	0.013

Source: ARB, 2011a

2.5.1 Anchorage Emissions

For 2012, there were 37 calls averaging 13.9 hours at anchorage either before or after calling at a Port berth. Emissions at anchorage were estimated in the same way as at berth emissions but with no adjustment for shore power use.

2.6 Emission Results

Estimated total emissions from the Port of Oakland ocean-going vessels are presented in Table 2-10 by operating mode (cruise, RSZ, maneuvering, and berthing). RSZ mode includes all transit between the Bay Bridge and the location where the Bar Pilot boards or disembarks. All vessels calling at the Port of Oakland were assumed to operate small auxiliary boilers on-board. Emissions from propulsion and auxiliary engines and boilers are included in Table 2-10. Because the ARB considers diesel particulate emissions to differ in toxicity from boiler particulate emission, total diesel particulate matter (DPM) emissions from the main and auxiliary diesel engines are provided in Table 2-10. All auxiliary engine PM emissions are DPM because all auxiliary engines are diesel engines. Propulsion steam and auxiliary boiler particulate emissions are not included in the DPM total.

Table 2-10. Emissions totals for OGV calling at the Port of Oakland in 2012 by mode for main and auxiliary engines and boilers – tons.

2012 Inventory	ROG	CO	NO_x	PM_{10}	DPM	$PM_{2.5}$	SO_x	CO_2	CH_4	N_2O	CO_2e
OGV – Cruise	30	42	618	14.0	12.0	13.0	65	24,434	3	1	24,712
OGV – RSZ	38	52	626	15.3	12.7	14.2	70	26,310	3	1	26,598
OGV – Maneuver	72	61	512	13.6	12.4	12.6	34	17,374	2	0	17,551
OGV – Berth	36	75	825	23.7	20.1	22.0	119	64,043	6	1	64,619
OGV – Anchorage	0	1	11	0.3	0.3	0.3	2	845	0	0	853
OGV subtotal	**176**	**232**	**2,591**	**66.9**	**57.4**	**62.1**	**289**	**133,005**	**14**	**3**	**134,332**

3 COMMERCIAL HARBOR CRAFT (DREDGING AND ASSIST TUGS)

This section describes the emissions estimation methodologies and results for two regularly occurring activities at the Port of Oakland: 1) operation and maintenance dredging and disposal, and 2) container vessel assists. Other than a few small work boats that assist dredging operations and the dredges themselves, tugs are the primary category of commercial harbor craft that are a part of the Port's maritime emissions inventory. This inventory does not include dredging and vessel assist activities at the privately owned Schnitzer Steel bulk terminal berths or emissions from harbor pilot boats based in San Francisco.

3.1 Operation and Maintenance Dredging and Disposal

3.1.1 Background and Limitations

Operation and maintenance (O&M) dredging is conducted annually at the Port of Oakland to maintain the depth of channels and berths and to ensure safe navigation. O&M dredging removes material that is deposited into the Bay by stream and urban runoff and eliminates shallow areas created by the redistribution of bottom sediments through a process known as "shoaling." To protect sensitive species, such as the California Least Tern, O&M dredging is conducted during a limited period. The channel dredging has begun as early as October and ended as late as March, while berth dredging was conducted from August through November.

The Port and the US Army Corps of Engineers (USACE) contract separately for O&M dredging at the Port's berths and in the Federal channels serving the Port, respectively. During 2012, dredging was conducted by a diesel-powered clamshell dredge, accompanied by a tender and supported by a survey boat.

Dredged material is transferred into scows (barges) which are then pushed or towed by a diesel-powered tug to a disposal or reuse site. After the barge is emptied, the tug returns with the empty barge to pick up a new load.

In 2012 contractors working for the Port and the USACE removed approximately 1.24 million cubic yards of material during O&M dredging operations (POAK, 2013 and USACE, 2013). All of the 183,084 cubic yards of material excavated from berths under contract to the Port was disposed of at the Montezuma wetlands, a privately owned and operated site located in the Sacramento-San Joaquin River delta adjacent to Montezuma Slough in Solano County. Of the material removed by USACE, 728,062 cubic yards of material dredged at the beginning of 2012 as completion of the 2011 fiscal year dredging in the Federal channel were sent to Montezuma wetlands. In addition, 328,700 cubic yards of material dredged in fall of 2012 were sent to the San Francisco Deep Ocean Disposal Site (SF-DODS). The SF-DODS is an open water site located approximately 49 nautical miles west of the Golden Gate.

3.1.2 Methodology

To estimate emissions, O&M dredging and disposal activities were treated as two separate activities: 1) dredging (operation of the clamshell dredge and associated support vessels), and

2) disposal (transport of dredge materials from the dredging area to disposal sites). Emissions from these activities were summed to form the final total emissions estimate.

3.1.2.1 Dredging

Dutra Construction, the contractor responsible for the 2012 POAK berth dredging project and more than half of the 2012 calendar year channel dredging volume, has provided a list of equipment used for O&M and channel deepening dredging; they include:

- A clamshell dredge with two diesel engines,
- A dredge tender with two diesel engines,
- A survey with two diesel engines,
- An unpowered scow into which the dredged material was loaded for disposal or reuse.

The basic equation used to calculate emissions from each of the engines involved in dredging is:

$$Equip_{Emiss} = \frac{EF \times Time_{hrs} \times Engine_{bhp} \times LF_{wt}}{(453.6 \times 2000)}$$

Where:

$Equip_{Emiss}$ is the engine's emissions in tons per year,
EF is the engine emission factor in grams per brake horsepower-hour,
$Time_{hrs}$ is the annual operating hours,
$Engine_{bhp}$ is the brake horsepower rating of the engine,
LF_{wt} is the time weighted engine load factor (fraction of full load), based on different engine operating modes during a round trip, and
(453.6 x 2000) is the conversion factor from grams to tons.

3.1.2.2 Dredged Materials Disposal

In 2012 all dredged material was disposed of by removing it to an offsite disposal area. In a typical operation, a diesel powered tug pushes or tows the loaded scow to its destination and, after unloading, pushes the empty barge back to the dredge. The tow boat tug has two main propulsion engines and one or two auxiliary engines.

The basic equation used to calculate main propulsion and auxiliary engine emissions from the tug is:

$$Tug_{emiss} = \frac{EF \times Engine_{bhp} \times Time_{hrs} \times LF_{wt} \times Trips}{(453.6 \times 2000)}$$

Where:

Tug_{emiss} is the tug emissions in tons per year,
EF is the tug main propulsion or auxiliary engine emission factor in grams per brake horsepower-hour,

> $Engine_{bhp}$ is the combined brake horsepower rating of a tug's main propulsion engines and the brake horsepower rating of the auxiliary engines,
> $Time_{hrs}$ is the tug operating time per round trip in hours,
> LF_{wt} is the time weighted engine load factor (fraction of full load), based on different engine operating modes during a round trip,
> *Trips* is the annual number of round trips per tug, and
> *(453.6 x 2000)* is the conversion factor from grams to tons.

Once it reaches the disposal area, a barge or scow is unloaded either by gravity or mechanically. Unloading at the ocean disposal site SF-DODS was accomplished by gravity - that is, by opening the bottom of the scow and allowing material to flow out. At land-based sites the scows are mechanically unloaded for redistribution ashore. At Montezuma, a dedicated shore powered electric "off-loader" was used to draw the wet material out of the barge and pump it upland for distribution.

Dredging performed by the USACE in the federal channel serving the Port during 2012 was all associated with normal maintenance activity and is therefore included in the Port's 2012 emission inventory.

3.1.3 Input Data and Emissions

Key input data for estimating dredging emissions include the physical characteristics of the equipment used by the Port and USACE contractors, equipment emission factors, engine load factors, the volume of material removed, and the hours of operation. ENVIRON has used engine characteristic data provided by the dredging contractor in combination with ARB-approved values for regional default emission factors, deterioration factors, fuel correction factors, and load factors to estimate emissions for all engines used (ARB 2011).

The 2012 berth dredging at the Port occurred from August to November, and all of the dredged material was sent to Montezuma wetlands. The USACE dredging occurred during two separate periods in 2012: (a) between January and March as a completion of the 2011-12 calendar year dredging, and (b) between October and December as part of the 2012-13 calendar year dredging. Dredged material from the CY2011-12 project was sent to Montezuma wetlands, and that from the CY2012-13 project was disposed at the deep ocean disposal site SF-DODS. ENVIRON has collected dredging volume and trip log data from both the Port and USACE. A one-way trip between the Port of Oakland and Montezuma wetlands was estimated at approximately 44.5 nautical miles, as shown in Figure 3-1 below. Because the SF-DODS disposal site is outside the geographic scope of the Port of Oakland emission inventory, ENVIRON included only the portion of the USACE disposal trips between the Bay Bridge and the West Buoy near the Farallon Islands in the inventory calculations; this one-way distance measures approximately 22.2 nautical miles. Taking live data from the Marine Traffic[3] website, ENVIRON observed that the Arthur Brusco traveled at 8 knots between the SF-DODS site and the Bay Bridge. ENVIRON assumes this is a representative average speed of the tugs.

[3] Marine Traffic live map http://www.marinetraffic.com/ais/

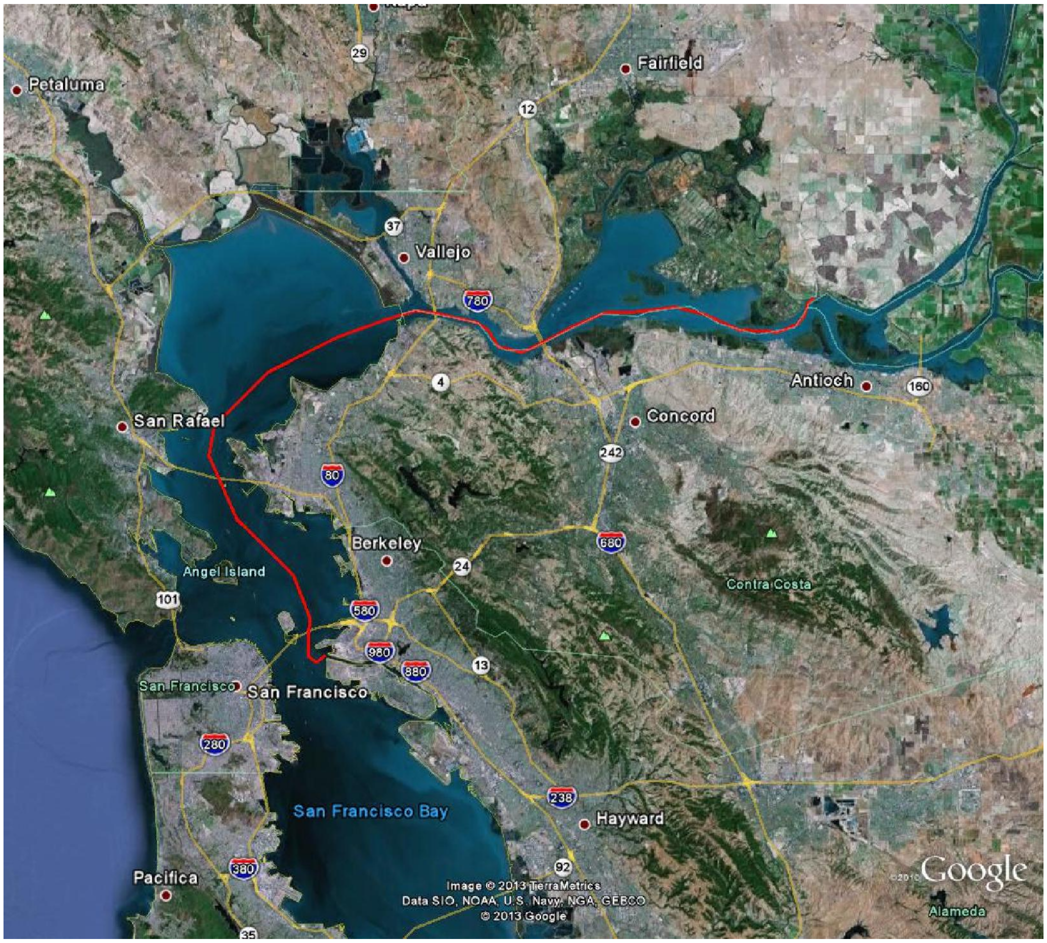

Figure 3-1. Approximate transit route for barge tugs between the Port of Oakland and the Montezuma site. Source: Google Earth.

The tug Arthur Brusco was used to transport most of the materials dredged from the Port berth maintenance dredge project in 2012, and no tugs were identified for the USACE contracted Federal Channel dredging projects. Therefore, ENVIRON used the characteristics of the Arthur Brusco (USACE 2010) to represent the tug boats used to transport materials from all dredging projects. Emptying of loaded barges at the SF-DODS (performed via a gravity method) and at Montezuma Slough (performed via use of an electric powered off-loader) did not result in any additional emissions.

Input data and assumptions for dredging are summarized in Table 3-1(a), and emission factors associated with each type of equipment are summarized in Table 3-1(b). Table 3-2 presents the resulting emissions.

Table 3-1(a). Operation & maintenance dredging - key data and variables.

Equipment	HP	Load Factor	Capacity (cy/hr)	Volume (cy)		Hours	
				POAK	USACE	POAK	USACE
DB 24 Dredger (berth dredging)	425	0.51	187	183,084	1,056,762	811	N/A
DB Paula (channel dredging)	1,200	0.51				N/A	4,684
Jeanette C. Tender [1]	920	0.38	N/A	N/A	N/A	243	1,405
Survey Boat [2]	300	0.38	N/A	N/A	N/A	162	937

[1] Per Dutra the tender operates 30% of the time the dredge operates
[2] Assume boats operate 20% of time the dredge operates

Table 3-1(b). Operation & maintenance dredging – emission factors.

