

# Characterization and Breadth of Rail Yard Specific Inventories

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## ABSTRACT

Recent interest in evaluating the impacts of rail yard facilities on local air quality includes the California Air Resources Board's recent rail yard health risk assessments and the Lake Michigan Air Directors Consortium's 2009 "Midwest Rail Study." In support of these two efforts, Sierra Research has completed comprehensive emission inventory evaluations for nine individual rail yard facilities. Based on these inventories, the characteristics of emissions-related activities are quantified and contrasted for particulate matter (PM) and oxides of nitrogen (NOx). Emissions results are presented as historical annual estimates using facility-specific data prepared in a ground up inventory evaluation effort.

The key characteristic impacting the design of the inventory development effort is the type of rail yard facility: classification, intermodal, maintenance and specialty. Each of these types is represented within the nine-facility sample discussed in this paper. Within any given yard, potentially more than 20 distinct emission sources could be present, including locomotives, on-road vehicles, non-road equipment, stationary engines, storage tanks, and wastewater treatment plants. The type of rail yard is broadly indicative of the types and proportions of locomotive and non-locomotive operations. Within the facilities evaluated, the locomotive fraction of total facility emissions ranges from 35 to 100 percent for PM and 56 to 100 percent for NOx. As such, the locomotive contribution ranges from encompassing nearly all of a facility-wide inventory to making up only a minority share of the emissions produced.

The main conclusions of this study are (1) the data requirements for properly preparing the facility inventory, depending on the type of facility, are significant and (2) there is no uniformly "typical" facility, and extrapolation or generalization from one facility to another is highly discouraged.

## INTRODUCTION

Concentrated centers for transportation and goods movement—such as shipping ports, airports, rail yards, freeways, and truck distribution centers—can be localized sources of air pollutant emissions. These transportation facilities are often located in urban areas, and can be found near communities where air quality impacts may be of concern. Recent efforts have focused on improved quantification of emissions from these transportation facilities as part of air quality planning and regulatory efforts. This paper covers the development of emission inventories from nine rail yards, each of which is located in an urban setting and whose localized impact on air quality was examined in detail. These rail yard inventories were developed as part of the two efforts listed below.

- In 2004, the California Air Resources Board (CARB) published a detailed examination of the Roseville rail yard facility<sup>1</sup> and followed this with publications of studies regarding 17 additional rail yards throughout California, most of which were completed in 2007.<sup>2</sup> Sierra Research organized and compiled the emission inventory analyses in support of eight of the 17 follow-up studies. (Sierra was assisted substantially in these efforts by Air Quality

Management Consulting.) Other follow-up rail yard studies—specific to intermodal yards—have been presented previously at this conference in 2008.<sup>3</sup>

- In 2009, the Lake Michigan Air Directors Consortium sponsored multiple contracts under the “Midwest Rail Study,” in which rail yard proximity to urban fine particulate matter (PM<sub>2.5</sub>) monitors was a concern for meeting federal air quality standards in three Midwest locations. The evaluation of the first yard, located just outside Detroit, has been completed, and Sierra Research provided the inventory analysis of the rail yard.<sup>4</sup>

This paper presents the combined results from nine rail yard facilities, eight from California and one from Michigan. Each yard was evaluated on an annual basis for a historical operating period (either calendar year 2005 or 2007) for which detailed facility-specific activity data were provided. This paper focuses on the results for criteria pollutants of particulate matter (PM) and oxides of nitrogen (NO<sub>x</sub>). (Other species, including greenhouse gases and individual HC-based toxic compounds, were evaluated in some, but not all, of the original inventory efforts.)

The remainder of this paper is divided into the topics of Methods, Results and Conclusions. References are provided at the end of the paper.

