TECHNICAL MEMORANDUM

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FROM: Stephen B. Reid, Manager, Emissions Assessment Group

SUBJECT: Documentation of emission estimation techniques for sources of diesel particulate matter (DPM) associated with truck-based businesses and construction projects in West Oakland, California (Contract No. 2006-144)

INTRODUCTION

This memorandum is a deliverable for the "West Oakland DPM Emission Inventory" project. This work was performed to support an evaluation by the Bay Area Air Quality Management District (the District) and the California Air Resources Board (ARB) of health risks from diesel exhaust in the Port of Oakland and the surrounding area. The ultimate goal of this collaboration is to conduct a three-part health risk assessment (HRA) using the California Puff model (CALPUFF):

Part 1. The Maritime Port of Oakland;
Part 2. The Union Pacific (UP) Railyard; and
Part 3. Emissions sources in West Oakland not directly associated with the Port of Oakland or the UP Railyard.

Information developed through the HRAs will be used to educate the public about air quality and the health impacts from diesel sources in West Oakland, and to address state, federal, District, and Port of Oakland emission reduction efforts. The work described in this document focuses on developing estimates of year-2005 emissions from diesel sources for Part 3 of the HRA. Specifically, STI assisted the District in developing a detailed inventory of diesel particulate matter (DPM) emissions in West Oakland for all diesel sources associated with truck-

based businesses[1] and major construction activity, other than those associated with the Maritime Port of Oakland and the UP Railyard (**Figure 1** shows the approximate boundaries of the study domain, which is roughly bounded by I-580 on the north, I-980 on the east, and the San Francisco Bay and inner harbor on the west and south). In addition, Sonoma Technology, Inc. (STI) reviewed emission estimates generated by ARB for other Part 3 diesel sources, such as ocean-going vessels (OGV), commercial harbor craft (CHC), locomotives, and on-road mobile sources, to ensure that the estimation methodologies used for Part 3 of the HRA were consistent with those used for Parts 1 and 2.

The purpose of this technical memorandum is to provide the District with documentation of the methodologies STI used to estimate emissions and generate spatial coordinates and temporal profiles for diesel sources associated with truck-based businesses and construction projects in West Oakland. District staff will use this documentation to update the initial emission estimates prepared by STI as improved data become available.

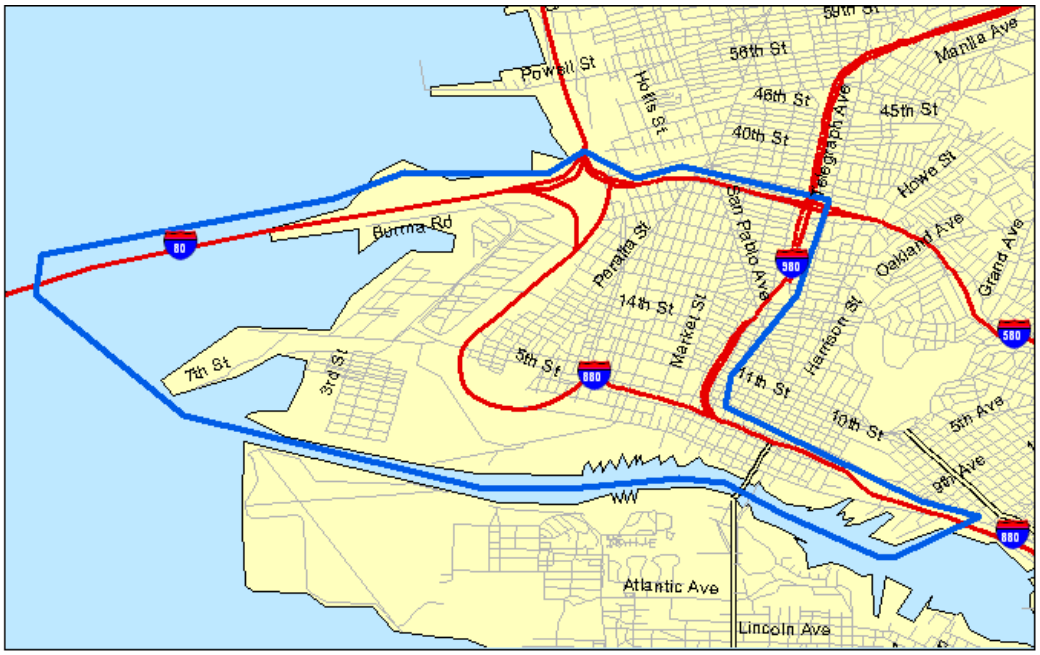

Figure 1. The approximate boundaries of the West Oakland study region.

TRUCK-BASED BUSINESSES

A major U.S. Postal distribution center and numerous other truck-based businesses operate within the West Oakland study region. Estimating year-2005 DPM emissions from on-road diesel trucks and off-road equipment at these businesses required the collection of several types of data:

[1] For purposes of this project, "truck-based businesses" were broadly defined as any business that generates significant levels of diesel truck activity (vehicle trips or idling).

- A list of West Oakland facilities that operate diesel trucks and/or equipment.
- An inventory of vehicle/equipment populations and characteristics (e.g., model year and engine power) associated with each facility.
- An estimate of activity data (e.g., hours of operation, vehicle speeds and idle times, and engine load factors) for each vehicle or piece of equipment.
- Emission factors that correlate quantities of DPM released with vehicle/equipment activity data (e.g., grams per mile traveled).
- Spatial and temporal data that allow emission estimates to be associated with a specific geographic location and hour of day for modeling purposes.

The remainder of this section describes the methodologies used to gather the data listed above and produce spatially and temporally resolved emission estimates for sources of diesel exhaust. A description is also provided of assumptions made to account for data that were not available within the constraints of this project.

Source Identification

STI developed a list of West Oakland facilities that operate diesel trucks and/or equipment by using a variety of data sources:

- The InfoUSA commercial database (InfoUSA, 2005).
- A list of 45 truck-related businesses identified in an earlier diesel particulate emissions study for West Oakland (Harding ESE, 2001).
- A list of 50 West Oakland trucking businesses assembled by the Port of Oakland (an additional 24 trucking businesses were identified as leasing space at the former Oakland Army Base near the western boundary of the study area).
- Visual inspections of the study area by STI and District staff.

As a first-cut effort to identify all West Oakland truck-based businesses, the InfoUSA commercial database was queried for businesses assigned to Standard Industrial Classification (SIC) codes associated with trucking activities (e.g., freight movement, warehousing, wholesaling, and recycling). This search was focused on postal ZIP Codes 94606, 94607, and 94612, which cover the majority of the study region and surrounding areas (see **Figure 2**).

When coupled with the list of truck-related businesses from the 2001 Harding study, the InfoUSA data produced an initial list of 130 facilities that potentially emitted DPM in the study region in 2005. This list was refined by

1. Using geographic information system (GIS) tools to eliminate businesses located outside the study boundaries;
2. Contacting selected businesses by phone or personal visit to eliminate operations that had closed or relocated, or that did not operate diesel vehicles/equipment; and
3. Adding businesses identified by the Port of Oakland or by visual inspections of the study region.

This process resulted in a final list of 52 businesses to be included in data collection efforts (see Table 1 in the following sub-section, "Survey Design and Implementation").