Equipment	Adjusted Emission Factors in g/bhp-hr								
	ROG	CO	NO_x	SO_x	PM_{10}	$PM_{2.5}$	CO_2	CH_4	N_2O
DB 24 Dredger (berth dredging)	0.14	1.12	2.45	0.01	0.11	0.10	565	0.04	0.00
DB Paula (channel dredging)	0.30	1.21	7.00	0.01	0.17	0.16	568	0.05	0.00
Jeanette C. Tender	1.67	3.86	16.34	0.01	0.68	0.63	670	0.15	0.02
Survey Boat	0.84	3.77	4.88	0.01	0.18	0.17	670	0.08	0.02

Table 3-2. Operation & maintenance dredging emissions - 2012 (tons/yr).

	Equipment	ROG	CO	NO_x	SO_x	PM_{10}	$PM_{2.5}$	CO_2	CH_4	N_2O	CO_2e
POAK	Dredger	0.06	0.23	1.36	0.00	0.03	0.03	110	0.01	0.00	110
	Tender	0.16	0.36	1.53	0.00	0.06	0.06	63	0.01	0.00	64
	Survey Boat	0.02	0.08	0.10	0.00	0.00	0.00	14	0.00	0.00	14
	Annual Tons	***0.23***	***0.67***	***2.99***	***0.00***	***0.10***	***0.10***	***187***	***0.03***	***0.00***	***188***
USACE	Dredger	0.44	3.53	7.75	0.02	0.34	0.31	1,786	0.13	0.00	1,788
	Tender	0.91	2.09	8.85	0.00	0.37	0.36	363	0.08	0.01	368
	Survey Boat	0.10	0.44	0.58	0.00	0.02	0.02	79	0.01	0.00	80
	Annual Tons	***1.45***	***6.07***	***17.18***	***0.02***	***0.73***	***0.69***	***2,227***	***0.22***	***0.01***	***2,236***
Total		**1.68**	**6.74**	**20.17**	**0.02**	**0.83**	**0.79**	**2,414**	**0.25**	**0.02**	**2,424**

3.1.3.1 Dredge Materials Disposal

Tables 3-3 and 3-4 summarize the key input data and assumptions used to calculate emissions from dredge materials disposal activities. Emissions are summarized in Table 3-5.

Table 3-3. Dredged material transport tug engine characteristics (Arthur Brusco was the representative tug).

Engine	HP	Load Factor	Adjusted Emission Factors in g/bhp-hr								
			ROG	CO	NO_x	SO_x	PM_{10}	$PM_{2.5}$	CO_2	CH_4	N_2O
Main	2460	0.68	0.73	3.87	5.41	0.01	0.18	0.16	670	0.07	0.02
Auxiliary	282	0.43	0.85	3.83	4.94	0.01	0.19	0.17	670	0.08	0.02

Reference: United State Army Corp of Engineers: http://www.ndc.iwr.usace.army.mil/veslchar/veslchar.htm

Table 3-4. Dredged material transport activities.

	Destination	Distance (naut mi)	Speed (knot)	Time (hours)	Trips	Volume (cy)
USACE	Montezuma	44.5	8	5.56	270	728,062
	SF-DODS[1]	22.2	8	2.78	85	328,700
POAK	Montezuma	44.5	8	5.56	61	183,084

[1] The location of SF-DODS is out of the scope of this inventory; the distance shown here and the emissions modeled reflect that from the Bay Bridge to the West outer buoy.

Table 3-5. Dredged material disposal emissions in 2012 (tons per year).

	Engine	ROG	CO	NO_x	SO_x	PM_{10}	$PM_{2.5}$	CO_2	CH_4	N_2O	CO_2e
POAK	Main	0.91	4.85	6.77	0.01	0.22	0.21	838	0.08	0.03	848
	Aux	0.08	0.35	0.45	0.00	0.02	0.02	61	0.01	0.00	61
	POAK Total	**0.99**	**5.19**	**7.22**	**0.01**	**0.24**	**0.23**	**899**	**0.09**	**0.03**	**909**
USACE	Main	4.65	24.82	34.68	0.04	1.13	1.10	4,294	0.42	0.13	4,342
	Aux	0.39	1.77	2.29	0.00	0.09	0.08	311	0.04	0.01	314
	USACE Total	**5.05**	**26.60**	**36.97**	**0.04**	**1.22**	**1.18**	**4,605**	**0.45**	**0.14**	**4,657**
Total		**6.03**	**31.79**	**44.19**	**0.05**	**1.46**	**1.41**	**5,504**	**0.54**	**0.16**	**5,566**

3.1.4 Dredging Emission Summary Results

Total emissions from Table 3-2 (dredging) and Table 3-5 (dredged material disposal) combined are listed in Table 3-6.

Table 3-6. Summary of operation & maintenance dredging emissions in 2012 (tons per year.

Activity	ROG	CO	NO_x	SO_x	PM_{10}	$PM_{2.5}$	CO_2	CH_4	N_2O	CO_2e
Dredging	1.68	6.74	20.17	0.02	0.83	0.79	2,414	0.25	0.02	2,424
Disposal	6.03	31.79	44.19	0.05	1.46	1.41	5,504	0.54	0.16	5,566
Total	**7.71**	**38.53**	**64.36**	**0.07**	**2.29**	**2.20**	**7,918**	**0.79**	**0.18**	**7,990**

3.2 Assist Tugs

3.2.1 Background

This section describes the emissions estimation methods and results for operation of tugs that assisted cargo vessel movements upon arrival and departure from the Port. Assist tug operations include two modes: the actual vessel assist operation and the transit trips the tugs make to and from their various berthing bases to conduct the assists.

The role of the assist tugs is to ensure safe navigation, which is particularly important in windy weather and when vessels turn to reverse direction within the Inner or Outer Harbors. As discussed in Section 2, cargo vessels operating in the San Francisco Bay have Bar Pilots on board to guide each vessel to and from its destination. On average, two tugs were used for each cargo vessel inbound or outbound between berths at the Port and the Federal Channel near the Bay Bridge.

Tugs perform a variety of services around the Bay including vessel escort, berthing and departure assists at Bay Area ports and refineries; and towing or pushing a wide variety of barges and other equipment. Not all tugs are equipped or certified to provide assist services to container vessels calling at the Port. Cargo vessels vary greatly in size and maneuverability, and the tugs that assist them have different power levels, rudders and other equipment. To ensure safe navigation, it is important that tugs be properly powered and equipped to handle the vessels they are assisting. The San Francisco Bar Pilots published a guideline document that sets minimum requirements for tugs based largely on the length and draft of the vessel they will assist (San Francisco Bar Pilots, 2013). As might be expected, larger vessels require more tugs (up to five) and the tugs must be larger and more powerful.

Tugs assigned to ships calling at the Port of Oakland are primarily from three companies; AMNAV (part of Foss Marine Holdings, so Foss and AMNAV activity was combined), Starlight Marine (part of Harley Marine), and Crowley (operates a combined fleet with BayDelta Maritime, so these two companies were assumed to be one fleet). These three combined fleets provided more than 99% of the tug assists at the Port in 2012. AMNAV and Crowley based their tugs at or near Berth 9 on the Outer Harbor of the Port, and Starlight tugs are based on the Alameda side of the Inner Harbor Turning Basin for the Port. Tugs from these companies also operate elsewhere in the Bay, but the activity estimated in this study included only activity necessary during transiting and assisting for the Port of Oakland ship calls.

Vessel call data specific to the Port of Oakland are available from the Marine Exchange as described in Section 2. These data include the number of tugs by tug operator that performed each vessel assist, but do not identify the individual tugs that provided the assist.

3.2.2 Methodology

ENVIRON closely followed the updated emissions estimation methodology that was developed for ARB's Commercial Harbor Craft Emission Inventory Database (ARB, 2011b). The ARB methodology provides emission factors that are specific to main propulsion and auxiliary engine model year, and applies both an engine emissions deterioration rate and a fuel correction factor.

The basic equation used to calculate emissions from each group of assist tugs is the following:

$$Tug\ Group_{Emiss} = \frac{AEF \times Time_{hrs} \times Engine_{bhp} \times LF_{wt}}{(453.6 * 2000)}$$

Where:

Assist Tug $_{Emiss}$ are the assist tug emissions in tons per year,
AEF is the main engine or auxiliary engine emission factor in grams per brake horsepower-hour, adjusted for model year, deterioration rate and fuel, and averaged by tug class,
Time $_{hrs}$ is the annual operating hours for the tugs in each group, based on the number of vessel calls, the average maneuvering time per call, and the average number of tugs assigned to each inbound and outbound assist,
Engine $_{Bhp}$ is the weighted average main propulsion and/or auxiliary engine brake horsepower rating of the engines in each tug group,
LF $_{wt}$ is the time weighted load factor for the maneuvering phase for the main engine and/or auxiliary engine, taken from the literature or the ARB methodology, stated as a fraction of full load, and
*(453.6 * 2000)* is the conversion of grams to tons.

3.2.3 Input Data and Emissions

There are a number of variables that affect actual tug emissions during an assist event. Among the most important are the following:

- The number of tugs assisting a vessel,
- The horsepower ratings of assist tug propulsion engines, which vary from tug to tug. The load carried by the tug's main propulsion engines, which varies substantially during the assist,
- The time required to complete the assist operation, which varies depending on where the vessel is berthing or departing, and
- The model year of the engines used on the vessel.

In the absence of a central record that identified individual assist tugs and their activities, ENVIRON sought to create a data base that is representative of the fleet of tugs that actually provided assists in 2012. ENVIRON identified individual tugs and their relevant characteristics from tug operator websites (AMNAV, Starlight, and BayDelta 2012), a federal report listing individual vessel characteristics (USACE, 2010), and from publicly available sources identified in Table 3-7.

For the top three assist providers, ENVIRON apportioned the assists for each company amongst the tugs assumed to be in regular use assisting calls to the Port of Oakland. The other tugs in the fleets were assumed to be used for tanker assist functions or were too old to meet the ARB harbor craft standards and assumed to be retired from regular use. The largest and most powerful tugs were assumed to be used primarily for tanker assists based on characteristics of the tugs used for Port of Oakland ship calls during the first part of 2013 and were therefore not included in the set of tugs assumed to be regularly serving the Port of Oakland. Average auxiliary engine horsepower ratings were based on data from tugs for which auxiliary engine characteristics were provided. Tugs operated by the other four companies (representing 0.6% of the assists in 2012), were assumed to have characteristics equivalent to the average characteristics of the top three operators.

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Table 3-7. Assist tug fleet characteristics and other fleet vessels.

	Main Engines				Auxiliary Engines			Assumed Use	Alternative Reference
Vessel	#	Model Year	Engine Model	HP total	#	HP total	Engine Model		
AMNAV (Foss)									
Delta Lindsay	2	2010	Caterpillar 3516C	6850	2	288		Primarily Tanker Assist	http://www.nicholsboats.com/tugboats-delta-lindsey.htm
Independence	2	2007	Caterpillar 3512B	5080				Assist Tug	
Revolution	2	2006	Caterpillar 3512B	5080				Assist Tug	
Sandra Hughes	2	2007	Caterpillar 3512B	5080				Assist Tug	
Liberty	2	2008[a] 1978	Unknown[a] Caterpillar 3512B	3400[a] 4000				Assist Tug	http://www.workboat.com/newsdetail.aspx?id=14814
Patriot	2	1981	EMD 12-645-E6	4800				Assist Tug	
Pacific Combi	2	1994	EMD 12-645	3600				Assist Tug	
Sarah	2	1949	Caterpillar 3508	1550				Retired Historic	
Sir Richard	2	1967	EMD 12-645-E2	3000				Retired Moved	
STARLIGHT (Harley)									
Millennium Falcon	2	2000	Caterpillar 3516B	4400	2	282	Cat. 3304BT	Assist Tug	
Millennium Star	2	2000	Caterpillar 3516B	4400	2	282	Cat. 3304BT	Assist Tug	
Royal Melbourne	2	1981	Cummins KTA 38	2100				Barge Moves	http://www.workboat.com/newsdetail.aspx?id=14814
Z-3	2	1999	Caterpillar 3516B	4000	2	274	Cat. 3406C, 3304DIT	Assist Tug	
Z-4	2	1999	Caterpillar 3516B	4000	2	274	Cat. 3406C, 3304DIT	Assist Tug	
CROWLEY (BayDelta)									
(Delta Billie)	2	2009	Caterpillar 3516C	6800				Tanker Assist	
(Delta Cathryn)	2	2009	Caterpillar 3516C	6800				Tanker Assist	
(Delta Linda)	2	1999	Caterpillar 3516B	4400				Assist Tug	
(Delta Deanna)	2	1999	Caterpillar 3516B	4400				Assist Tug	
Goliah	2	1997	Caterpillar 3516B	4400				Assist Tug	

[a] repowered in 2008

ENVIRON used Port of Oakland specific data to estimate the time tugs spent in the assist mode by assuming that the assist operation coincides with the vessel maneuvering mode. While all assists generally start and end near the Bay Bridge, the time required for ships to maneuver between this location and each berth varies between the Inner and Outer Harbors as described for ocean-going vessel maneuvering time in Section 2. ENVIRON estimated a specific maneuvering time for each vessel call based on berth location (Inner or Outer Harbor) and vessel length.

ENVIRON estimated the time transiting to and from assists for each tug operator using the distances from each operator's home base to various assist destinations, and assuming the transit trips were made at an average speed of 8 knots. Occasionally, tugs may 'lay up' near their next assignment (such as at Berth 38-Nutter Terminal nearest the Bay Bridge or at the berth for the next outbound ship), but no adjustment was made for this circumstance, so assuming a return to base for each assist may result in an overestimate of emissions associated with tug transiting. Transit trips included the following:

- Base to incoming vessel pickup point (about 3.25 nautical miles from Berth 9, and 4 nautical miles from the Inner Harbor turning basin),
- Return trip to base from the Inner and Outer Harbor berths,
- Trip from base to Inner and Outer Harbor berths to begin outbound vessel assist,
- Return to base from the outbound vessel assist.