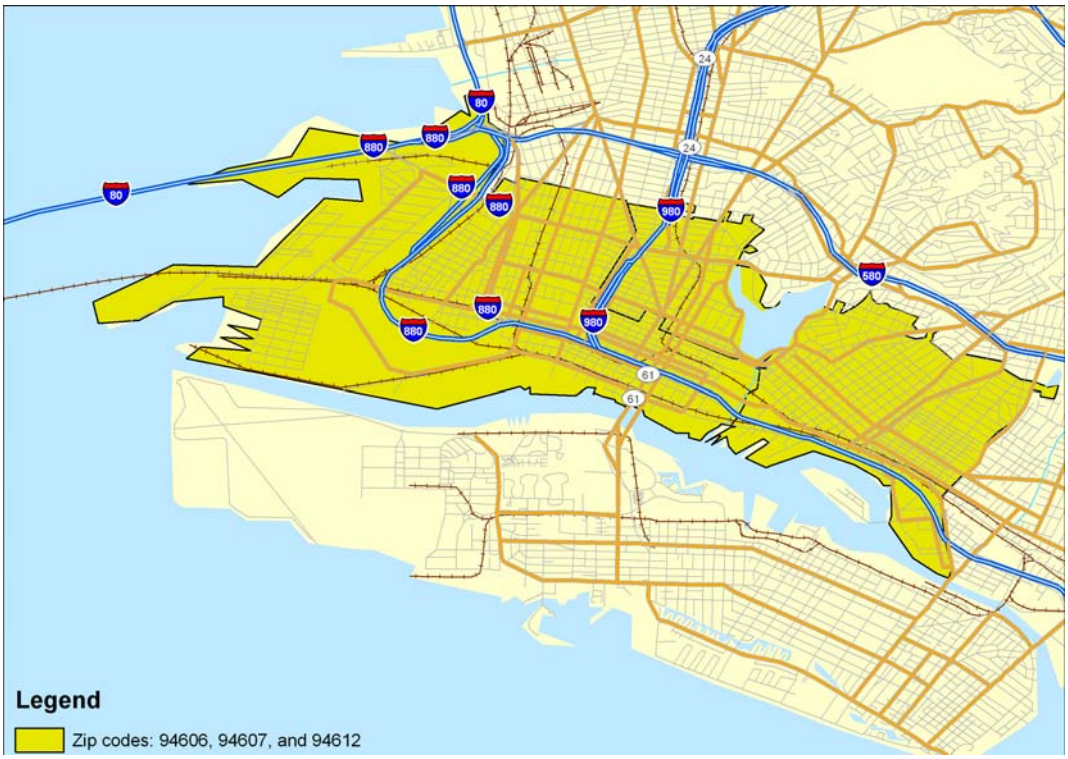

Figure 2. Region covered by STI's initial InfoUSA database query.

Survey Design and Implementation

STI identified the types of activity data required to estimate emissions from on-road diesel sources (truck movement, truck idling, and transportation refrigeration units [TRU]) and off-road diesel equipment (such as forklifts) operating at truck-based businesses in West Oakland. Required data include

- numbers of daily truck trips, including the number of trucks with TRUs;
- truck sizes (number of axles) and model years;
- average distance traveled by trucks on-site;
- average truck idle times and TRU run times (per visit);
- diesel equipment types and populations;
- diesel equipment sizes (in horsepower) and model years; and
- operating characteristics of diesel equipment (hours per day, days per week, etc.).

STI designed a one-page survey that could be used to collect these data, as well as other general information such as business operating hours, number of employees, and number of loading docks (see Appendix A for a sample survey form). This survey form was then

distributed to each of the 52 sites listed in **Table 1**, with instructions to return the completed form to the District by fax. Approximately half the sites were visited in person by STI and District staff over a two-day period, with survey forms distributed by hand. Forms were distributed by fax to the remaining sites after an initial telephone contact. Ultimately, survey forms were provided to all but five facilities. Two of the businesses (Mason Dickson Intermodal and REM Transportation) had closed or moved out of the area, and we were unable to contact the remaining three businesses (Access Plastics, American Road Lines, and Team One) within the time constraints of the study.

Within approximately one week of the distribution of survey forms, businesses that had not completed a survey were given a follow-up telephone call, personal visit, or both. Ultimately, 24 businesses responded to the survey, either by returning a completed form or by providing a verbal activity estimate when contacted by phone. For businesses that did not respond to the survey, truck activity was estimated at 9 facilities based on findings from the 2001 Harding study, and truck activity at 5 more facilities was estimated based on observations made during a site visit.[2] Of the remaining 14 facilities, it was determined that 2 businesses had closed or relocated out of the area, and that the other 12 businesses were likely to be low-activity sites.[3] In all, truck activities at 40 sites were accounted for, or 77% of the total population of truck-based businesses (see **Figure 3**). The geographic distribution of truck-based businesses in West Oakland is shown in **Figure 4**, and daily truck trip estimates and sources of data utilized for each facility are shown in Table 1. Total daily truck activities at truck-based businesses in West Oakland were estimated to be 2,937 trips per day, about 20% higher than the 2,491 truck trips per day that were estimated during the 2001 study.

[2] Curb-side observations were made for a period of approximately two hours, and daily truck trips and idling times were estimated from these observations.

[3] The 2001 Harding Study showed that facilities with 20 or more truck trips per day accounted for 93% of the total truck trips in West Oakland. Based on limited observations of a facility's size, number of loading areas, and truck activity, facilities that appeared to fall below this threshold were deemed "low activity". For facilities that did not respond to the survey but appeared to have significant truck activity (20 or more trips per day), curb-side observations were made as described above.

Table 1. Final list of West Oakland truck-based businesses and accompanying activity data.

No.	Company Name	Address	Daily Truck Trips	Data Source	Comment
1	Oakland Maritime Support Services (OMSS)	11 Burma Road	1,250	Survey response	OMSS leases space to about two dozen trucking companies at the former Oakland Army Base.
2	US Postal Service	1675 7th Street	1,034	Survey response	
3	Golden Bear Produce	315 Franklin Street	90	Observations	Data represent all produce companies on this block of Franklin Street between 2nd and 3rd Streets.
4	East Bay MUD	2020 Wake Avenue	84	Survey response	
5	Central Concrete Co.	2400 Peralta Street	56	Observations	
6	Greyhound Bus Station	2103 San Pablo Avenue	55	Survey response	
7	California Waste	1819 10th Street	44	2001 Harding Study	
8	Matheson Postal Service	2500 Poplar Street	30	2001 Harding Study	
9	Online Trucking	1155 3rd Street	30	Survey response	
10	Narayan's Trucking	1155 3rd Street #260	30	Survey response	
11	Quintero Trucking	2590 Union Street	30	Survey response	
12	A M & S Transportation Co.	1700 24th Street	25	Survey response	
13	Roadway Express Inc.	1708 Wood Street	25	Survey response	
14	Mutual Express	1700 W Grand Avenue	22	Survey response	
15	Custom Alloy and Scrap	2730 Peralta Street	20	2001 Harding Study	
16	Svenhard's Bakery	335 Adeline Street	16	Observations	Trips likely underestimated (most probably occur in early AM).
17	Lehman Transportation	1155 3rd Street #180	12	Survey response	
18	Sutta Co.	1221 3rd Street	11	Survey response	
19	National Recycling Corp.	1312 Kirkham Street	10	Survey response	
20	VA Transportation/Joint Intermodal	1225 Mandela Parkway	8	Observations	
21	Saroni Co.	1301 26th Street	7	Survey response	
22	Macy Movers Inc.	200 Victory Court	6	Observations	
23	Eastshore Charter Lines	2400 Adeline Street	6	2001 Harding Study	
24	Morgan Southern	425 Market Street	5	2001 Harding Study	

Table 1. Final list of West Oakland truck-based businesses and accompanying activity data.