In summary, ENVIRON estimated the tug assist activity during the assist phase of their operation at the Port of Oakland as follows:

- Allocated annual assists by tug operator, based on the information contained in the Marine Exchange report described above. The report indicated that six tug operators provided assists services but that more than 99% of the assists in 2012 were conducted by three fleets considering subsidiaries and operating arrangements.
- Developed a database that described the key characteristics of the fleet of likely tugs that the three primary tug companies operate at the Port of Oakland.
- Assigned the number of tugs to incoming and outgoing vessel calls based on the Marine Exchange (2013) report, which showed an average of 1.9 tugs per movement.
- Estimate the time that assist tugs operate on Port of Oakland vessel maneuvering
    - While engaged in maneuvering ships inbound and outbound from the Port and
    - While transiting to and from maneuvering assists.

ENVIRON used zero hour emission factors, engine emissions deterioration factors and fuel correction factors for both main propulsion and auxiliary engines from ARB's database emission inventory tool. (ARB, 2011b) However, the main engine load factor was estimated to be 0.31, and the auxiliary engines load factor was estimated to be 0.43. These load factors corresponding to values used in both the Port of Oakland 2005 Seaport Air Emissions Inventory (ENVIRON, 2008) and the latest Port of Los Angeles Inventory of Air Emissions (POLA, 2012).

Table 3-8 summarizes the 2012 activity factors for both the assist and transit modes; emissions estimates for assist tugs are shown in Table 3-9.

Table 3-8. Assist tug emissions, activity input, 2012.

# of Inner Harbor Assists		# of Outer Harbor Assists		Assist Hours	Transit Hours	Total Hours
Inbound	Outbound	Inbound	Outbound			
2117	1874	1286	1486	7,341	3,811	11,152

Average # of tugs per call	Inbound	1.87
	Outbound	1.86

Table 3-9. Tug assist emissions (tons per year).

Engine	ROG	CO	NO_x	SO_x	PM_{10}	$PM_{2.5}$	CO_2	CH_4	N_2O	CO_2e
Main	15.43	50.87	159.19	0.09	6.59	6.39	11,214	1.39	0.33	11,347
Auxiliary	1.48	5.46	11.49	0.01	0.45	0.44	993	1.39	0.03	1,031
Total	**16.92**	**56.33**	**170.69**	**0.10**	**7.04**	**6.83**	**12,207**	**2.78**	**0.36**	**12,378**

Note: Includes both assist and transit modes

3.3 Oil Tanker Barge Tow Boats

3.3.1 Activities and Emissions

In addition to assist tug services, ENVIRON also estimated emissions from towing of an oil tanker barge (OTB) which arrived at Alameda during 2012, made a berth shift and conducted hotelling operations at the Port of Oakland, eventually departing to the Oleum docks near Mare Island. The tow boat used in this operation is modeled after the Millennium Star tug shown in Table 3-7 with the exception that the load factors are representative of those of a tow boat, obtained from the ARB harbor craft database (ARB, 2011b). Besides accounting for the time spent towing the barge from Alameda to Oakland and from Oakland to the Oleum docks, ENVIRON also assumed the tow boat was hotelling where the OTB was berthed, and the auxiliary engine was running during this time. The activities of the tow boat and emissions factors are summarized in Table 3-10(a) and Table 3-10(b), respectively.

Table 3-10(a). Tow boat characteristics and key data input.

	Horsepower		Load Factor		Distance	Time (hours)	
Name	Main	Aux	Main	Aux	(nautical mi)	Shift	at Berth
Millennium Star	4400	282	0.68	0.43	27.8	3.48	10.75

Table 3-10(b). Tow boat emission factors.

Engine	ROG	CO	NO_x	SO_x	PM_{10}	$PM_{2.5}$	CO_2	CH_4	N_2O
Main	0.818	2.198	8.019	0.006	0.370	0.359	670	0.074	0.020
Aux	0.918	2.995	7.801	0.006	0.387	0.375	670	0.083	0.020

Emissions associated with the OTB tow boat are summarized in Table 3-11. All emissions are from diesel engines so all of the PM_{10} is DPM.

Table 3-11. OTB tow boat emissions.

Name	ROG	CO	NO_x	SO_x	PM_{10}	$PM_{2.5}$	CO_2	CH_4	N_2O	CO_2e
Millennium Star	0.01	0.03	0.10	0.00	0.01	0.00	9	0.00	0.00	9

3.4 Summary of Commercial Harbor Craft Emissions

Table 3-12 summarizes the emissions of harbor craft engaged in both O&M dredging and vessel assists. All of the PM_{10} emissions listed here come from diesel engines and are therefore DPM.

Table 3-12. Total harbor craft & dredge emissions, 2012 (tons per year).

Harbor Craft	ROG	CO	NO_x	SO_x	PM_{10} [a]	$PM_{2.5}$	CO_2	CH_4	N_2O	CO_2e
O&M Dredging Emissions	7.71	38.53	64.36	0.07	2.29	2.20	7,918	0.79	0.18	7,990
Assist Tug Emissions	16.92	56.33	170.69	0.10	7.04	6.83	12,207	2.78	0.36	12,378
OTB Tow Boat Emissions	0.01	0.03	0.10	0.00	0.01	0.00	9	0.00	0.00	9
Total Emissions	**24.64**	**94.89**	**235.15**	**0.17**	**9.33**	**9.03**	**20,134**	**3.57**	**0.54**	**20,377**

[a] All PM_{10} emissions are DPM.

4 CARGO HANDLING EQUIPMENT

This section documents the emission estimation methods and results for cargo handling equipment (CHE) operated at Port of Oakland terminals and the rail yard. This inventory does not include CHE at the Schnitzer facility and Union Pacific rail yard because those privately owned facilities are not part of the Port.

4.1 Background

CHE is primarily used to transfer freight between modes of transportation, such as between marine vessels and trucks or between trains and trucks. CHE are used in many types of operations, but at the Port of Oakland, CHE is used almost exclusively to transfer shipping containers. As such, the types of CHE at the Port are mostly limited to yard trucks (hostlers), rubber-tired gantry cranes, top or side handlers (also called picks), and forklifts. Other types of equipment used as CHE for transfer of bulk materials are not found at the Port. Some general purpose equipment types including sweepers, construction, and other off-road equipment used for facility maintenance and construction, are included in the other off-road equipment category (see Section 7) and not in the CHE category.

4.2 Emission Calculation Methodology

The approach used to estimate CHE emissions was to determine annual 2012 emissions for each piece of equipment by terminal according to engine characteristics (model year, rated power, and equipment type) and equipment operation (hours of operation and fuel consumption rates). The equipment population and operation estimates were derived from terminal and rail yard surveys conducted in during the first part of 2013 by the Port of Oakland. Where there were missing data from the surveys, default input estimates were obtained from the inventory guidance documentation published by ARB (2011c).

Per ARB (2011c) guidance, the following types of equipment were used to categorize CHE:

- Cranes (including rubber tire gantry cranes)
- Forklifts
- Container Handling Equipment
- Yard Trucks

Other off-road equipment may be listed under CHE and include general industrial and construction equipment that are most often used to transfer liquid and solid bulk cargo. At the Port, equipment listed as industrial or construction equipment is used primarily for sporadic maintenance and construction activity and may not be considered CHE. The equipment activity and emissions for these equipment types are included in this emission inventory under Section 7.

CHE emissions were calculated using the following equation:

$$Equip_{emiss} = \frac{(EF_{zh} + dr \times CHrs) \times Engine_{bhp} \times FCF \times LF_{wt} \times CF \times Time_{hrs} \times Pop}{(453.6 \times 2000)}$$

Where:

Equip $_{emiss}$ is the annual emissions in tons per year,
EF $_{zh}$ is the zero-hour emission factor in grams per brake horsepower-hour,
dr is the deterioration rate or the increase in zero-hour emissions as the equipment is used (grams/bhp-hr^2),
CHrs is the cumulative hours or total number of hours accumulated on the equipment
FCF is the fuel control factor (% reduction) used to correct for emission reductions due to California diesel fuel,
LF $_{wt}$ is the weighted load factor (average load expressed as a % of rated power),
CF is the control factor (% reduction) associated with use of emission control technologies where applicable,
Time $_{hrs}$ is the annual operating hours of the equipment,
Pop is the population number of the equipment, and
(453.6 x 2000) is a conversion from grams to tons.

4.3 Input Data and Use

Surveys were sent out to the Port of Oakland terminals and rail yards requesting the following detailed information for each piece of CHE. This information was used as input for the emissions calculations.

1. Equipment Type
2. Number of equipment
3. Engine Model
4. Engine Model Year
5. Engine Retrofit Type/Repower
6. Chassis Make / Model
7. Chassis Model Year
8. Fuel Type
9. Annual hours of operation
10. Engine Rated horsepower
11. Fuel consumption per piece of equipment

Surveys were returned for five facilities, and three terminals chose not to provide data. For equipment specific operation and characteristics that were not provided, default assumptions from the CHE emissions inventory guidance documentation published by ARB (2011c) were used. For diesel-powered equipment, the zero-hour emission factors, deterioration rates, fuel correction factors, and emission control factors for HC, CO, NO_x, and PM were obtained from ARB's Cargo Handling Equipment Inventory (CHEI) model (ARB, 2012). Because the current version of the CHEI model does not support emission estimates for other pollutants or other fuel types , emission factors for gasoline and propane powered equipment, and for SO_x and CO_2, were obtained from ARB's 2007 CHE Calculator, following methodologies described in the 2005 Mobile CHE at Ports and Intermodal Rail Yards original rulemaking (ARB, 2005). Emissions factors for greenhouse gases CO_2, CH_4 and N_2O were estimated using OFFROAD 2007 because they were unavailable from either the CHEI or the CHE Calculator. Note that the OFFROAD 2007 model reports N_2O emissions as zero for all of the equipment included in this inventory.

CHE were grouped into equipment type categories as defined by ARB (2011c). The resulting populations by equipment type for the Port of Oakland are summarized in Table 4-1. Out of 585 total pieces of cargo handling equipment, 536 were diesel powered, 30 were gasoline powered, and 19 were LPG (liquid petroleum gas) powered.

Table 4-1. Cargo handling equipment - population by type.

Equipment Type	Equip Population	% Total
Container Handling Equipment	127	22%
Forklift	49	8%
RTG Crane	28	5%
Yard Tractor	237	41%
Yard Tractor On-road	144	25%
Total	**585**	**100%**

Table 4-2 summarizes the average horsepower and annual use by equipment type and power range. Actual annual hours of operation for each piece of equipment were used to estimate emissions.

Table 4-2. Cargo handling equipment - Average horsepower and actual hours of operation by equipment type and horsepower range.

Equipment Type	HP Bin	Equipment Population	Average HP	Average Annual Operation (Hours)
Container Handling Equipment	100	2	85	1,884
	175	5	152	1,862
	300	40	233	1,274
	600	80	330	2,451
Forklift	75	4	64	744
	100	21	97	297
	175	16	148	954
	300	8	208	840
RTG Crane	600	15	385	1,484
	750	3	625	497
	9999	10	1,005	1,500
Yard Tractor	175	198	172	1,852
	300	39	209	2,177
Yard Tractor On-road	175	23	173	11,960
	300	121	223	3,467

4.4 Cargo Handling Equipment Emission Results

Table 4-3 and Table 4-4 present emission results for the CHE by equipment type and by fuel type, respectively, based on the survey data. All PM_{10} from diesel engines listed in Table 4-4 is DPM. $PM_{2.5}$ emissions were calculated as a fraction of PM_{10} based on fuel type using factors provided by ARB (http://www.arb.ca.gov/planning/tsaq/eval/pmtables.pdf).

Table 4-3. 2012 Port of Oakland CHE emissions by equipment type (tons per year).

Equipment Type	ROG	CO	NO_x	SO_x	PM_{10}	CO_2	CH_4	N_2O[a]	CO_2e
Container Handling Equipment	19.30	60.38	222.47	0.23	3.59	12,272	2.24	0.00	12,319
Forklift	1.43	10.11	10.20	0.01	0.15	736	0.87	0.00	754
RTG Crane	2.49	7.21	36.16	0.03	0.50	1,900	0.18	0.00	1,903
Yard Tractor	8.60	87.91	91.49	0.12	2.38	9,398	0.94	0.00	9,417
Yard Tractor On-road	3.55	41.83	53.07	0.16	1.40	14,251	1.09	0.00	14,274
Total	**35.37**	**207.44**	**413.39**	**0.55**	**8.03**	**38,556**	**5.32**	**0.00**	**38,667**

[a] The OFFROAD 2007 model reports N_2O emissions as zero.

Table 4-4. 2012 Port of Oakland CHE emissions by fuel type (tons per year).

Fuel Type	ROG	CO	NO_x	SO_x	PM_{10}	$PM_{2.5}$	CO_2	CH_4	N_2O	CO_2e
Diesel	34.05	152.84	405.84	0.53	7.88[b]	7.25	38,387	4.54	0.00	38,482
Gasoline	0.61	47.44	4.68	0.02	0.13	0.12	N/A	N/A	N/A	N/A
Propane	0.71	7.17	2.87	0.00	0.02	0.01	168	0.79	0.00	185
Total	**35.37**	**207.44**	**413.39**	**0.55**	**8.03**	**7.38**	**38,556**[a]	**5.32**[a]	**0.00**[a]	**38,667**[a]

[a] Assumes GHG emissions from gasoline powered equipment are negligible.
[b] All diesel PM_{10} emissions are DPM.

5 ON-ROAD HEAVY-DUTY TRUCKS

Operations at the Port of Oakland create a demand for truck trips to transport containers between marine terminals, freeway interchanges, and nearby rail yards. Historically, emissions from on-road trucks servicing the Port (drayage trucks) have been an important component of diesel exhaust emissions at the Port. Prior to implementation of the California Air Resources Board's Drayage Truck Regulation, the average drayage truck was older than that of the general on-road truck fleet, resulting in higher emission rates. In addition, drayage trucks generally follow driving patterns consisting of shorter trips, lower average speeds and more stop-and-go driving which generally tend to result in higher emissions per mile traveled.

In 2009, the State of California instituted the Drayage Truck Regulation (ARB, 2009) in an effort to reduce emissions from the relatively old drayage truck fleet. Under this regulation, drayage trucks must be powered by engines with model years 1994 or newer and engines with model years 1994 through 2004 must use a level 3 verified diesel emission control strategy (VDECS) retrofit for PM emissions effectively mandating diesel particulate filters for these engines or be 2007 or later model year engines. By December 31, 2013, all drayage trucks engines must meet or exceed the emission standards for 2007 model year engines. Different emission standards and compliance dates apply to non-drayage trucks.

ENVIRON has defined the study area for the Port of Oakland air emissions inventory to include truck routes between the marine terminals and three nearby freeway interchanges and the two port area rail yards. Trucks must arrive at or depart from the Port area via the three freeway interchanges: Maritime/West Grand Street, Seventh Street, and Adeline/Market Street. Even if trucks arrive by surface streets, they must pass through one of these access points to enter the Port area. The Port emissions inventory also includes truck trips that move intermodal cargo containers between marine terminals and two rail yards in the Port area: Oakland International Gateway (OIG) operated by BNSF and the Union Pacific rail yard.

The following sections describe ENVIRON's methods of calculating the 2012 drayage truck emission inventory, including the equations, assumptions, and the underlying truck activity data and emission factors. ENVIRON combined truck activity from the port with emission factors from the California Air Resources Board's (ARB) on-road emissions factor model (EMFAC2011) to estimate emissions from the drayage trucks moving and idling within the Port area. A summary of the 2012 Port of Oakland truck emission inventory is provided at the end of this chapter.

5.1 Emission Calculation Methodology

ENVIRON calculated emissions separately for four categories: (1) emissions during idling inside marine terminals, (2) emissions during idling at gate queues, (3) emissions from driving within marine terminals, and (4) emissions during driving on surface streets between terminals and freeway interchanges or rail yards.

Emissions were calculated by multiplying the appropriate emission factor (idling or by speed) with the activity level indicator (idling time or trip length). As expressed in the following equation, emissions are the product of the number of trips, distance per trip, and emission rate per mile traveled. For the idling calculation, the emissions are the product of number of trips, average idling time per trip, and emission rate per hour of idling.

$$E_p = (n_{truck\ trip})(miles_{trip})(EF_{p,trip})$$

Where E_p = emissions of pollutant p

n_p = number of trips

$miles_{trip}$ = trip mileage or hours at idle

$EF_{p,\ trip}$ = trip emission factor (grams/mile or grams/hour) for pollutant p

(Requires trip-based EFs defined on the basis of individual link speeds)

A "link" is a term used by transportation planners to describe a segment of roadway. A "trip" for this analysis refers to one-way travel along a multiple links pieced end-to-end. For example, one-way travel from the freeway interchange of 880 at Adeline Street to Hanjin terminal is defined as one trip made up of seven links. Truck speeds differ by link, due to link-specific variables such as posted speed limits, traffic lights, and stop signs.

Inputs to the emissions calculations are:

1. Number of truck trips, traveling between
    a. Marine terminal and freeway
    b. Marine terminal and rail yard
    c. Rail yard and freeway
2. Trip mileage
    a. Outside terminals and rail yards
    b. Within terminals and rail yards
3. Truck idling time
    a. Entrance queues at terminals and rail yards
    b. Within terminals and rail yards
4. Emission Factors derived from the EMFAC2011 model based on
    a. Age distribution
    b. Individual link speeds comprising a trip
    c. Idle emission rate

5.2 Truck Trip Counts

ENVIRON estimated the number of truck trips from two data sources: 1) a survey of gate counts and 2) container lifts. A gate count refers to the terminal recordkeeping of the number of trucks entering a marine terminal. Container lifts (i.e., the number of containers moved onto or off a ship) provide a second data source by which to estimate the number of truck trips. Container lift data are considered to be reliable because payments to operators are based on the number of lifts. However, trucks may move a container in and out on single terminal entry or move no containers at all when repositioning empty chasses or other reasons.

ENVIRON estimated the 2012 truck trip counts two ways. First, for the three terminals which did not respond to the survey questionnaire, ENVIRON multiplied the truck trips from a survey conducted in 2008 by the ratio of lifts in 2012 to lifts in 2008. Second, ENVIRON compared the gate count survey data for the remaining terminals with the lift-based estimates. In general, ENVIRON considered the 2012 surveyed gate counts to be more representative of the actual number of truck trips than using the 2008 estimates multiplied by a ratio of lift data because the gate counts represented 2012 data provided by terminal operators. Table 5-1 summarizes the resulting estimated total number of truck trips for the Port area in 2012.

Table 5-1. On-road trucking – estimated truck trips in 2012.

Terminal Type	Estimated 2012 truck trips
Marine	2,244,966
Rail[1]	94,826

[1] Rail results are only reported for the rail yard located within the Port boundary (BNSF-operated OIG). Trips to the Union Pacific rail yard were assumed to be twice the number to the OIG rail yard reflecting a small decrease in activity at this rail yard from 2005.

5.3 Truck Trip Definitions

This section defines trip routes and link speeds for trucks traveling outside the marine terminals, between marine terminals and rail yards or any of the three freeway interchanges. In-terminal driving is discussed separately. The scope of this study precluded identifying the precise routes of individual trips. Instead, ENVIRON used a simple but accurate method to capture the VMT and estimate trip speeds.

As previously mentioned, one-way trips can occur between any marine terminal and any freeway interchange or rail yard as listed in Table 5-2.

Table 5-2. On-road trucking – list of marine terminals, freeway interchanges, and rail yards.

Berths	Terminal
B 20-23, 24-26	PortsAmerica
B 30, 32	Trapac
B 35, 37	Nutter
B 55-56	Hanjin
B 57-59	OICT
B 60-63	APL
B 67-68	Howard

Freeway Interchange
Adeline/Market Street
7th Street
Grand/Maritime Street

Rail yard
OIG (BNSF)
Union Pacific

These locations are shown on the Port of Oakland map in Figure 5-1. Roadway links numbered 0 through 33, which make up potential truck routes, are also labeled.

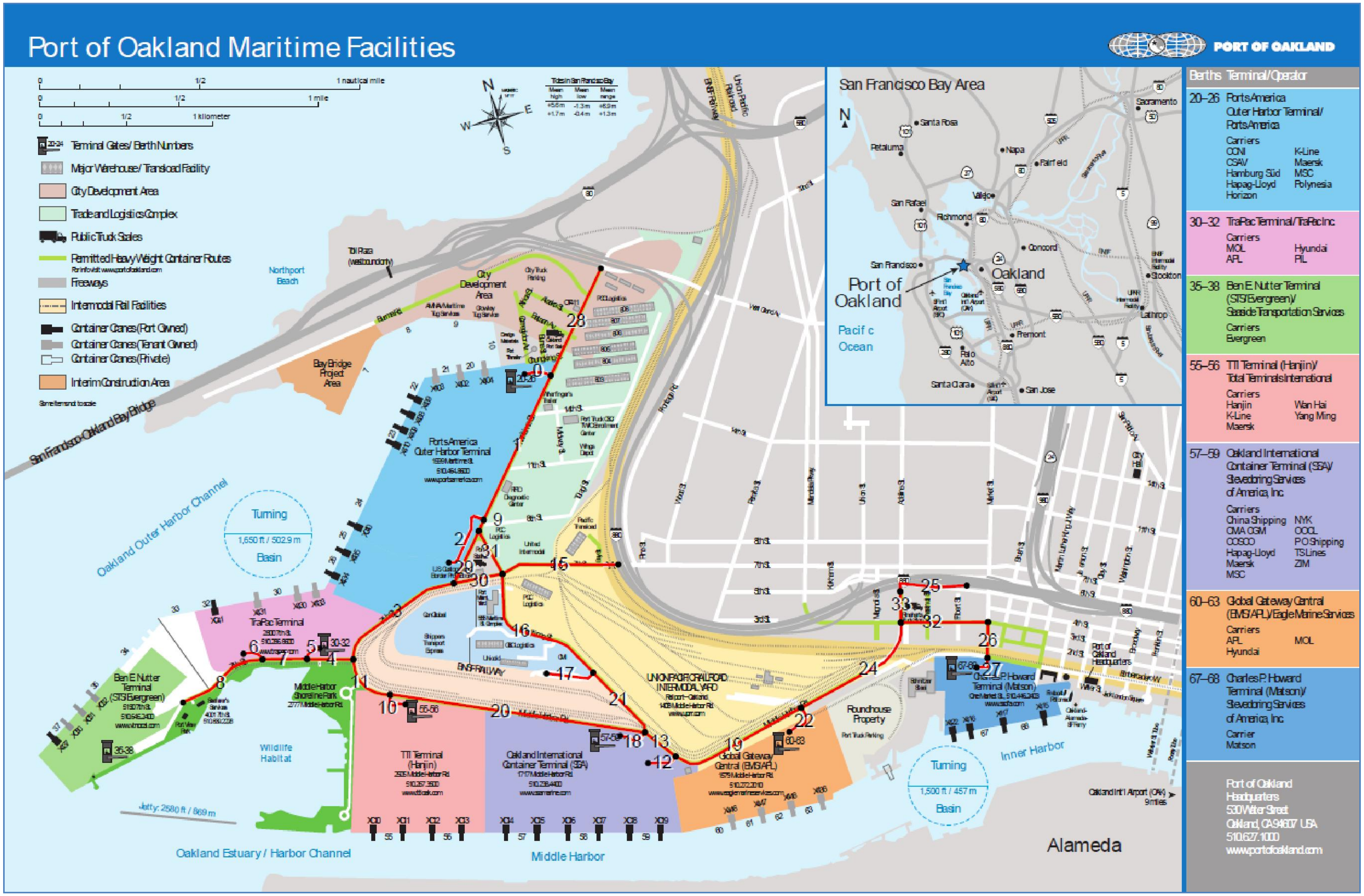

Figure 5-1. On-road trucking – roadway links within the Port of Oakland.

While the precise routes for truck trips between terminals and the highway are not known, geographic proximity influences which highway interchange truck drivers will prefer—Adeline/Market Street, 7th Street, or Grand/Maritime Street. ENVIRON used the distribution of truck trips between freeway and Port terminals shown in Table 5-3. This trip distribution is based on historic surveys conducted at the port (CCS, 2003) and ENVIRON's subsequent analysis of the data for the Port's 2005 emission inventory (ENVIRON, 2008).

Table 5-3. On-road trucking distribution of truck trips between freeway and Port Terminals.

Berths	Terminal	Fraction of Traffic		
		Adeline/Market	7th Street	West Grand/ Maritime
B 20-26	PortsAmerica	0%	30%	70%
B 30-32	Trapac	0%	65%	35%
B 35-37	Nutter	0%	65%	35%
B 55-56	Hanjin	0%	65%	35%
B 57-59	OICT	5%	65%	30%
B 60-63	APL	40%	40%	20%
B 67-68	Howard	100%	0%	0%

Based on the preferred routes indicated in Table 5-3, ENVIRON combined individual links to create realistic trip routes to assign to the total trip counts. Table 5-4 lists all possible constructed trips, their constituent links, total distance, and average speed. ENVIRON determined the trip distances by summing over individual links. Reported average speeds are the VMT-weighted averages of the links by trip. ENVIRON used the same link-level speeds determined from a previous study performed for the 2005 calendar year inventory (ENVIRON, 2008).

Table 5-4. On-road trucking – trip IDs, constituent link IDs, total distance, and average speeds.

Trip ID	Terminal	Berth	Trip Beginning/ End	Road Link Segments, One-way	One-way Trip Length (feet)	Average Speed (mph)
T1	PortsAmerica	B 20-23	West Grand	0, 28	3,193	30
T2	PortsAmerica	B 20-23	7th	0, 1, 9, 31, 15	6,780	32
T3	PortsAmerica	B 20-23	Adeline	0, 1, 9, 31, 16, 21, 13, 19, 24, 33, 25	15,635	31
T4	PortsAmerica	B 20-23	BNSF	0, 1, 9, 31, 16, 17	8,816	29
T5	PortsAmerica	B 20-23	Union Pacific	0, 1, 9, 31, 16, 21, 13, 19	12,189	32
T6	PortsAmerica	B 24-26	West Grand	2, 1, 28	6,401	34
T7	PortsAmerica	B 24-26	7th	2, 9, 31, 15	4,580	26
T8	PortsAmerica	B 24-26	Adeline	2, 9, 31, 16, 21, 13, 19, 24, 33, 25	13,435	29
T9	PortsAmerica	B 24-26	BNSF	2, 9, 31, 16, 17	6,616	24
T10	PortsAmerica	B 24-26	Union Pacific	2, 9, 31, 16, 21, 13, 19	9,989	29
T11	Trapac	B 30	West Grand	5, 4, 3, 29, 9, 1, 28	9,888	33
T12	Trapac	B 30	7th	5, 4, 3, 30, 15	6,280	30
T13	Trapac	B 30	Adeline	5, 4, 11, 20, 13, 19, 24, 33, 25	13,462	34
T14	Trapac	B 30	BNSF	5, 4, 3, 30, 16, 17	8,316	27