No.	Company Name	Address	Daily Truck Trips	Data Source	Comment
25	JB Truck Repair	1639 18th Street	5	2001 Harding Study	
26	J&O Truck/Tire	2401 Union/2236 Poplar	5	2001 Harding Study	Operations assumed to be equal to activity reported for JB Truck repair.
27	J&A Truck Repair	2221 Union Street	5	2001 Harding Study	Operations assumed to be equal to activity reported for JB Truck repair.
28	JAC Truck Repair	Myrtle & Grand	5	2001 Harding Study	Operations assumed to be equal to activity reported for JB Truck repair.
29	California Cereal Products	1267 14th Street	5	Survey response	
30	Tighe Drayage Co.	2230 Willow Street	3	Survey response	
31	KMC Paper (Chang's)	2505 Poplar Street	2	Survey response	
32	East Bay Resources	2430 Willow Street	1	Survey response	
33	BBC Trucking	1155 3rd Street	0	Survey response	All trucks use OMSS lot; no traffic on-site.
34	Kamal Trucking	526 2nd Street	0	Survey response	All trucks use OMSS lot; no traffic on-site.
35	Wilson Trucking	1155 3rd Street #2	0	Survey response	Broker only; no traffic on-site.
36	Alberto's Trucking	2826 Myrtle Street	0	Survey response	Services only gasoline-fueled vehicles.
37	Stockmyer Trucking	2799 Wood Street	0	Survey response	All trucks use OMSS lot; no traffic on-site.
38	Subterranean Wine Storage	2240 Filbert Street # J	0	Survey response	Car traffic only.
39	Mason Dickson Intermodal	1724 Mandela Parkway	0	Observations	This business has closed or relocated.
40	REM Transportation	418 3rd Street	0	Observations	This business has closed or relocated.
41	Lange Trucking Inc.	2226 Campbell Street			Did not return survey.
42	Eighteen Trucking	2230 Willow Street			Did not return survey.
43	Bridge Terminal Transport	445 9th Avenue			Did not return survey.
44	Modern Express & Courier Service	2525 Mandela Parkway			Did not return survey.
45	Box Brothers	1001 24th Street			Did not return survey.
46	Reliable Transportation Service	2799 Wood Street			Did not return survey.
47	A V Trucking Co.	1155 3rd Street # 300			Did not return survey.
48	S Line Transportation Inc.	780 W Grand Avenue # B			Did not return survey.
49	Sutter Transportation Inc.	780 W Grand Avenue			Did not return survey.

Table 1. Final list of West Oakland truck-based businesses and accompanying activity data.

No.	Company Name	Address	Daily Truck Trips	Data Source	Comment
50	Access Plastics	1301 24th Street			Unable to contact.
51	American Road Lines	1155 3rd Street			Unable to contact.
52	Team One	2515 Magnolia Street			Unable to contact.
	Total Truck Trips Per Day		**2,937**		

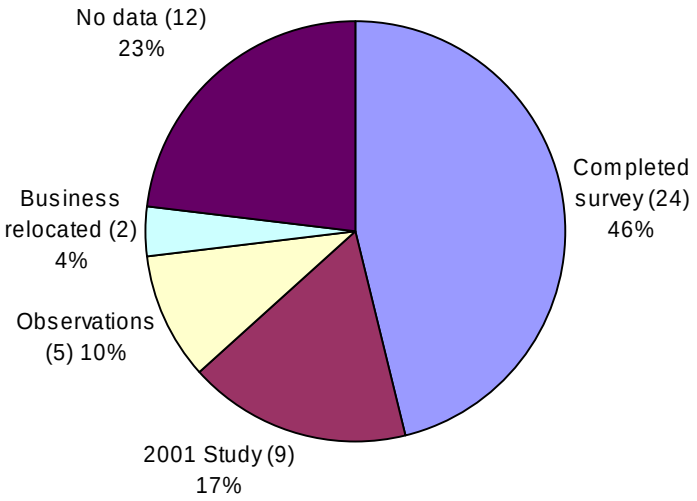

Figure 3. Breakdown of data sources used for truck-based businesses in West Oakland.

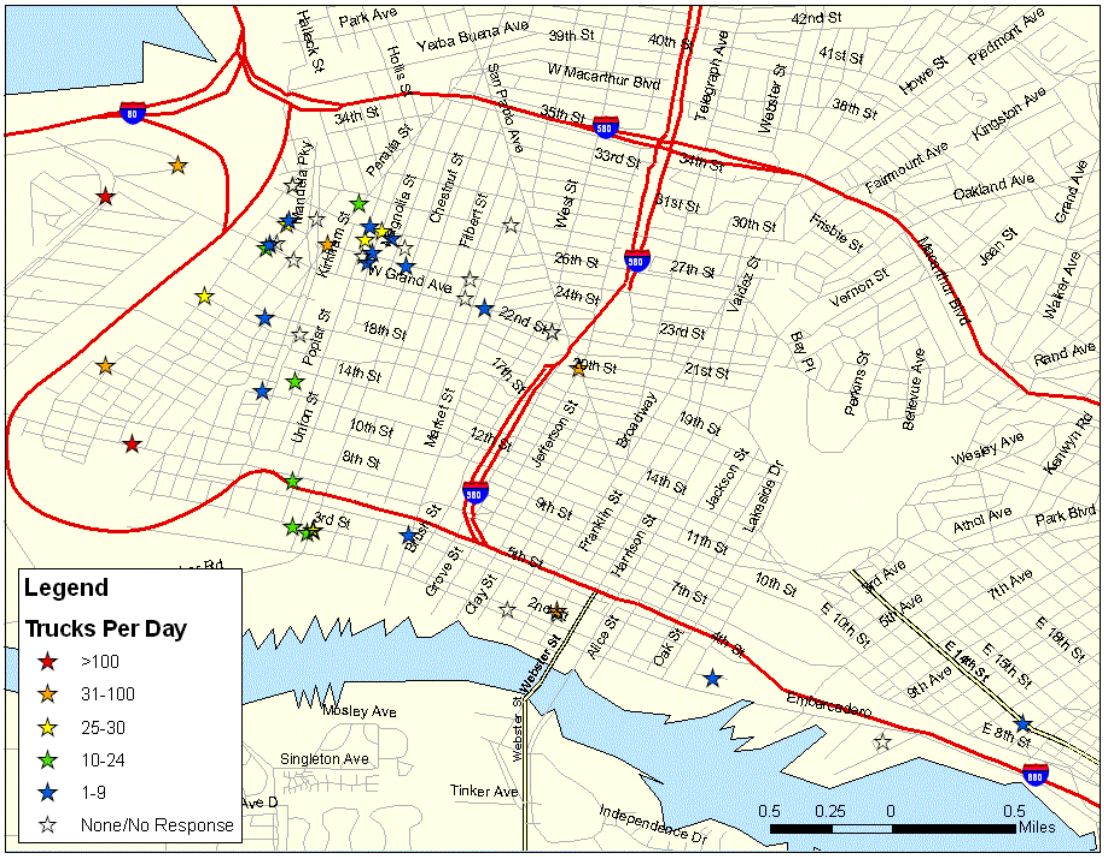

Figure 4. Locations and activity levels of truck-based businesses in West Oakland.

It should be noted that the 2001 Harding study did not report facility-specific idling times, maneuvering distances, or axle categories, and some survey responses were incomplete. Therefore, the following assumptions were made for facilities with incomplete activity data:

- An idle time of 10 minutes per truck was assumed based on the average idle time reported by the 13 facilities that provided idling data (reported idling times ranged from 1 to 30 minutes).
- All trucks were assumed to have 5 axles.
- Truck maneuvering distances were estimated using Google Earth™ facility images.

These assumptions are consistent with the findings of a similar study conducted in the Los Angeles community of Wilmington (Sax, 2004). Surveys of industrial-commercial facilities in Wilmington conducted in support of a local-scale emission inventory indicated that the vast majority of trucks entering and exiting study facilities were five-axle, heavy-duty diesel trucks. In addition, the survey results showed that reported on-site idling times for trucks ranged from 2 to 15 minutes.

Complete activity data used to estimate emissions from on-road truck activities at truck-based businesses in West Oakland are listed in Appendix B, Table B-1.