Trip ID	Terminal	Berth	Trip Beginning/ End	Road Link Segments, One-way	One-way Trip Length (feet)	Average Speed (mph)
T15	Trapac	B 30	Union Pacific	5, 4, 11, 20, 13, 19	10,016	36
T16	Trapac	B 32-33	West Grand	6, 7, 4, 3, 29, 9, 1, 28	11,301	32
T17	Trapac	B 32-33	7th	6, 7, 4, 3, 30, 15	7,693	29
T18	Trapac	B 32-33	Adeline	6, 7, 4, 11, 20, 13, 19, 24, 33, 25	14,875	34
T19	Trapac	B 32-33	BNSF	6, 7, 4, 3, 30, 16, 17	9,729	28
T20	Trapac	B 32-33	Union Pacific	6, 7, 4, 11, 20, 13, 19	11,429	35
T21	Nutter	B 34-35, 37-38	West Grand	8, 7, 4, 3, 29, 9, 1, 28	12,474	34
T22	Nutter	B 34-35, 37-38	7th	8, 7, 4, 3, 30, 15	8,866	33
T23	Nutter	B 34-35, 37-38	Adeline	8, 7, 4, 11, 20, 13, 19, 24, 33, 25	16,048	35
T24	Nutter	B 34-35, 37-38	BNSF	8, 7, 4, 3, 30, 16, 17	10,902	30
T25	Nutter	B 34-35, 37-38	Union Pacific	8, 7, 4, 11, 20, 13, 19	12,602	37
T26	Hanjin	B 55-56	West Grand	10,11, 3, 29, 9, 1, 28	11,201	33
T27	Hanjin	B 55-56	7th	10,11, 3, 30, 15	7,593	30
T28	Hanjin	B 55-56	Adeline	10, 20, 13, 19, 24, 33, 25	11,555	32
T29	Hanjin	B 55-56	BNSF	10, 20, 21, 17	7,068	32
T30	Hanjin	B 55-56	Union Pacific	10, 20, 13, 19	8,109	34
T31	OICT	B 57-59	West Grand	18, 21, 16, 31, 9, 1, 28	11,849	32
T32	OICT	B 57-59	7th	18, 21, 16, 15	7,534	28
T33	OICT	B 57-59	Adeline	18, 13, 19, 24, 33, 25	8,307	27
T34	OICT	B 57-59	BNSF	18, 21, 17	3,820	21
T35	OICT	B 57-59	Union Pacific	18, 13, 19	4,861	26
T36	APL	B 60-63	West Grand	22, 19, 13, 21, 16, 31, 9, 1, 28	15,632	31
T37	APL	B 60-63	7th	22, 19, 13, 21, 16, 15	11,317	28
T38	APL	B 60-63	Adeline	22, 24, 33, 25	5,214	25
T39	APL	B 60-63	BNSF	22, 19, 13, 21, 17	7,603	25
T40	APL	B 60-63	Union Pacific	22	1,768	15
T41	Howard	B 67-68	West Grand	27, 26, 32, 24, 19, 13, 21, 16, 31, 9, 1, 28	19,074	32
T42	Howard	B 67-68	7th	27, 26, 32, 24, 19, 13, 21, 16, 15	14,759	30
T43	Howard	B 67-68	Adeline	27, 26, 32, 33, 25	3,720	23
T44	Howard	B 67-68	BNSF	27, 26, 32, 24, 19, 13, 21, 17	11,045	28
T45	Howard	B 67-68	Union Pacific	27, 26, 32, 24	5,210	28

5.4 Truck Idling and VMT inside Terminals

The amount of vehicle miles traveled (VMT) within marine and rail terminals is limited to driving between the terminal gates and container storage areas. Previously, the Port conducted surveys of terminal operators to determine in-terminal VMT and average speed in 2005 and again in 2008. ENVIRON used these previous survey data to estimate 2012 per-truck activity, but with an important update to reflect more on-terminal VMT per truck within the expanded Trapac terminal. In addition, ENVIRON cross-checked the previous study data with new survey data of '*Turn Time*,' which represents the elapsed time spent in the terminal as measured by the Out-Gate Time stamp minus the In-Gate Time stamp. For each terminal, ENVIRON calculated the total in-terminal time as the sum of idling time plus VMT divided by speed and compared this result to the survey Turn Time, where available. Where the times spent in terminal did not match survey turn time, ENVIRON adjusted the idling time assumptions accordingly. Table 5-5 below shows the activity summary for the average truck idling at gates, idling in terminal, and driving in-terminal along with average speed in-terminal.

Table 5-5. On-road trucking – average in-terminal activity parameters.

Mode	Average estimate
Idling at gate (hrs)	0.17
Idling in terminal (hrs)	0.33
Distance traveled (mi)	2.59
Speed (mph)	13.3

5.5 Emission Factors and Age Distribution

ENVIRON used the California ARB's on-road emission factor model *EMFAC2011* to calculate emission factors for trucks idling and moving in the Port area. Emission factors from on-road trucks depend on the age distribution of the trucks and site conditions such as temperature, humidity, and especially average speeds. The age distribution is particularly important because of ARB's drayage truck regulations that affect specific model years, causing steep declines in NO_x and PM in 2003 as shown in Figure 5-2. The EMFAC2011 model accounts for the benefits of all (as of March 2013) drayage truck regulations applicable to calendar year 2012, including:

1. Model years 1993 and older are prohibited.
2. Model years 1994-2004 must reduce PM by 85% with a Level 3 VDECS.[4]
3. Model years 2005-2006 are exempt from PM standards during CY 2012.
4. Model years 2007-2009 meet 2007 engine emission standards for NO_x and PM.
5. Model years 2010 and newer meet 2010 engine emission standards for NO_x.

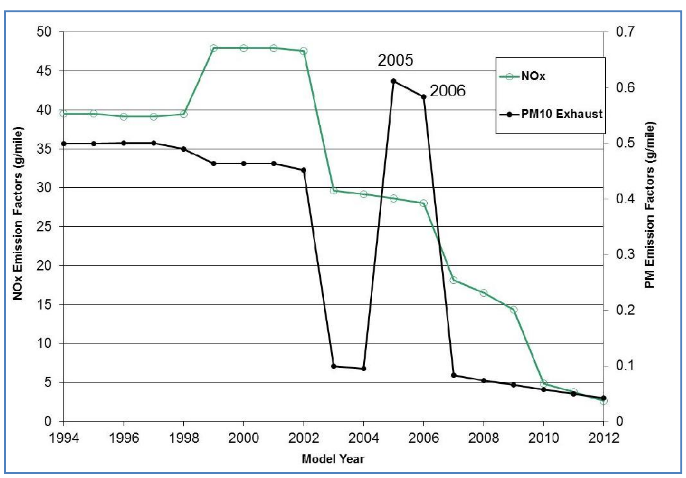

Figure 5-2. EMFAC2011 calendar year drayage truck emission factors by model year for PM and NO_x at 25 mph.

[4] Very few model year 2004 trucks are in the drayage fleet since retrofitting these trucks is not cost-effective given the short (two year) compliance window.

The truck age distribution used in this analysis was developed from early November 2012 registration data[5] collected by the Port under the Secure Truck Enrollment Program (STEP). Approximately 6,500 trucks are registered for STEP. Out of those, 5 trucks are older than model year 1994 and thus are prohibited from performing drayage under the ARB rule, so ENVIRON assumed these trucks did not participate in any trips. To simplify the calculations, ENVIRON grouped approximately 200 model year 2013 trucks with the 2012 model year category. The resulting age distribution is shown in Figure 5-3, along with emission factors for multiple pollutants by model year. Emission factors shown in Figure 5-3 represent emissions per mile for an average speed of 25 miles per hour (mph).

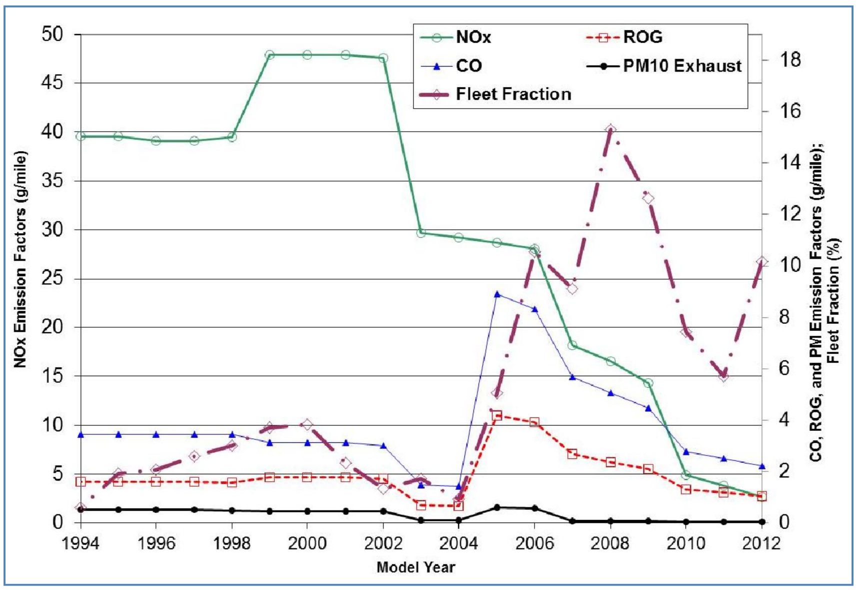

Figure 5-3. Drayage trucking – drayage truck emission factors and age distribution.

The age distribution (fleet fraction) shown in Figure 5-3 indicates that model year 2008 comprised the largest percentage (15%) of the Port's truck fleet in 2012. Modern low emission trucks between model years 2007-2012 together made up 60% of the truck fleet in 2012.

Table 5-6 lists all emission factors for the Port's truck fleet in 2012, including idling (grams/hour) and driving (grams/mile) by speed.

[5] http://www.portofoakland.com/maritime/truck_registry_fact.asp

Table 5-6. Port of Oakland specific average drayage truck emission factors in 2012.

Speed	ROG	CO	NO_x	PM_{10} Total	PM_{10} Exhaust	SO_x	Unit
Idle	7.96	42.75	70.10	0.55	0.55	0.067	g/hour
5 mph	3.67	7.01	30.27	0.40	0.30	0.017	g/mile
10 mph	2.14	4.49	21.41	0.33	0.24	0.017	g/mile
15 mph	1.09	2.72	15.25	0.28	0.19	0.017	g/mile
20 mph	0.46	1.55	11.45	0.24	0.14	0.017	g/mile
25 mph	0.40	1.42	10.69	0.23	0.13	0.017	g/mile
30 mph	0.34	1.32	10.06	0.22	0.12	0.017	g/mile
35 mph	0.29	1.25	9.55	0.22	0.12	0.017	g/mile
40 mph	0.25	1.21	9.17	0.23	0.13	0.017	g/mile
45 mph	0.22	1.20	8.91	0.24	0.14	0.017	g/mile

5.6 Drayage Truck Emissions Results

Drayage trucks that provided service to the Port of Oakland marine terminals and rail yards emitted approximately 135 tons of NO_x and 3 tons of PM within the Port area during 2012 as shown in Table 5-7. Trucks travel on surface roads represented the largest source of emissions of NO_x, PM, and SO_x. For the pollutants ROG and CO, the largest contributors were in-terminal driving and in-terminal idling, respectively. This demonstrates the relative importance of each source area for different pollutants. Idling and slow speed driving produces higher emission rates for all pollutants, but for some pollutants the difference is more extreme. For example, CO has much higher emission rates during idling than during driving (refer back to Table 5-6), relative to the other pollutants. For PM and SO_x, idling contributed a relatively minor amount to total emissions. The $PM_{2.5}$ size fraction estimate was derived from an ARB estimate (http://www.arb.ca.gov/planning/tsaq/eval/pmtables.pdf) for diesel exhaust, tire and brake wear. All trucks use diesel engines, so the PM_{10} exhaust emissions are all DPM emissions.

Table 5-7. 2012 total emissions by trucks within the terminal and outside the terminal to the nearest freeway entrance (tons per year).

Emission Category	Emissions (tons/year)										
	ROG	CO	NO_x	PM_{10} Total	PM_{10} Exhaust[a]	$PM_{2.5}$	SO_x	CO_2	CH_4	N_2O	CO_2e
Surface roads	3.14	11.19	80.0	1.76	1.02	1.21	0.127	14,849	0.185	0.455	14,994
Gate idling in queue	1.76	9.48	15.5	0.12	0.12	0.11	0.015	1,544	0.104	0.051	1,562
In terminal driving	4.32	9.86	9.9	0.88	0.60	0.65	0.049	8,594	0.254	0.175	8,654
In terminal idling	3.38	18.15	29.8	0.23	0.23	0.22	0.028	2,955	0.199	0.097	2,989
Truck totals	**12.60**	**48.69**	**135.18**	**3.00**	**1.97**	**2.19**	**0.22**	**27,942**	**0.74**	**0.78**	**28,198**

[a] All PM_{10} exhaust emissions are DPM.

6 LOCOMOTIVE EMISSIONS

This section describes the data and methods used in estimating emissions from locomotives at the Oakland International Gateway (OIG) rail yard. OIG is a Port of Oakland terminal operated under a lease by the Burlington Northern Santa Fe (BNSF) railway. The Union Pacific (UP) rail yard (also known as UP Railport – Oakland), sits adjacent to the Port terminals and serves as an intermodal yard for freight movements through the port, is not considered in this evaluation because the UP yard is privately owned. UP provided ARB an independent analysis of the emissions in their Oakland facility.[6]

Locomotives are used for line-haul (long haul trains into and out of California) and switching (moving rail cars to make up trains). Line-haul locomotives move into and out of the rail yard with idle periods after arrival and prior to departure. Switching engines work in the yard with idle periods interspersed throughout the day. While line-haul and switching locomotives typically undergo maintenance, engine load testing, and refueling while in a rail yard, maintenance and load testing is not performed at the OIG. Refueling of locomotives occurs at the OIG but only infrequently.

Locomotives operate using a series of load modes called “notches”. These notches and the locomotive idle periods constitute the operating profile for locomotives. ENVIRON’s methodology for estimating emissions from locomotives followed ARB (2006a) guidance for rail yard emission modeling that requires per engine per mode emission rates to be used with average time in mode profiles for each visit scaled to the number of engines visiting the rail yard.

6.1 Summary of Locomotive Emission Factors by Engine Model

Emission factors and fuel consumption by notch used in this study are the same as those used in the Port of Oakland 2005 Seaport Air Emissions Inventory (ENVIRON, 2008) with adjustments for updated fuel sulfur values and new emission standards applied as described here.

The PM emissions were corrected to 15 ppm fuel sulfur using the methodology described by ARB (2005) to adjust PM emission rates from an average fuel sulfur level of 0.3% used during emissions testing. Low sulfur fuel was mandated nationwide starting in 2012 and in California before 2012. Emission reductions in terms of percent reduction by notch calculated for GE and EMD engines shown in Table 6-1 were applied to the base emission rates to calculate the emission rates at the in-use fuel sulfur levels for each locomotive model.

[6] http://www.arb.ca.gov/railyard/hra/hra.htm

Table 6-1. Locomotive - Fuel sulfur PM emission reductions by notch and engine type.

Notch	Coefficient B[1]	Coefficient A[1]	Fuel Sulfur 0.3% PM (g/hp-hr)	Fuel Sulfur 15 ppm PM (g/hp-hr)	Reduction
GE 4-stroke Engine					
8	0.00001308	0.0967	0.13594	0.0968962	28.72%
7	0.00001102	0.0845	0.11756	0.0846653	27.98%
6	0.00000654	0.1037	0.12332	0.1037981	15.83%
5	0.00000548	0.132	0.14844	0.1320822	11.02%
4	0.00000663	0.1513	0.17119	0.1513995	11.56%
3	0.00000979	0.1565	0.18587	0.1566469	15.72%
EMD 2-stroke engine					
8	0.0000123	0.3563	0.3932	0.3564845	9.34%
7	0.0000096	0.284	0.3128	0.284144	9.16%
6	0.0000134	0.2843	0.3245	0.284501	12.33%
5	0.000015	0.2572	0.3022	0.257425	14.82%
4	0.0000125	0.2629	0.3004	0.2630875	12.42%
3	0.0000065	0.2635	0.283	0.2635975	6.86%

[1] Coefficients are used in the ARB fuel sulfur adjustment equation: PM emissions = B x (fuel sulfur) + A

No emissions data were available for Tier 0, 1, and 2 rebuilt engines or new Tier 3 engines, so the emission factor ratio adjustment shown in Table 6-2 was applied to the pre-rebuild engine emission rates using the EPA estimated emission factors (EPA, 2009). No change in CO or fuel consumption was expected due to the rebuild, and Tier 2 rebuild (labeled 2+) emission rates were assumed the same as Tier 3 engines because the emission standards are identical.

Table 6-2. Emission ratio due to rebuild.

Tier	THC	NO_x	PM
0+ / 0	0.625	0.837	0.625
1+ / 1	0.617	1.000	0.625
2+ / 2	0.500	0.900	0.444

To estimate methane (CH_4) and nitrous oxide (N_2O) emissions, a ratio was applied to THC emissions and fuel consumption, respectively. The CH_4/THC ratio was determined using the ARB SPECIATE TOG profile number 818 for diesel engines, which provides the weight fraction of methane and other chemical species in the exhaust emissions. The fraction of TOG that is THC was determined by subtracting the weight fraction of the oxygenated species (alcohol, aldehydes, and ketones) that do not respond to the flame ionization detection method that is used to measure THC. The N_2O estimate was derived from the emission factor of 0.018 g/kW-hr available in the ARB emission inventory tool for Ocean-Going Vessels (http://www.arb.ca.gov/msei/categories.htm#ogv_category) and dividing by an assumed average fuel consumption of 210 g/kW-hr. This leads to an N_2O emission factor of 0.039 g/lb-fuel.

6.2 Overview of the OIG Yard

BNSF uses the OIG as a near dock transfer point for Port of Oakland maritime cargo containers. Only Port containers are handled at this yard. As shown in the schematic of the Port terminals in chapter 5, the OIG site is situated along a generally northwest-southeast axis. Entrance and exit tracks curve north and east of the main yard. Locomotives and trains enter the general port area from the north via the Union Pacific (UP) main line, and leave in the same direction via tracks going north through Richmond and onto BNSF lines out of the Bay Area.

6.3 Locomotive Facility Operations

The OIG locomotive operations consist of several activities including locomotive refueling, switching locomotive movements, and line-haul locomotive movements via train arrival and departure. As noted above, locomotive load testing and maintenance do not occur at the OIG.

Because different locomotive types and engine models have different emission characteristics, it was necessary to characterize the types and models of the locomotives that are operated at OIG based on data provided by BNSF. Locomotive types and models for each of the railyard activity are described below.

6.3.1 Basic Locomotive Refueling

Locomotive refueling rarely occurs in the OIG yard. The duty cycles provided for switching and line-haul locomotives include all activity when operating in the yard and includes refueling idling.

6.3.2 Switching Engine Movements

Switching engine fleet characteristics in the OIG area were determined from a sample of engines operating at OIG in 2012 made available by BNSF. Switching engines assigned to OIG rotate in and out of service, but were all of similar power and type to the locomotive found most often at the yard that is shown in Table 6-3.

Table 6-3. Locomotive – Switching engine characterization for the OIG facility in 2012.

Locomotive Model	Certification Tier	HP	Number of Engines	Engine Surrogate
GP39-2	Precontrolled or Tier 0	2300	1	GP-3x precontrolled

The time in mode for switching engine activity from the 2005 Port of Oakland emission inventory (ENVIRON, 2008) was used for this work and is shown in Table 6-4.

Table 6-4. Locomotive – Switching engine relative time in mode at the OIG facility in 2005.

Throttle Notch	Time in Mode
DB	1.4%
Idle	59.8%
1	6.6%
2	15.0%
3	9.5%
4	4.4%
5	1.9%
6	0.3%
7	0.0%
8	1.0%

Source: (ENVIRON, 2008)

Total switching engine activity in 2005 was estimated as one engine operating at all times each day of the year (i.e., 24 hours of switching engine use per day, or 8,760 hours per year). This 2005 switching engine activity was associated with a total of 203,424 lifts. The number of lifts in 2012 was down to 83,735, so the number of switching engine hours was reduced proportionally to 3,606 hours per year. Estimated annual THC, CO, NO_x, and diesel PM emissions for switching activities at the OIG facility are presented in Table 6-5. The $PM_{2.5}$ size fraction of PM_{10} was assumed to be 0.92 consistent with ARB literature (http://www.arb.ca.gov/planning/tsaq/eval/pmtables.pdf).

Table 6-5. Locomotive - Estimated annual emissions (tons/year) associated with switching engine activity at the OIG facility in 2012.

THC	CO	NO_x	PM_{10}	$PM_{2.5}$	SO_x	CO_2	CH_4	N_2O	CO_2e
0.62	1.50	14.47	0.31	0.29	0.01	575	0.03	0.02	581

Under an agreement with ARB, BNSF agreed to use 15 ppm sulfur fuel during refueling in California and 15 ppm sulfur was required to be used nationwide staring in 2012, so the PM and SO_x emissions rates were adjusted to be consistent with the use of 15 ppm sulfur fuel.

6.3.3 Train Arrival and Departures in the Yard

The primary locomotive activity at OIG was from arriving and departing line-haul locomotives and their operation throughout the yard. Activities of line-haul engines in the OIG yard include: arriving with a train, separating from the train, perhaps moving to the ready area where the engines are assigned to a train, and assigned to a train and leaving the yard. BNSF provided the locomotive counts by models that arrived at the yard in 2012 are shown in Table 6-6. The number of engines moving through the yard was determined to be 1,189 for 2012 based on a BNSF-supplied train arrival and departure database.

Table 6-6. Locomotive – Fleet characterization for locomotive arrival and departure at the OIG facility in the OIG facility in 2012.

Model	Tier	Fleet Fraction	Count
GP-3x	X[1]	1.57%	19
GP-60	0	0.66%	8
SD-7x	0	0.20%	2
Dash 8	0	0.00%	0
Dash 9	0	16.49%	196
Dash 9	1	0.86%	10
ES44	2	36.48%	434
SD-70	2	0.00%	0
Dash 9	0+	0.10%	1
Dash 9	1+	22.98%	273
ES44	2+	0.25%	3
ES44	3	20.40%	243

[1] Precontrolled means that the engines predate emission regulations or have yet to be rebuilt to any emission standard. These precontrolled engines were switching engines arriving or leaving the yard at the beginning and end of assignment.

BNSF provided duty cycle information for 13 separate locomotives arriving and departing from OIG. ENVIRON calculated the average time in mode for all locomotive movements and idling using event recorder data, which unfortunately does not distinguish between engine-off and engine-on idle modes. Because most locomotives have automatic shut off devices and BNSF has instituted idle reduction programs, BNSF provided a crank file with time stamps each time the engine was started. By determining the time between starts (minus a minimum of 15 minutes timed allowance by automatic shut-off devices) and time between the last movement and the next start (minus an assumed 30 minutes for movement to an idle location and the timed allowance), the true engine-on idle time was estimated. The resulting average time in mode data are summarized in Table 6-7.

Table 6-7. Locomotive – Time in mode for arriving and departing locomotives at the OIG facility in 2012.

Throttle Notch	Average Operation Time (hours)
DB	0.2963
Idle	4.7436*
1	0.1726
2	0.0758
3	0.0340
4	0.0049
5	0.0059
6	0.0004
7	0.0036
8	0.0017

* Adjusted from 11.8 hours to account for engine-off idle periods

The fleet characterization for locomotives, provided in Table 6-6, was derived from all engines entering the site in 2012, and the operating profile for 13 sample arrivals were combined with the emission rates for each engine model to estimate total emissions. The diesel emission estimates for BNSF freight movements during the one-year period are presented in Table 6-8.

Table 6-8. Locomotive emissions (tons/year) from Arriving/Departing locomotives at the OIG in 2012.

THC	CO	NO_x	PM_{10}	$PM_{2.5}$	SO_x	CO_2	CH_4	N_2O	CO_2e
0.40	0.57	4.78	0.14	0.13	0.00	350	0.02	0.01	354

6.3.4 Freight Movements on Adjacent Mainline

All freight trains enter and leave through the UP rail yard and those movements should be captured as part of the UP assessment of rail yard emissions estimates for its yard.

6.3.5 Commuter Rail Operations on the Adjacent Mainline

No commuter rail operations occur within the OIG facility.

6.4 Summary Locomotive Emission Estimates for OIG

The locomotive emissions for the OIG facility are summarized in Table 6-9. Note that all locomotive PM emissions are classified as diesel particulate matter (DPM).

Table 6-9. Locomotive – Estimated annual locomotive emissions (tons) at the OIG facility - 2012.

Source Type	THC [a]	CO	NO_x	PM_{10} [b]	$PM_{2.5}$	SO_x	CO_2	CH_4	N_2O	CO_2e
Switching Engines	0.62	1.50	14.47	0.31	0.29	0.01	575	0.03	0.02	581
Train Arrival / Departure	0.40	0.57	4.78	0.14	0.13	0.00	350	0.02	0.01	354
Total	1.02 (ROG 1.22)	2.06	19.25	0.46	0.42	0.01	926	0.06	0.02	935

[a] ROG to THC ratio for diesel engines is 1.21 from Walter Wong, ARB on May 29, 2007.

[b] All PM_{10} emissions are DPM.

7 OTHER OFF-ROAD EQUIPMENT

This section documents the emission estimation methods and results for construction and maintenance equipment operated at Port of Oakland terminals and the rail yard. This inventory does not include equipment at the Schnitzer facility and Union Pacific rail yard because those privately owned facilities are not part of the Port.

7.1 Background

Off-road equipment considered in this section include general industrial and construction equipment that are most often used to transfer liquid and solid bulk cargo or other sporadic maintenance and construction activity occurring at the Port. They are not to be confused with cargo-handling equipment (CHE), which is primarily used to transfer shipping containers or intermodal freight cargo. The CHE activities and emissions are discussed in this emission inventory under Section 4. In this section, there are three sources off-road equipment considered: (1) facility maintenance and construction at each terminal, (2) Port of Oakland general maintenance, and (3) construction for the Port's shore power system.

7.2 Emission Calculation Methodology

To estimate the annual 2012 off-road equipment emissions, a list of equipment including engine characteristics (model year, rated power, and equipment type) and equipment operation (hours of usage and fuel consumption rates) were collected from terminal operators and the Port. The equipment population and operation estimates by terminal were derived from surveys conducted by the Port of Oakland. Fleet data for the Port's general maintenance equipment and equipment used for the shore power project construction were provided by the Port. Where there were missing data, default input estimates were obtained from the applicable inventory guidance documentation (ARB, 2007 and 2010).

The types of construction and maintenance equipment considered in this inventory include:

- Aerial lifts
- Air compressors
- Excavators
- Forklifts
- Generator sets
- Graders
- Other construction equipment
- Pavers
- Pressure washers
- Rollers
- Skid steer loaders
- Sweepers / Scrubbers

- Tractors / Loaders / Backhoes
- Welders

Off-road equipment emissions were calculated using the following equation:

$$Equip_{emiss} = \frac{EF_{adj} \times Engine_{bhp} \times LF_{wt} \times Time_{hrs} \times Pop}{(453.6 \times 2000)}$$

Where:

Equip $_{emiss}$ is the annual emissions in tons per year,
EF $_{adj}$ is the emission factor adjusted for deterioration, in grams per brake horsepower-hour,
Engine $_{bhp}$ is the brake horsepower of the engine,
LF $_{wt}$ is the weighted load factor (average load expressed as a % of rated power),
Time $_{hrs}$ is the annual operating hours of the equipment,
Pop is the population number of the equipment, and
(453.6 x 2000) is a conversion from grams to tons.

7.3 Input Data and Use

For terminal maintenance equipment, the same surveys as those presented for CHE (Section 4) were used. Off-road equipment included in those survey responses that were characterized as "non-CHE" are included in this section. The Port and the shore power construction contractor have provided the rest of the maintenance and construction equipment data. For equipment specific operation and characteristics that were not provided, default assumptions from the off-road emissions inventory guidance documentation (ARB, 2007 and 2010) were used.

A combination of the OFFROAD 2007 and OFFROAD 2011 models were used to estimate emissions. Because emission factors are back-calculated from these inventory models, they are adjusted for engine deterioration. For diesel-powered equipment, the emission factors for HC, NO_x, and PM were derived from OFFROAD 2011. Because this newer version of the OFFROAD model does not support emission estimates for other pollutants and other fuel types, emission factors for gasoline and propane powered equipment, and for CO, SO_x and greenhouse gases, were obtained from the OFFROAD 2007 model.

The populations of off-road equipment evaluated in this section are summarized in Table 7-1 below. Among 134 pieces of construction and maintenance equipment at the Port of Oakland in 2012, 97 were diesel powered (72% of total), 36 were gasoline powered (27% of total), and only 1 aerial lift was powered by LPG (liquid petroleum gas).

Table 7-1. Construction and maintenance equipment - population by type.