Emission Estimation – On-road Trucks

DPM emissions for diesel trucks operating at truck-based businesses were estimated using emission factors from the 2007 version of ARB's EMFAC model. EMFAC generates emission factors[4] for several classes of on-road motor vehicles (see **Table 2**), and emission factors for diesel trucks were applied to facility-specific truck activity data estimates to calculate DPM emissions for each truck-based business in West Oakland. EMFAC was run using the input parameters listed in **Table 3**.

For ease of reporting during the survey, truck-based businesses were asked to provide activity data for trucks according to the number of axles; however, EMFAC generates truck emission factors according to a gross vehicle weight (GVW) classification scheme (see Table 2). Data from a goods movement study in Southern California (VRPA Technologies, 2002) were used to convert weight-based emission factors from EMFAC into axle-based emission factors.[5] **Table 4** shows the assumed distribution of trucks by axle category across various GVW ratings, and **Table 5** shows the final emission factors by axle category for truck idling and maneuvering (5 mph).

[4] Emission factors represent the amount of a pollutant produced per unit of activity. EMFAC emission factors are reported as grams per mile traveled or grams per hour of idling for a variety of pollutants, including PM.
[5] The VRPA study was the only source of California-specific data on gross vehicle-weight distributions by axle category that could be identified within the time constraints of this study. It was assumed that the distributions estimated for truck fleets operating in Southern California were representative of trucks operating near the Port of Oakland.

Table 2. EMFAC2007 Vehicle Classes.

Vehicle Class	Description	Gross Vehicle Weight (lb)	Abbreviation
1	Light-Duty Autos	N/A	LDA
2	Light-Duty Trucks	0-3750	LDT1
3	Light-Duty Trucks	3751-5750	LDT2
4	Medium-Duty Trucks	5751-8500	MDV
5	Light-Heavy-Duty Trucks	8501-10000	LHD1
6	Light-Heavy-Duty Trucks	10001-14000	LHD2
7	Medium-Heavy-Duty Trucks	14000-33000	MHD
8	Heavy-Heavy-Duty Trucks	33001+	HHD
9	Other Buses	N/A	OBUS
10	Urban Buses	N/A	UBUS
11	Motorcycles	N/A	MCY
12	School Buses	N/A	SBUS
13	Motor Homes	N/A	MH

Table 3. Settings used to run EMFAC2007.

Input Parameter	Setting
Geographic area	Alameda County
Calendar year	2005
Season or month	Annual
Model years[a]	All
Vehicle classes	MDV, LHD1, LHD2, MHD, HHD, OBUS, UBUS
Speeds	0 mph (idle) and 5 mph (maneuvering)
Temperature[b]	57 F
Relative humidity[b]	67%
Other[c]	Default

[a] Use of model year information collected from truck-based businesses was limited, so EMFAC was run with the default model year distribution for Alameda County.

[b] Temperature and relative humidity values represent annual averages for Oakland. However, PM emission rates are not sensitive to meteorological variables.

[c] Default settings were used for other input parameters, such as inspection and maintenance (I/M) program options.

Table 4. Truck distributions by axle category and GVW ratings.

Axles	Gross Vehicle Weight in lbs (EMFAC Class)				
	<6000 (MDV)	6001-10000 (MDV/LHDT1)[a]	10001-14000 (LHDT2)	14001-33000 (MHDT)	33001+ (HHDT)
2	11.83%	26.36%	14.42%	34.45%	12.91%
3	0.00%	1.40%	1.44%	11.69%	85.44%
4	0.00%	0.00%	0.00%	2.80%	97.14%
5	0.00%	0.00%	0.00%	0.00%	100.00%
6+	0.00%	0.00%	0.00%	0.00%	100.00%

[a] The 6001-10000 GVW range spans two EMFAC vehicle classifications, so percentages in this column were evenly split between the MDV and LHDT1 classifications.

Table 5. Truck and bus emission factors.

Axles	Weighted PM EFs	
	Idle (g/hr)	5 mph (g/mile)
2	1.172	0.850
3	2.664	3.379
4	2.880	3.752
5	2.934	3.839
6+	2.934	3.839
Bus	1.373	1.029

The emission factors in Table 5 were applied to activity data collected from truck-based businesses to estimate PM emissions from on-road trucks. For example, Roadway Express reported an average of 25 truck trips per day (24 two-axle trucks and 1 three-axle truck). All trucks idle on-site for an average of 5 minutes and have an on-site travel distance of 0.25 miles. Truck emissions for this business were calculated as follows:

Idle: $PM_{2\text{-axle}} = 1.172 \text{ g/hr} \times \frac{5}{60} \text{ hr/truck} \times 24 \text{ trucks/day} = 2.34 \text{ g/day}$

$PM_{3\text{-axle}} = 2.664 \text{ g/hr} \times \frac{5}{60} \text{ hr/truck} \times 1 \text{ truck/day} = 0.22 \text{ g/day}$

Maneuvering: $PM_{2\text{-axle}} = 0.850 \text{ g/mi} \times 0.25 \text{ mi/truck} \times 24 \text{ trucks/day} = 5.10 \text{ g/day}$

$PM_{3\text{-axle}} = 3.379 \text{ g/mi} \times 0.25 \text{ mi/truck} \times 1 \text{ trucks/day} = 0.84 \text{ g/day}$

These calculations resulted in a total PM (idle plus maneuvering) estimate of 8.5 g/day from diesel trucks at this facility, and similar calculations were performed for all other truck-based businesses. Total PM emissions from on-road diesel trucks operating at truck-based businesses in West Oakland were estimated to be 4,726 g/day, or 1.9 tons per year (see Appendix B, Table B-3, for a complete list of on-road truck emissions by facility).

Emission Estimation – TRUs and Off-road Equipment

TRUs

For TRUs installed on on-road trucks and for off-road equipment (such as yard tractors and loaders) operated at truck-based businesses, emission estimates were prepared using activity data collected from individual businesses and emission factors from ARB's OFFROAD model. OFFROAD generates county-level emission estimates for various types of off-road equipment based on California-specific data on equipment populations and usage patterns. OFFROAD also utilizes emission factors that are specific to a given equipment type, fuel type, and horsepower range and are expressed in units of grams per brake horsepower hour (g/bhp-hr). These emission factors represent new engine emissions and are adjusted within the model to account for engine deterioration that occurs with use, resulting in increasing hourly emission rates. Emissions for a given equipment type are then calculated according to the following equation:

$$PM = PM_{EF} \times HRS \times HP \times LF$$

where:

PM	=	Total PM emissions from the equipment population at the specified horsepower and model-year range (g/day)
PM_{EF}	=	deterioration-adjusted PM emission factor for the specified horsepower and model-year range (g/hp-hr)
HRS	=	the aggregate daily hours of operation for the total equipment population (default values included in OFFROAD)
HP	=	average engine horsepower for the specified horsepower range
LF	=	average engine load factor (default values included in OFFROAD)

For TRUs, no data were available for model years or engine sizes, so STI ran OFFROAD for Alameda County for the year 2005 using default input parameters and analyzed the resulting model outputs to identify the most likely engine size bin for TRUs operating in West Oakland. **Table 6** shows how OFFROAD output data were weighted to calculate an average horsepower value of 31 hp for TRUs in Alameda County.

Because this fleet average value falls within OFFROAD's largest horsepower bin for TRU (26-50 hp), output emission rates for that range were used to calculate a fleet average PM emission factor. This calculation was performed as follows:

$$PM_{EF} = 105{,}233.4 \text{ g per day} / (34 \text{ hp} \times 0.53 \times 7281.7 \text{ hrs}) = 0.80 \text{ g/hp-hr}$$

where:

105,233.4 g/day	=	PM emissions for Alameda County TRUs in the 26-50 hp range
34 hp	=	average engine horsepower for TRUs in the 26-50 hp range
0.53	=	average engine load factor for TRUs in the 26-50 hp range
7281.7 hrs	=	total daily hours of operation in Alameda County for TRUs in the 26-50 hp range

Table 6. Example fleet average horsepower calculation.

Equipment Type	HP Range	Avg. HP	Activity (hrs/day)	Weighted Avg. HP[a]
Transportation Refrigeration Units	0-15	10	724.4	0.9
	16-25	17	283.3	0.6
	26-50	34	7281.7	29.9
		Totals	8289.4	**31**

[a] Values in this column were calculated using the equation: AvgHP*Activity/Total Activity, where "Total Activity" is the total hours per day of operation for pavers of all sizes (8289.4 hours).

The emission factor calculated above, the default OFFROAD load factor (0.53) for TRUs in the 26-50 hp range, and the default average engine size of 34 hp for TRUs in the 26-50 hp range were applied to site-specific activity data to calculate PM emissions from TRUs. For example, daily PM emissions for a TRU reported to be operating for 10 minutes per day at a truck-based business in West Oakland would be calculated as follows:

$$PM = 0.80 \text{ g/hp-hr} \times 34 \text{ hp} \times 0.53 \times \frac{10}{60} \text{ hrs/day} = 2.4 \text{ g/day}$$

Off-road Equipment

For off-road equipment, STI ran OFFROAD for Alameda County for the year 2005 using default input parameters and the "by model year" output option, producing annual emission rates by equipment type, horsepower range, and model year. STI then calculated deterioration-adjusted PM emission factors for equipment types and model years operating at truck-based businesses in West Oakland from OFFROAD's model year-specific outputs. For example, Roadway Express reported the operation of two 200-hp yard tractors—a 1996 model and a 1994 model. The deterioration-adjusted PM emission factor for the 1996 tractor was calculated from OFFROAD outputs as follows:

$$PM_{EF} = 92.53 \text{ g per day} / (249 \text{ hp} \times 0.55 \times 3.35 \text{ hrs}) = 0.20 \text{ g/hp-hr}$$

where:

92.53 g/day	=	PM emissions for Alameda County tractors of model year 1996 in the 176-250 hp range
249 hp	=	average engine horsepower for tractors in the 176-250 hp range
0.55	=	average engine load factor for tractors in the 176-250 hp range
3.35 hrs	=	total daily hours of operation in Alameda County for tractors of model year 1996 in the 176-250 hp range

To calculate PM emissions, this emission factor and the default OFFROAD load factor (0.55) were then applied to activity data for this yard tractor collected from Roadway Express:

$$PM = 0.20 \text{ g/hp-hr} \times 200 \text{ hp} \times 0.55 \times 8.8 \text{ hrs/day} = 194 \text{ g/day}$$

Similar calculations were performed for other pieces of off-road equipment operating at truck-based businesses in West Oakland. Total PM emissions from all TRUs and off-road equipment were estimated to be 672 grams per day, or 0.3 tons per year. Appendix B, Table B-2, is a complete list of activity data and emission factors used to estimate emissions from off-road equipment operating at truck-based businesses in West Oakland, and TRU/off-road emissions by facility are listed in Table B-3.

Spatial and Temporal Allocation

For purposes of CALPUFF modeling, emission estimates developed for truck-based businesses in West Oakland were assigned to spatial coordinates and diurnal temporal profiles. Each business was treated as a CALPUFF area source, which requires that the model be provided with four location coordinates that represent the polygon-shaped perimeter around each source. These coordinates were obtained by entering each facility's address into Google Earth, then using the Google Earth pointer feature to obtain the latitude and longitude of the four corners that bound each facility's property. **Figure 5** shows a Google Earth image for Roadway Express and the latitude and longitude values that were obtained for each polygon corner.

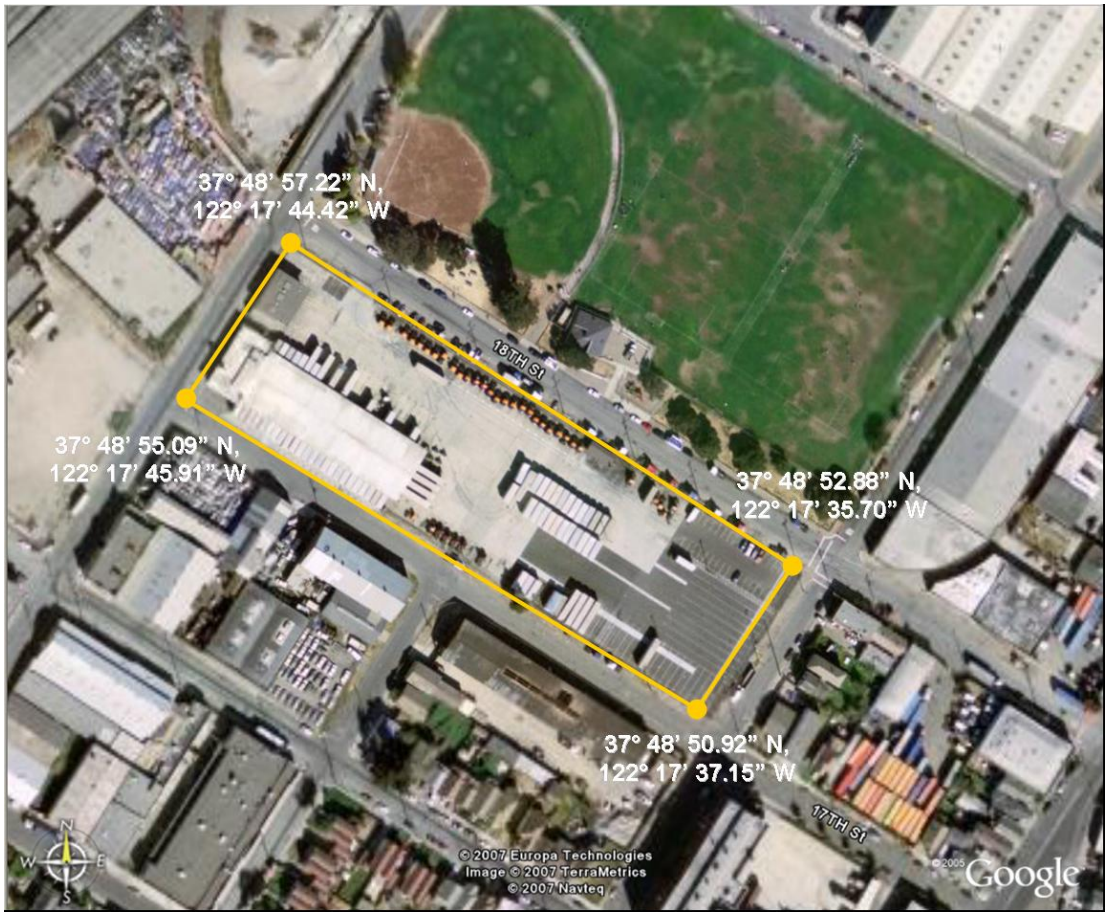

Figure 5. Spatial coordinates for the Roadway Express facility derived from Google Earth.

After a set of latitude and longitude values were developed for each truck-based business, the values were converted to the Universal Transverse Mercator (UTM) coordinates, one of the coordinate systems supported by CALPUFF.

Diurnal temporal profiles were developed for each truck-based business based on information gathered during the survey process. Each business was asked to provide information on operating hours and usage patterns for off-road equipment, and these data were used to develop hourly emission profiles for on-road vehicles and off-road equipment at each business (see Tables B-1 and B-2). In cases for which no operating data were available, businesses were assigned a diurnal profile that distributes emissions evenly across the hours from 7 a.m. to 5 p.m.

CONSTRUCTION PROJECTS

Several major construction projects were undertaken within the West Oakland study region during 2005, including work on the new eastern span of the Bay Bridge. Estimating year-2005 DPM emissions from off-road diesel equipment operating at these construction sites required the collection of several types of data:

- A list of West Oakland construction projects that were active during 2005 and during which diesel construction equipment was used.
- An inventory of equipment populations and characteristics (e.g., model year and engine horsepower) associated with each construction project.
- An estimate of activity data (e.g., hours of operation and engine load factors) for each piece of diesel equipment.
- Emission factors that correlate quantities of DPM released with equipment activity data (e.g., g/hp-hr).
- Spatial and temporal data that allow emission estimates to be associated with a specific geographic location and hour of day for modeling purposes.