Equipment	Count	% Total
Aerial Lifts	5	4%
Air Compressors	40	30%
Excavators	1	1%
Forklifts	21	16%
Generator Sets	13	10%
Graders	1	1%
Other Construction Equipment	7	5%
Pavers	1	1%
Pressure Washers	1	1%
Rollers	2	1%
Skid Steer Loaders	1	1%
Sweepers/Scrubbers	5	4%
Tractors/Loaders/Backhoes	16	12%
Welders	20	15%
Total	**134**	**100%**

Table 7-2 summarizes the average horsepower and annual use by equipment type and power range. Actual annual hours of operation for each piece of equipment were used to estimate emissions.

Table 7-2. Construction and maintenance equipment - Average horsepower and hours of operation by equipment type and horsepower range.

Equipment Type	HP Bin	Average HP	Average Annual Operation Hours[a]
Aerial Lifts	50	30	100
	120	100	100
	175	140	57
Air Compressors	50	30	54
	120	80	815
Forklifts	120	102	227
	500	300	11
Generator Sets	50	26	88
	120	84	52
Graders	175	150	209
Other Construction Equipment	50	39	374
	120	99	474
	175	123	518
Pavers	50	36	351
Pressure Washers	250	215	1231
Rollers	50	43	271
Skid Steer Loaders	120	74	319
Sweepers/Scrubbers	120	63	656
	175	150	92
Tractors/Loaders/Backhoes	120	99	219
	175	129	588
	500	260	435
Welders	50	10	100
	120	64	8

[a] Equipment that logged zero hours in 2012 are excluded in Table 7-2.

7.4 Construction and Maintenance Equipment Emission Results

Table 7-3 and Table 7-4 present emission estimates for the construction and maintenance equipment by equipment type and by fuel type, respectively. The $PM_{2.5}$ size fraction of PM_{10} was assumed to be 0.92 for diesel engines and 0.93 for other fuel types consistent with ARB literature.[7] DPM emissions are equivalent to the diesel PM_{10} emissions listed in Table 7-4.

Table 7-3. 2012 Port of Oakland construction and maintenance equipment emissions by equipment type (tons per year).

Equipment	ROG	CO	NO_x	PM_{10}	$PM_{2.5}$	SO_x	CO_2	CH_4	N_2O
Aerial Lifts	0.01	0.35	0.07	0.01	0.00	6	0.00	0.01	6
Air Compressors	0.10	1.10	0.39	0.04	0.00	34	0.00	0.01	35
Excavators	0.00	0.00	0.00	0.00	0.00	0	0.00	0.00	0
Forklifts	0.05	0.32	0.49	0.04	0.00	44	0.00	0.01	44
Generator Sets	0.04	0.11	0.13	0.01	0.00	13	0.00	0.00	13
Graders	0.01	0.05	0.14	0.01	0.00	8	0.00	0.00	8
Other Construction Equipment	0.05	0.38	0.36	0.03	0.00	48	0.00	0.01	48
Pavers	0.01	0.05	0.03	0.00	0.00	3	0.00	0.00	3
Pressure Washers	0.16	0.46	0.86	0.08	0.00	72	0.00	0.01	72
Rollers	0.02	0.09	0.06	0.01	0.00	5	0.00	0.00	6
Skid Steer Loaders	0.00	0.03	0.05	0.00	0.00	5	0.00	0.00	5
Sweepers/Scrubbers	0.03	0.17	0.28	0.02	0.00	24	0.00	0.01	24
Tractors/Loaders/Backhoes	0.08	0.57	1.02	0.07	0.00	100	0.00	0.01	100
Welders	0.02	0.62	0.04	0.00	0.00	5	0.00	0.00	6
Total	**0.57**	**4.32**	**3.91**	**0.31**	**0.00**	**368**	**0.00**	**0.08**	**370**

Table 7-4. 2012 Port of Oakland construction and maintenance equipment emissions by fuel type (tons per year).

Fuel Type	ROG	CO	NO_x	PM_{10}	$PM_{2.5}$	SO_x	CO_2	N_2O	CH_4	CO_2e
Propane	0.00	0.31	0.01	0.00	0.00	0.00	2	0.00	0.01	2
Gasoline	0.05	1.51	0.07	0.00	0.00	0.00	11	0.00	0.00	12
Diesel	0.52	2.50	3.83	0.31[a]	0.29	0.00	355	0.00	0.07	356
Total	**0.57**	**4.32**	**3.91**	**0.31**	**0.29**	**0.00**	**368**	**0.00**	**0.08**	**370**

[a] All diesel PM_{10} emissions are DPM.

[7] http://www.arb.ca.gov/planning/tsaq/eval/pmtables.pdf

8 COMPARISON OF 2005 AND 2012 EMISSIONS INVENTORIES

8.1 Introduction

This section provides a comparison of the calendar 2012 and 2005 air emissions inventories for the Port of Oakland. For each source category, we highlight the major changes that have occurred.

There have been changes to the emission inventory method, default activity, and emission factors since the time of the 2005 inventory. However, ENVIRON has sought to maintain the 2012 emission inventory approach as consistent as possible with the 2005 estimates. In addition, the fleets of vessels, equipment and vehicles have been updated through normal attrition, incentives, or as required to comply with the California regulations.

The container activity at the port, as measured by twenty-foot equivalent units (TEU), has been relatively constant recently during recovery from the 2008 recession, as shown in Table 8-1; TEU throughout has increased 3% since 2005.

Table 8-1. Port of Oakland TEU throughput.

Year	Full		Empty		Grand Total	Change from Previous Years
	Import	Export	Import	Export		
1990	253,864	600,595	218,366	51,298	1,124,123	+3.1%
1991	286,696	630,557	228,789	48,676	1,194,718	+6.3%
1992	354,490	656,674	205,737	74,593	1,291,494	+8.1%
1993	365,114	667,879	202,866	69,275	1,305,134	+1.1%
1994	403,845	764,237	249,625	73,295	1,491,002	+14.2%
1995	404,842	809,894	266,506	68,644	1,549,886	+3.9%
1996	360,717	782,913	283,314	71,258	1,498,202	-3.3%
1997	398,157	769,172	288,304	75,555	1,531,188	+2.2%
1998	458,470	747,064	237,176	132,696	1,575,406	+2.9%
1999	469,226	789,873	234,121	170,536	1,663,756	+5.6%
2000	503,858	818,521	244,359	210,184	1,776,922	+6.8%
2001	486,389	758,958	223,894	174,344	1,643,585	-7.5%
2002	547,230	732,537	206,418	221,642	1,707,827	+3.9%
2003	599,411	799,547	206,267	317,879	1,923,104	+12.6%
2004	694,314	813,716	184,863	354,611	2,047,504	+6.5%
2005	836,258	846,579	197,988	393,165	2,273,990	+11.1%
2006	877,778	840,145	192,455	481,367	2,391,745	+5.2%
2007	870,284	909,633	204,943	403,051	2,387,911	-0.2%
2008	796,404	910,700	192,569	333,860	2,233,533	-6.5%
2009	701,501	966,882	209,258	167,570	2,045,211	-8.4%
2010	802,657	955,579	209,878	362,343	2,330,457	13.9%
2011	797,272	993,826	264,471	286,957	2,342,526	0.5%
2012	791,624	986,760	271,212	294,796	2,344,392	0.1%
2005 to 2012	(44,634)	140,181	73,224	(98,369)	70,402	3.1%

8.2 Ocean Going Vessels (OGV)

OGV calls to the Port were fewer in calendar year 2012 at 1,812, compared with 1,916 calls in calendar year 2005. Ships calling in 2012 were generally larger and off-loaded more TEUs per call on average. Berthing time per ship call did not change appreciably at 21 hours per call on average.

Steamship calls reduced from 200 in 2005 to 96 in 2012. Steam propulsion emissions are lower in NO_x but higher in PM compared to diesel engines. However, PM from steam boilers are not classified as DPM. The result of a lower fraction of steamship calls is therefore to increase NO_x emissions and marginally increase DPM emissions, all else being equal. A small number of calls (13) in 2013 were from vessels meeting Tier II NO_x emission requirements but this did not significantly affect fleet average NO_x emission.

Changes to the emission inventory approach affected the estimated emissions. An increase in the estimated OGV ROG emission factors resulted in an increase in the estimated OGV ROG emissions. The THC emission factor (g/kW-hr) used in the 2005 inventory was 0.6 for slow speed 2-stroke engines (the primary propulsion engine type) and 0.4 for auxiliary engines. The THC to ROG conversion provided by ARB was 0.8347, so the ROG emission factors (EFs) were 0.5 and 0.33, respectively, in the 2005 inventory. The revised ROG EF that ARB is currently using in their statewide inventory and was used in the 2012 inventory is 0.78 which is a 50 – 100% increase over the 2005 EF. If the ROG EFs from the Port's 2005 inventory had been used to develop the Port's 2012 OGV inventory, ROG emissions would have been calculated to be 119 tons which is very close to the value of 117 tons reported in the 2005 inventory.

Updated auxiliary boiler load factors estimated by ARB and used in the 2012 inventory are higher than those used in the 2005 inventory. This resulted in higher non-DPM emissions.

The significant operational change from 2005 was the use of 0.3% or lower sulfur fuel during 2012 following the California requirement for main and auxiliary diesel engines and auxiliary boilers.[8] The result of the low sulfur fuel requirement is to provide significant reductions in diesel and other particulate matter emissions.

8.3 Harbor Craft

Harbor craft activity and emissions have changed from 2005 due to greater dredging activity, and updated harbor craft fleets made largely in response to ARB's Commercial Harbor Craft regulations.[9]

8.3.1 Dredging Emissions

There was a significant increase in 2012 dredging emissions compared to the 2005 estimates for several reasons. First, 2005 was an atypical year for maintenance dredging because deepening dredging to -50 feet and maintenance dredging occurred simultaneously, thus reducing much of

[8] http://www.arb.ca.gov/ports/marinevess/ogv.htm
[9] http://www.arb.ca.gov/ports/marinevess/harborcraft.htm

the need for normal maintenance dredging. Secondly, the 2005 deepening dredging was accomplished using an electric-power dredge so much of the maintenance material was picked up by the electric dredges. Typically, maintenance dredging is performed using diesel powered equipment as was the case in 2012. Lastly, the location of dredged material disposal sites switched from the nearby in-bay sites used in 2005 to more remote sites such as the Montezuma wetlands in Solano County and deep ocean disposal, resulting in significantly longer transport distances and consequently greater emissions from the barge tugs.

8.3.2 Assist Tugs

In contrast to 2005, nearly all tugs engaged in assist activity are now based near the Port reducing the transit time calculated for ship moves in- and out-bound. In addition, the tug fleet vessels and engines were updated through normal attrition and compliance with California Commercial Harbor Craft regulations.[10]

8.4 Cargo Handling Equipment

Cargo handling equipment activity was similar to that used in 2005. Emission retrofits and fleet replacements used to comply with the California regulations[11] resulted in reduced emission rates.

8.5 Drayage Trucks

Drayage truck activity in 2012 was similar to that used in 2005. Substantially lower emissions in 2012 are a result of vehicle replacements encouraged through incentive programs and implementation of ARB regulations that require diesel particulate filters for nearly all drayage trucks.[12] The filters reduce DPM by at least 85%. Furthermore, the Port's Comprehensive Truck Management Program banned older trucks from Port terminals, in support of the ARB regulations.

8.6 Locomotives

Rail activity was lower in 2012 compared with 2005. In addition, the line-haul locomotive fleet has been upgraded through normal attrition, resulting in reduced fleet average emission rates. The specific switch locomotives used at the yard were not precisely identified by BNSF, and so no change was made to the switch locomotive model specifications used in the emissions analysis. Switch locomotives appeared in the arrival data when they were transferred to the yard at the beginning of long-term assignments. Even though low emission generator set Tier 3 switch locomotives were found to be at the OIG yard during 2012, the predominant types of switch locomotives used in 2012 were the older models used in the 2005 emissions inventory and it was assumed that these models were used exclusively at OIG during 2012 for purposes of estimating the 2012 inventory.

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[10] http://www.arb.ca.gov/ports/marinevess/harborcraft.htm
[11] http://www.arb.ca.gov/ports/cargo/cargo.htm
[12] http://www.arb.ca.gov/msprog/onroad/porttruck/porttruck.htm

8.7 Other Off-Road

This category was not included in the 2005 emissions inventory. However, offroad equipment is subject to California's In-Use Off-Road Diesel Vehicle regulations.[13]

8.8 Emissions Comparison

The comparisons of 2012 with 2005 emissions provided in Table 8-2 show a general reduction in emissions, mostly due to the use of more modern engines, retrofits and cleaner fuels. Notably, the DPM and SO_x emissions are substantially lower in 2012 for all source categories. Changes to emission factors for ROG resulted in increases in estimated OGV and harbor craft ROG emissions. A small increase in the OGV NO_x emissions between 2005 and 2012is a result of relatively more OGVs with diesel engines and fewer steamship calls in 2012 which is only slightly offset by minor reductions of NO_x from incorporation of newer engines in the fleet and the use of cleaner fuels.

[13] http://www.arb.ca.gov/msprog/ordiesel/ordiesel.htm

Table 8-2. Port of Oakland 2012 and 2005 air emissions inventory comparison.