The remainder of this section describes the methodologies used to gather the data listed above and produce spatially and temporally resolved emission estimates for sources of diesel exhaust associated with construction projects. A description is also provided of assumptions made to account for data that were not available within the constraints of this project.

Source Identification

To begin the process of identifying year-2005 construction projects in West Oakland, the District obtained two lists of major development projects in Oakland from personnel at the City of Oakland.[6] These lists represented projects that were at various stages of the permitting or building process during spring and fall 2005, and STI combined these lists to develop a unique list of 111 projects. Using construction project addresses and GIS tools, we then identified

[6] The City of Oakland also provided a list of street paving projects undertaken in Oakland during 2005, but none of these projects took place in the West Oakland study region.

31 projects that were located within the boundaries of the West Oakland study area. However, it appeared that many of these projects were still in the permit application process and not active during 2005. Therefore, District staff worked with the City of Oakland to develop a final list of 8 projects that were engaged in emission-producing activities during 2005 (see **Figure 6** and **Table 7** in the following sub-section, "Survey Design and Implementation").

Figure 6. Locations of major construction projects in West Oakland during 2005 (Bay Bridge construction project not shown).

Survey Design and Implementation

STI identified the types of activity data required to estimate emissions from off-road diesel equipment operating at construction project sites in West Oakland:

- Equipment populations for the various types of equipment operating at each site.
- Model year and engine size (in horsepower) for each piece of equipment.
- Number of days of operation in 2005 for each piece of equipment.
- Average hours per day of operation for each piece of equipment.
- The typical start hour for daily equipment operation.

The District designed a one-page survey that could be used to collect these data, as well as other general information such as the project's total square footage (see Appendix A for a sample survey form). The District then distributed this survey form to the construction companies responsible for the eight projects listed in **Table 7**. This table shows that the District received completed survey forms for four projects, including the Bay Bridge construction. Appendix C**,** Table C-1, lists the data collected through the surveys.

For the four construction projects for which activity data were unavailable, it was assumed that activity data from the Harbor View Lofts project could be used as a surrogate. The Harbor View Lofts project was selected as a surrogate for several reasons:

- The project was similar in scope to the four projects with no activity data (100 condominium units were completed at Harbor View Lofts, while the remaining projects involved the construction of 91-157 condominium or live/work units).
- The 206 Second Street project, which was also similar in scope to the four projects with no activity data, was constructed by a "green" building company that utilized electric equipment wherever possible.
- Activity data from the 66 Franklin Street project was judged inapplicable to the four projects with no activity data, as this project involved the renovation of existing commercial space.

Table 7. Major construction projects in West Oakland during 2005.

Project	Location	Project Details	Completed Survey
206 Second Street	206 Second Street	2,380 ft^2 of live/work; 1,310 ft^2 of retail space; 70 condominium units	✓
300 Harrison Street	300 Harrison Street	91 condominium units	
66 Franklin Street	66 Franklin Street	Renovation of existing building (90,000 ft^2); part of the Jack London Square redevelopment project	✓
8 Orchids	620-636 Broadway	3,600 ft^2 retail; 157 condominium units	
Ettie Street/Mandela Parkway	2818 Mandela Parkway	91 live/work units	
Harbor View Lofts (Aqua Via)	121-129 2nd Street	100 condominium units; 10,000 ft^2 of retail	✓
Wheelink Project	426 Alice Street	94 residential units; 9,800 ft^2 office	
Bay Bridge Construction	N/A	Replacement of eastern span	✓

Emission Estimation

Emission estimates for construction equipment were prepared in the same way as emission estimates for TRUs at truck-based businesses, by combining activity data collected for individual construction projects and "fleet-average" emission factors from ARB's OFFROAD model. Surveyed construction companies were not able to provide information on the model year or engine size of equipment used at construction sites in West Oakland, so year-2005 OFFROAD outputs for Alameda County were analyzed to develop average emission factors and horsepower ranges for various types of construction equipment.[7] For example, **Table 8** shows how OFFROAD data were weighted to calculate an average horsepower value of 100 hp for pavers in Alameda County.

Table 8. Example fleet average horsepower calculation.

Equipment Type	HP Range	Avg. HP	Activity (hrs/day)	Weighted Avg. HP[a]
Pavers	0-25	24	1.7	0.1
	26-50	36	99.6	11.6
	51-120	89	117.5	33.8
	121-175	165	73.0	38.9
	176-250	250	8.8	7.1
	250-500	300	9.0	8.7
		Totals	309.7	**100**

[a] Values in this column were calculated using the equation: AvgHP*Activity/Total Activity, where "Total Activity" is the total hours per day of operation for pavers of all sizes (309.7 hours).

Because this fleet average value falls within OFFROAD's 51-120 hp range, output emission rates for that range were used to calculate a fleet average PM emission factor. This calculation was done as follows:

$$PM_{EF} = 5642.7 \text{ g per day} / (89 \text{ hp} \times 0.62 \times 117.5 \text{ hrs}) = 0.87 \text{ g/hp-hr}$$

where:

5642.7 g/day	=	PM emissions for Alameda County pavers in the 51-120 hp range
89 hp	=	average engine horsepower for pavers in the 51-120 hp range
0.62	=	average engine load factor for pavers in the 51-120 hp range
117.5 hrs	=	total daily hours of operation in Alameda County for pavers in the 51-120 hp range

To calculate PM emissions, this emission factor, the default OFFROAD load factor (0.62) for pavers in the 51-120 hp range, and the fleet average engine size of 100 hp were then

[7] The survey completed by KFM Joint Venture for the Bay Bridge project contained model year information but no horsepower data. Because this is a heavy-construction project, model-year specific emission factors were selected for the largest horsepower bin in each equipment category.

applied to site-specific activity data. For example, daily PM emissions for a paver reported to be operating for 8 hours per day at the Harbor View Lofts project were calculated as follows:

PM = 0.87 g/hp-hr x 100 hp x 0.62 x 8 hrs/day = 431.5 g/day

Similar calculations were performed for other pieces of off-road equipment operating at construction projects in West Oakland, and a complete listing of equipment types and corresponding emission factors is shown in Table C-1. Total PM emissions from diesel construction equipment operating in West Oakland in 2005 were estimated to be 30,086 grams per day at the Bay Bridge project and 1,510 grams per day at the remaining 7 projects. Combined, these PM emissions from construction activities in West Oakland total 12.7 tons per year (see Table C-2 in Appendix C for a complete list of emissions by construction project).

Spatial and Temporal Allocation

Spatially and temporally, emissions from diesel sources at construction projects in West Oakland were allocated in the same way as truck-based businesses. Each construction site was treated as a CALPUFF area source, with location coordinates derived from Google Earth images. For the Bay Bridge project, a year-2005 Google Earth image shows a series of large derrick barge cranes around the eastern span of the bridge, and emissions were assumed to occur within a rectangular area encompassing these cranes (see **Figure 7**).

Diurnal temporal profiles for construction activity were developed based on information gathered during the survey process (hours per day of operation and start hour). In cases for which no temporal data were available, construction equipment was assumed to operate for 8 hours per day beginning at 7 a.m. Table C-1 lists the temporal information gathered from each construction project.

DISCUSSION OF RESULTS

The emission estimates summarized in this document represent the best available information and are useful for evaluating health risks from diesel exhaust in the West Oakland neighborhood adjacent to the Port of Oakland. Emission estimates were prepared for 40 truck-based businesses (77% of the estimated total) and 8 construction projects (100% of the identified year-2005 projects). Surveys and observations were used to gather new activity data from 29 truck-based businesses and 4 construction projects, and activities at the remaining truck-based businesses and construction projects were estimated based on existing data sources and assumptions derived from survey results.