2012 Inventory	ROG	CO	NO_x	PM_{10}	DPM	SO_x
Ocean-going vessels	176	232	2,591	66.9	57.4	289
Harbor craft	25	95	235	9.3	9.3	0
CHE	35	207	413	8.0	7.9	1
Trucks	13	49	135	3.0	2.0	0
Locomotives	1	2	19	0.5	0.5	0
Other Offroad Equipment	1	4	4	0.3	0.3	0
Total	**250**	**589**	**3,398**	**88**	**77**	**290**
2005 Inventory	**ROG**	**CO**	**NO_x**	**PM**	**DPM**	**SO_x**
Ocean-going vessels	117	235	2,484	220	208	1,413
Harbor craft	22	83	345	13	13	2.85
CHE	53	408	766	22	21	7
Trucks	49	149	334	16	15	2.2
Locomotives	7	11	76	2	2	2
Total	**248**	**886**	**4,005**	**272**	**261**	**1,427**
% Change from 2005	**ROG**	**CO**	**NO_x**	**PM**	**DPM**	**SO_x**
Ocean-going vessels	50%[a]	-1%	4%[b]	-70%	-72%	-80%
Harbor craft	11%[c]	14%[c]	-32%	-30%	-30%	-94%
CHE	-33%	-49%	-46%	-63%	-63%	-92%
Trucks	-74%	-67%	-60%	-81%	-88%	-90%
Locomotives	-83%	-81%	-75%	-77%	-77%	-100%
Total	**1%**	**-33%**	**-15%**	**-68%**	**-70%**	**-80%**

[a]OGV ROG increase due to change in emissions factor (see Sec. 8.2)

[b]OGV NO_x increase due to lower fraction of calls by steamships in 2012 (see Sec. 8.2).

[c]Harbor craft ROG and CO increase due to increased dredging activity included in inventory (see Sec. 8.3).

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APPENDIX A
Summary of Comments on Draft Report Received From the Bay Area Air Quality Management District (BAAQMD) and the Air Resources Board (ARB) and ENVIRON Responses

Appendix A. Summary of Comments on Draft Report Received From the Bay Area Air Quality Management District (BAAQMD) and the Air Resources Board (ARB) and ENVIRON Responses

BAAQMD Comments, Received from Phil Martien, August 29, 2013

1. *For OGV emissions (No. 1 above), the number of vessel calls in 2012 vs 2005 is not significantly different. Yet, ROG emissions have increased by about 50% while, NO_x and CO remained relatively the same. Did the ROG emission factor change?*

ENVIRON Response: Yes, the ROG emission factor changed. In 2005, the THC emission factor was 0.6 for slow speed 2-stroke (the primary propulsion engine type) and 0.4 for auxiliary engines. The THC to ROG conversion provided by ARB was 0.8347, so the ROG EFs were 0.5 and 0.33 for the 2005 inventory. The revised ROG EF that ARB is using in their statewide inventory is 0.78, so a 50 – 100% increase in the emission factor is used in this emission inventory. Using the ROG emission factor from the 2005 air emission inventory report with the 2012 OGV activity yields ROG emissions of 119 tons of ROG emission compared with the 2005 air emission inventory of 117 tons of ROG.

2. *For OGV PM emissions in 2012, 11 tons/yr came from boiler of LPG engine emissions; for 2005 PM emissions was 0.5 tons/year from boiler or LPG engine emissions. Was there an increase in boiler usage during this period or emissions that were unaccounted for in 2005?*

ENVIRON Response: The PM from boilers in 2005 was 11.0 tons and in 2012 it is 10.4 tons. Gasoline and LPG engines produced 0.15 tons of PM in 2012 and 0.53 in 2005. Steamship visits were down from 200 in 2005 to 96 in 2012, reducing the main boiler emissions by about half; however, the ARB auxiliary boiler load factor estimates used for the 2012 inventory are significantly higher than the estimates used for the 2005 inventory.

3. *For commercial harbor craft, the dredging activities have increased (1.24 million cubic yard in 2012 vs 43,520 cubic yards)and OGV vessel calls did not significantly change (thus, [the number of] tug assists should not significantly change). It isn't clear why NO_x emissions have gone down by 32%, but ROG and CO has gone up by 12 and 14% respectively.*

ENVIRON Response: The ARB Harbor Craft rule and normal equipment turnover has resulted in the use of newer engines, thus reducing NO_x and PM emission factors. However, ROG and CO emission factors have not changed with the updated fleet of tugs. Dredging activity was significantly higher in 2012 than in 2005. All assist tugs are now based close to the Port, so there are less in-transit emissions estimated. So overall activity is up, but NO_x and PM emissions are lower due to the effects of fleet turnover accelerated by the Harbor Craft rule.

4. *In Table 6-9 of 2012 report, ROG value (1.22) is higher than THC value (1.02). Does ROG include aldehydes, while THC does not? Please clarify.*

ENVIRON Response: TOG is defined as THC plus carbon-hydrogen-oxygen compounds in which a carbon atom is bound to oxygen as in aldehydes, ketones, carboxylic acids, and alcohols. ROG is equal to TOG minus methane. ROG is usually higher than THC for diesel engines because aldehydes (and ketones) are usually more abundant than methane. In SPECIATE profile 818 (diesel light & heavy) used to estimate the ROG to THC ratio, formaldehyde and other oxygenated species are more abundant than methane.

5. *For Other Off Road Equipment, the emission data in N_2O column in table 7-3 and 7-4 should show 3 significant figures. This will help to explain the calculated CO_2 equivalent value.*

ENVIRON Response: The CO_2e incorporates the CO_2, N_2O (to many decimal places), and CH_4 emissions in the global warming potential weighted total; N_2O is a minor contributor to CO_2e.

6. *For Other Off Road Equipment, the global warming potentials of N_2O and CH_4, 310 and 21 respectively, should be included in the footnote.*

ENVIRON Response: Yes, these are the factors that we used, as listed in the final report.

7. *For on-road trucks, the methodology employed for the previous round (2005) was sound and followed for year 2012.*

ENVIRON Response: No response required.

8. *Emission reductions shown above are largely due to the ARB's aggressive Diesel Truck Regulations, especially those applicable to port trucks.*

ENVIRON Response: Yes.

9. *Two different versions of the EMFAC model were used. However, this does not have a significant impact on the results. In other words, if relevant emission factors from EMFAC2011 were used to re-calculate 2005 emissions, the results would be very similar. (EMFAC2011 emissions factors for 2005 fleet have not changed significantly).*

ENVIRON Response: The version of EMFAC used has a small effect on the emissions calculated.

10. *Truck trip reduction also contributes to the emission reductions. The 2013 Report should say more about the reasons for this reduction, however, the 2005 Report did observe and note a downward trend on truck trips from previous years due to better container management. The continuing trend (5% reduction per year) could be a result of this improvement or the impact of recession but this should be clarified.*

ENVIRON Response: Gate counts provided for use in developing the 2012 inventory show lower totals than used in the 2005 inventory. Specific reasons for these reductions were not investigated by ENVIRON.

11. We looked for more information in Section 8 of the 2013 Report "Comparison of 2012 Emissions with 2005 Emissions" for more information. This Section is yet to be completed.

ENVIRON Response: A comparison of the 2005 and 2012 emission inventory is now included in Section 8 of the final report.

ARB Comments, Received from Nicole Dolney September 10, 2013

In general the inventory looks good. We were able to confirm that for many of the category inputs there was good agreement between the POAK inventory and our official ARB mobile source inventories/models. However we weren't able to confirm consistency for all inputs due to the level of detail provided in the report. Below are some specific comments for the main mobile source categories:

OGV

- *We recommend using a 0.3% sulfur content instead of 0.5% for compliance with the fuel rule to be consistent with ARB's model and inventories.*

ENVIRON Response for OGV: Emission calculations shown in the final report have been updated to reflect the use of 0.3% sulfur content fuel.

Trucks

- *With the level of detail provided in the report we were not able to compare at a detailed level many of assumptions in the report relative to EMFAC. It appears that the emission rates, age distribution, population and VMT are generally consistent with EMFAC.*

ENVIRON Response for Trucks: Emission calculations shown in the final report have been updated to reflect the use of 0.3% sulfur content fuel. Additional background data and details for trucks and other source categories are available in our summary calculation spreadsheet.

Locomotives

- *The sulfur adjustment section references an ARB (2005) document but no description of the sulfur adjustment formula is provided. Can you provide the specific formula that was used and where it specifically came from?*

ENVIRON Response for Locomotives: We provided the original ARB reference for the sulfur correction. It is the only reference we found to correct emission rates of engine emissions tested at high sulfur levels to the lower sulfur levels in use. The formula used is a subnote to Table 6-1 (and found on page 21 of the attached reference), and used to determine the percentage reduction by notch setting also provided in Table 6-1. The percentage reduction was applied to the by notch emission factors.

Harbor Craft

- *The equations for estimating emissions in section 3.1 do not contain Deterioration Rates or Fuel Correction Factors. However, in section 3.2, it says that Emission Factors are adjusted for DR and FCF. We did some spot checking and the emission rates in the report do not match exactly with emission rates from our inventory. Can you please confirm that you do in fact include deterioration and fuel correction factors and then compare your data to estimates from the official harbor craft inventory?*
- *We noticed that sometimes in the report a single piece of equipment is used to represent others. Emission factors, deterioration rates, and fuel correction factors vary by age and horsepower so using a single piece of equipment to represent multiple equipment types can introduce error unless the rest of the fleet is very similar in age and engine specs.*
- *Regarding load factors:*
    - *In table 3-1(a), the Tender and the survey boat use a load factor of 0.32. There is no main engine load factor in our inventories with a value of 0.32. Where does this load factor come from?*
    - *In table 3-3 the representative tug boat has a load factor of 0.68 and 0.43 for main and auxiliary engines, respectively. In ARB's Harbor Craft inventory there are load factors for a 'tow' boats, not 'tug' boats. Again, depending on the operating characteristics of this boat, it might be intentional.*
    - *The section on Assist Tugs (3.2) did not show what load factors were used so we could not compare it to assumptions used in ARB inventories.*
- *Assist Tugs and Barge Tow Boats: These sections had a less detail available for inputs used (no load factors, no emission factors) so we couldn't compare to ARB inventories.*

<u>ENVIRON Response for Harbor Craft:</u>

- Yes, we did use zero hour with deterioration factors and fuel adjustment factors, and will provide our calculation sheets for detailed review.
- The only instance where a single piece of equipment was used to represent all activity was the dredge and tug used for the channel dredging. We were unable to obtain the Manson equipment (responsible for less than half the channel dredging in 2012), so we use the equipment that Dutra used for the same purpose earlier in 2012. The equipment used is specific to this occupation, and so will be a single piece per project, but perhaps different for Manson than Dutra.
- Regarding load factors:
    - Table 3-1 did have an error in the written table for the load factor in the early draft that you reviewed. For the emission calculations for the tender and survey boat, we used a load factor of 0.38 for the main engines (0.32 is the

auxiliary engine load factor incorrectly inserted in the document) taken from the Crew and Supply Vessel Database (linked reference) for 'crew and supply' boats. We asked, and Dutra responded that these two boats do not have auxiliary engines (see *California Crew and Supply Vessel Emissions Inventory Database;* (http://www.arb.ca.gov/msei/categories.htm#chc_category)

- The disposal of dredge material was performed by a tug towing a scow barge to disposal site. Because this tug was used to tow a scow, we have used the tow boat load factors.
- In section 3.2 in the text, we described the emissions calculations and load factors for assist tugs as, "*ENVIRON used zero hour emission factors, engine emissions deterioration factors and fuel correction factors for both main propulsion and auxiliary engines from ARB's database emission inventory too. (ARB, 2011b). However, the main engine load factor was estimated to be 0.31, and the auxiliary engines load factor was estimated to be 0.43. These load factors corresponding to values used in both the Port of Oakland 2005 Seaport Air Emissions Inventory (ENVIRON, 2008) and the latest Port of Los Angeles Inventory of Air Emissions (POLA, 2012).*"
  - We want to stress the origin of the load factor by providing reference with the factors used in the text description.

- Lastly, the one call by a fuel barge was added for completeness because it appeared on the calls the Marine Exchange provided. We used an average tug, model year 2000, and tow boat load factors.

Additional BAAQMD Comments, Received From Michael Murphy, October 29th, 2013

1) *In the ocean going vessel section, it will be useful to have a table that shows ship visits by fleet. This will give an early indication of the potential number of ships that may "plug-in" starting in 2014. This is important since the draft projections shared with us on 9/17/2013 show the ships as the major source of future emissions, and shore power will be the main effort to control them further.*

2) *In the locomotive section, the discussion on switching locomotives uses the term "lifts" in explaining why hours of operations are much less in 2012 compared to 2008; however, "lifts" usually refers to work by cranes and top-picks. If there was just fewer containers moved by rail in 2012, it will be much clearer to just say so. Otherwise, a definition of "lifts" for switcher locomotives is needed.*

3) *Also regarding locomotives, one of the MAQIP strategies is the increased use of "GenSet," Tier 3 switchers. The inventory is based on an emissions rate from an unregulated engine. It will be helpful to have a statement on the actual use (or lack thereof) of the GenSet switchers. If there was 2012 use of GenSet locomotives, then Environ is currently overestimating the emissions and should revise them for the final inventory. If there was no use of cleaner switcher locomotives, then the Introduction and/or Executive Summary accompanying the inventory should clearly note that emission reductions in this category stems from fewer containers moved by rail in 2012.*

4) *For the Cargo Handling Equipment, since information on the make-up of the fleet was collected for estimating 2012 emissions, a statement in the inventory on percentage compliance with the CARB diesel risk-reduction/toxic control measure will be useful in understanding the emission factors used, and, more importantly, estimating future reductions.*

As mentioned by Phil Martien in your recent telephone conversation, where we, and others likely, will want to see more discussion in the Inventory on the following areas:

- *future year emissions projections;*
- *adoption of new technologies that will go beyond current regulatory requirements;*
- *discussion of development plans, including at the old Oakland Army Base.*

<u>ENVIRON Response</u>
With regard to Comment #1: OGV fleet information is not currently available. Significant additional effort would be required to identify common owners/operators for vessels visiting the Port.

With regard to Comment #2: Each lift corresponds to the movement of a container onto or from a rail car so the level of activity of the switcher engine is assumed to be proportional to the number of lifts.

With regard to Comment #3: BNSF does not keep records of switch assignments so a conservative approach was used for the 2012 inventory as described in Section 6.

With regard to Comment #4: This information is not available to ENVIRON.

With regard to the comments about future year emissions and technologies: This 2012 Seaport Emissions Inventory report is intended to be a technical document focused on reporting the 2012 results with comparisons to the previous 2005 results. Therefore, any discussion of emissions projections and future reductions and projects will be captured by the Port in the context of the broader MAQIP Progress Report meeting agenda and dialogue.