Figure 7. Assumed area for construction emissions from the Bay Bridge project.

However, because these emission estimates were generated with limited time and resources, the resulting emission inventories should be viewed as "first cut" efforts that can be used to prioritize further inventory development activities in West Oakland. Specific recommendations for continued inventory development follow:

- Collect more detailed data on diesel truck traffic patterns in West Oakland. The results of this project indicate that nearly 3,000 diesel trucks are being operated in West Oakland on a given weekday, but emission estimates were limited to idling and maneuvering activities occurring at truck-based businesses. Truck trip data collected during this project could be used to identify potential high-traffic areas in the neighborhood where additional data collection efforts could be undertaken. These data could then be used to refine existing estimates of emissions from on-road diesel truck traffic.
- Refine estimates of truck idling activities in West Oakland. Many survey respondents reported no idling information or very low idling times (5 minutes or less) for diesel trucks. Additional data collection efforts should be undertaken to "ground truth" truck idling times in West Oakland, particularly near schools and residential areas.

- Gather additional data on Bay Bridge construction activities during 2005. Although data on Bay Bridge equipment populations were obtained, limited information was available on the temporal and spatial distribution of Bay Bridge construction activities. Therefore, conservative assumptions were applied to emission estimates for this project (e.g., assuming that equipment operated 8 hours a day, 365 days a year). Improved temporal and spatial data would allow for more accurate assessments of the actual impact of this project on air quality in West Oakland.

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APPENDIX A

SURVEY FORMS FOR TRUCK-BASED BUSINESSES AND CONSTRUCTION PROJECTS

TRUCK-BASED BUSINESS SURVEY

Interviewer Initials: _____ Date: _____

Facility Name: _____

Facility Address: _____

Contact Person/Title: _____ Phone: _____

Facility Information: Business Type: _____

Size (acres): _____ Employees: _____

Number of loading docks: _____

Facility Operations: Start hour: _____ End hour: _____

Days per week: _____ Weeks per year: _____

Please provide the information shown in the tables below for all diesel-powered trucks and equipment (such as forklifts and cargo handling equipment) operating at this facility. Truck activity should be reported according to the classifications shown on the back of this page. *(Note: Providing a range of values is acceptable if exact values are not known.)*

Diesel-powered truck information

Number of axles	Number of trucks per day	Number that have TRUs[a]	Truck age range	Avg. idle time per truck (min.)	Estimated onsite distance traveled	TRU[a] onsite run time (min.)
2						
3						
4						
5						
6+						

[a]TRU = Transport Refrigeration Unit

Diesel-powered off-road equipment information (if applicable)

Equipment Type	Number of Equipment	HP	Engine Year	Days per week Operated	Avg. Hours Per Day	Start Hour	Fuel Consumed (gal/day)	% Time at Idle	% Time Under Load

CONSTRUCTION EQUIPMENT SURVEY
Please estimate construction activity that occurred in 2005

1. Project Name:_____ Contact:_____

2. Project Size: Acres_____; Number of units and/or commercial/retail sq. ft._____

Construction Equipment	Activity: Demolition, Grading, Construction, Coating/Paving, Etc.	# of pieces of equipment	Year / Make	# Days on job	# Hours per day	Start Time	Horsepower/ fuel type
Rubber Tired Dozers							
Concrete/ Industrial Saws							
Excavators							
Bore/Drill Rigs							
Tractors/Loaders /Backhoes							
Graders							
Scrapers							
Cranes							
Welders							
Forklifts							
Generator Sets							
Pavers							
Paving Equipment							
Cement and Mortar Mixers							
Plate Compactors							
Rollers							
Diesel Generators							
Other:							
Other:							

APPENDIX B

ACTIVITY AND EMISSION ESTIMATES FOR TRUCK-BASED BUSINESSES

Table B-1. Activity data for on-road trucks operating at truck-based businesses.

Company Name	Business Hours		Days per week	Weeks per year	Number of axles	Trucks per day	Number w/ TRU	Idle time (min.)	Onsite travel (mi.)	TRU run time (min.)
	Start	End								
A M & S Transportation Co.	0500	1700	5	52	3	25	20	5	0.085	5
California Cereal Products	0000	2400	7	52	2	1	0	10	0.095	0
			7	52	5	4	0	10	0.095	0
California Waste	0700	1700	5	52	5	44	0	10	0.114	0
Central Concrete Co.	0700	1700	5	52	2	48	0	20	0.08	0
			5	52	5	8	0	30	0.08	0
Custom Alloy and Scrap	0700	1700	5	52	5	20	0	10	0.059	0
East Bay MUD	0000	2400	7	52	3	37	0	5	0.095	0
			7	52	5	11	0	5	0.095	0
			7	52	6+	36	0	5	0.095	0
East Bay Resources	0700	1630	5.5	52	2	1	0	10	0.066	0
Eastshore Charter Lines	0700	1700	5	52	5	6	0	10	0.023	0
Golden Bear Produce	0000	2400	5	52	2	90	22	5	0.07	5
Greyhound Bus Station	0500	0130	7	52	2 (Bus)	55	0	10	0.014	0
J&A Truck Repair	0700	1700	5	52	5	5	0	10	0.019	0
J&O Truck/Tire	0700	1700	5	52	5	5	0	10	0.019	0
JAC Truck Repair	0700	1700	5	52	5	5	0	10	0.019	0
JB Truck Repair	0700	1700	5	52	5	5	0	10	0.019	0
KMC Paper (Chang's)	0900	1600	5	52	3	2	0	10	0.019	0
Lehman Transportation	0700	1700	7	52	5	12	0	10	0	0
Macy Movers Inc.	0700	1700	5	52	5	6	0	10	0.028	0
Matheson Postal Service	0700	1700	5	52	5	30	0	10	0.057	0
Morgan Southern	0700	1700	5	52	5	5	0	10	0.034	0
Mutual Express	0700	1700	5	52	5	22	0	10	0.047	0
Narayan's Trucking	0000	2400	7	52	3	30	0	10	0	0
National Recycling Corp.	0600	1730	6	52	2	7	0	1	0.047	0
			6	52	3	3	0	1	0.047	0

Table B-1. Activity data for on-road trucks operating at truck-based businesses.

Company Name	Business Hours		Days per week	Weeks per year	Number of axles	Trucks per day	Number w/ TRU	Idle time (min.)	Onsite travel (mi.)	TRU run time (min.)
	Start	End								
Oakland Maritime Support Services (OMSS)	0700	1900	5	52	3	350	0	5	1	0
			5	52	5	900	0	5	1	0
Online Trucking	0700	1700	5	52	5	30	0	10	0	0
Quintero Trucking	0700	1800	5	50	4	30	0	5	0.028	0
Roadway Express	0000	2400	5	52	2	24	0	5	0.25	0
			5	52	3	1	0	5	0.25	0
Saroni Co.	0600	1400	5	52	2	4	4	10	0.038	10
			5	52	3	3	3	10	0.038	10
Sutta Co.	0700	1600	5	52	2	1	0	10	0.052	0
			5	52	3	10	0	10	0.052	0
Svenhard's Bakery	0000	2400	5	52	5	16	0	10	0.08	0
Tighe Drayage Co.	0700	1630	5	52	5	3	3	30	0.038	30
US Postal Service	0000	2400	5	52	2	181	0	5	0.333	0
			5	52	3	254	0	5	0.333	0
			5	52	4	127	0	5	0.333	0
			5	52	6+	472	0	5	0.333	0
VA Transportation/Joint Intermodal	0700	1700	5	52	5	8	0	10	0.025	0

Table B-2. Activity data for off-road equipment operating at truck-based businesses.

Business Name	Equipment Type	Pieces of equipment	Model Year	Days per week	Hours per day	Start Hour	Horse-power	Load Factor	PM Emission Factor (g/hp-hr)
East Bay Resources	Loader	1	2006	5.5	5.5	0730	100	0.55	0.2659
Mutual Express	Off-highway truck	1	1990	5	1	0700	175	0.57	0.5290
Roadway Express	Yard tractor	1	1994	5	8.8	0700	200	0.55	0.5326
	Yard tractor	1	1996	5	8.8	0700	200	0.55	0.2015

Table B-3. Annual PM emissions for truck-based businesses.

Business Name	PM (annual average lbs/day)					PM (tons/year)				
	Maneuvering	Idle	TRU	Offroad	Total	Maneuvering	Idle	TRU	Offroad	Total
A M & S Transportation Co.	0.011	0.009	0.038	0.000	0.058	0.002	0.002	0.007	0.000	0.011
California Cereal Products	0.003	0.005	0.000	0.000	0.008	0.001	0.001	0.000	0.000	0.001
California Waste	0.030	0.034	0.000	0.000	0.064	0.006	0.006	0.000	0.000	0.012
Central Concrete Co.	0.009	0.048	0.000	0.000	0.057	0.002	0.009	0.000	0.000	0.010
Custom Alloy and Scrap	0.007	0.015	0.000	0.000	0.022	0.001	0.003	0.000	0.000	0.004
East Bay MUD	0.064	0.043	0.000	0.000	0.107	0.012	0.008	0.000	0.000	0.020
East Bay Resources	0.000	0.000	0.000	0.139	0.139	0.000	0.000	0.000	0.025	0.025
Eastshore Charter Lines	0.001	0.005	0.000	0.000	0.005	0.000	0.001	0.000	0.000	0.001
Golden Bear Produce	0.008	0.014	0.042	0.000	0.064	0.002	0.003	0.008	0.000	0.012
Greyhound Bus Station	0.002	0.028	0.000	0.000	0.029	0.000	0.005	0.000	0.000	0.005
J&A Truck Repair	0.001	0.004	0.000	0.000	0.004	0.000	0.001	0.000	0.000	0.001
J&O Truck/Tire	0.001	0.004	0.000	0.000	0.004	0.000	0.001	0.000	0.000	0.001
JAC Truck Repair	0.001	0.004	0.000	0.000	0.004	0.000	0.001	0.000	0.000	0.001
JB Truck Repair	0.001	0.004	0.000	0.000	0.004	0.000	0.001	0.000	0.000	0.001
KMC Paper (Chang's)	0.000	0.001	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000
Lehman Transportation	0.000	0.013	0.000	0.000	0.013	0.000	0.002	0.000	0.000	0.002
Macy Movers Inc.	0.001	0.005	0.000	0.000	0.006	0.000	0.001	0.000	0.000	0.001
Matheson Postal Service	0.010	0.023	0.000	0.000	0.033	0.002	0.004	0.000	0.000	0.006
Morgan Southern	0.001	0.004	0.000	0.000	0.005	0.000	0.001	0.000	0.000	0.001
Mutual Express	0.006	0.017	0.000	0.083	0.106	0.001	0.003	0.000	0.015	0.019
Narayan's Trucking	0.000	0.029	0.000	0.000	0.029	0.000	0.005	0.000	0.000	0.005
National Recycling Corp.	0.001	0.001	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000
Oakland Maritime Support Services	7.283	0.468	0.000	0.000	7.751	1.329	0.085	0.000	0.000	1.414
Online Trucking	0.000	0.023	0.000	0.000	0.023	0.000	0.004	0.000	0.000	0.004
Quintero Trucking	0.005	0.011	0.000	0.000	0.016	0.001	0.002	0.000	0.000	0.003
Roadway Express Inc.	0.009	0.004	0.000	1.116	1.129	0.002	0.001	0.000	0.204	0.206
Saroni Co.	0.001	0.003	0.026	0.000	0.031	0.000	0.001	0.005	0.000	0.006
Sutta Co.	0.003	0.007	0.000	0.000	0.010	0.001	0.001	0.000	0.000	0.002

Table B-3. Annual PM emissions for truck-based businesses.

Business Name	PM (annual average lbs/day)					PM (tons/year)				
	Maneuvering	Idle	TRU	Offroad	Total	Maneuvering	Idle	TRU	Offroad	Total
Svenhard's Bakery	0.008	0.012	0.000	0.000	0.020	0.001	0.002	0.000	0.000	0.004
Tighe Drayage Co.	0.001	0.007	0.034	0.000	0.042	0.000	0.001	0.006	0.000	0.008
US Postal Service	1.726	0.345	0.000	0.000	2.071	0.315	0.063	0.000	0.000	0.378
VA Transportation/Joint Intermodal	0.001	0.006	0.000	0.000	0.007	0.000	0.001	0.000	0.000	0.001
Total	9.195	1.195	0.140	1.338	11.867	1.678	0.218	0.025	0.244	2.166

APPENDIX C

ACTIVITY AND EMISSION ESTIMATES FOR CONSTRUCTION PROJECTS

Table C-1. Activity data for off-road equipment operating at construction sites.

Project	Equipment Type	Pieces of equipment	Days on job	Hours per day	Start Hour	Horse-power	Load Factor	PM Emission Factor (g/hp-hr)
66 Franklin Street	Bore/Drill Rigs	1	30	8	0700	200	0.75	0.1454
	Tractors/Loaders/Backhoes	1	20	8	0700	100	0.55	0.8028
	Cranes	1	2	8	0700	270	0.43	0.3035
	Welders	2	40	6	0700	45	0.45	0.7456
	Forklifts	4	100	4	0700	145	0.3	0.4733
	Paving Equipment	1	1	8	0700	100	0.53	0.8608
206 Second Street	Gradeall Lifter	1	120	4	0730	90	0.6	0.8206
Harbor View Lofts[a]	Rubber Tired Dozers	2	30	8	0700	330	0.59	0.3811
	Concrete/Industrial Saws	1	7	8	0700	65	0.73	0.7143
	Excavators	1	15	8	0700	165	0.57	0.4615
	Bore/Drill Rigs	1	45	8	0700	200	0.75	0.1454
	Tractors/Loaders/Backhoes	1	30	8	0700	100	0.55	0.8028
	Welders	1	30	8	0700	45	0.45	0.7456
	Forklifts	1	180	8	0700	145	0.3	0.4733
	Pavers	1	2	8	0700	100	0.62	0.8699
Bay Bridge	Cranes	6	365	8	0700	1800	0.43	0.2579
	Welders	24	365	8	0700	297	0.45	0.0978
	Forklifts	10	365	8	0700	295	0.3	0.1166
	Cement and Mortar Mixers	1	365	8	0700	25	0.56	0.4716
	Diesel Generators	24	365	8	0700	145	0.74	0.1493
	Other - Crew Boats	5	365	8	0700	212	0.43	0.2806
	Other - Aux. Engine	5	365	8	0700	54	0.43	0.2824
	Other - Light Plants	12	365	8	0700	327	0.62	0.1038
	Other - Air Compressors	25	365	8	0700	808	0.48	0.1384

[a] Activity data from the Harbor View Lofts project was used as a surrogate for four other projects in West Oakland: 300 Harrison Street, 8 Orchids, Ettie Street/Mandela Parkway, and Wheelink.

Table C-2. Annual PM emissions for construction projects.

Project	PM Emissions	
	Annual Average lbs/Day	Tons/Year
66 Franklin Street	0.323	0.059
206 Second Street	0.129	0.023
Harbor View Lofts	0.576	0.105
300 Harrison Street	0.576	0.105
8 Orchids	0.576	0.105
Ettie Street/Mandela Parkway	0.576	0.105
Wheelink	0.576	0.105
Bay Bridge Construction	66.329	12.105
Total	69.658	12.713