## **METHODS**

The basic building blocks of any emissions inventory are population data, activity data, and emission factors. Although many regulatory agencies publish extensive guidance, and in some cases sophisticated models, for the development of emission inventories and the underlying data, minimal federal guidance exists on procedures for the preparation of emission inventories for locomotive activities or from the combined activities of all sources that operate within rail yards. Moreover, the variability in activities from one yard to the next, and differences in data collection techniques between railroads, prohibits the development of default factors or assumptions that would be accurate in any given situation. In short, the best procedures for inventory development are from the ground up using facility-specific data, whenever possible. The facility inventories were therefore completed with the cooperation and invaluable assistance of the yard owners; this type of cooperation and assistance is essential to the development of detailed rail yard inventories.

The identification of facility-specific activities and emission sources, as well as the collection of the supporting activity data and other key assumptions, was completed in consultation with yard personnel through a combination of surveys, e-mail, interviews, and onsite visits. Additional assumptions, such as emission factors, were extracted from standard USEPA and CARB references and models. The discussion below summarizes the emission inventory modeling methods and data employed for the yard evaluations.

### **Potential Emissions Sources**

Listed below are potential emission activities/sources at rail yards; not all of these activities/sources will be found at every facility. This list of potential sources was examined with respect to each facility to determine which were present and which were not.

1. Line haul locomotives (i.e., those that transport passengers or cargo from one location to another)
2. Switch locomotives (i.e., those that perform yard-specific operations)
3. Locomotive service facilities (related to fuel, sand, and lubricating oil)
4. Locomotive maintenance facilities
5. Locomotive-based auxiliary power units (APUs)
6. Refrigerated railcars (a.k.a. reefers)

7. Evaporative emissions from tanks and refueling
8. Cargo handling non-road equipment
9. Rail maintenance non-road equipment
10. Other heavy-duty non-road equipment (e.g., cranes, forklifts)
11. Other portable non-road equipment (e.g., power washers, welders)
12. Fugitive PM from use of unpaved surfaces by on-road vehicles
13. Fugitive PM from aggregate handling and storage piles
14. Employee-owned on-road vehicles
15. Facility-owned on-site vehicles
16. Vendor delivery vehicles
17. Drayage or cargo hauling on-road trucks
18. Container-based transportation refrigeration units (TRUs)
19. Stationary IC engines (e.g., generators and air compressors)
20. Solvent usage (e.g., degreasers and paints)
21. Sand tower activity
22. Wastewater treatment plants
23. Space and water heaters

At some of the yards studied, some of these activities were found to exist, but the contributions to the overall emissions inventory were *de minimis* and a detailed analysis of the sources was ultimately excluded. For the purposes of reporting in this paper, the PM results include only the exhaust component. Fugitive PM and PM from brake and tire wear are excluded from the results contained herein.

## **Yard Types**

The nine rail yards are grouped into four yard types defined based on the fundamental activities occurring. One or more of these yard types can be applicable to any given rail yard. These four classifications are outlined below.

- Classification Yards – Classification yards separate railcars from inbound trains and reassemble railcars into complete outbound trains. Activities at classification yards include line haul locomotive operations from arriving, departing, and through trains; yard (or switch) locomotive operations in transporting railcars; and locomotives for the breaking down and building up of trains.
- Maintenance Yards – Maintenance yards are facilities principally dedicated to the maintenance of locomotives and/or railcars. Activities include idling and load testing of locomotives as part of maintenance, and the movement of locomotives in and out of the yard. Maintenance yards can be stand-alone facilities or, more commonly, are a part of other multi-purpose yards.
- Intermodal Yards – Intermodal yards involve the transfer of cargo from one transportation mode to another, most typically between rail and truck-based transport. Significant non-locomotive activity at intermodal facilities is attributable to non-road cargo handling equipment and on-road drayage trucks.
- Specialty Yards – Specialty yards are those equipped to handle a specific single type of cargo (either loading or unloading) whose activities are typically unique to the facility. These may include bulk cargo (chemicals, grain, coal, etc.) or automobiles.

Table 1 summarizes the characterization of the nine rail yards covered in this paper. Five of nine facilities conduct classification activities, five conduct locomotive maintenance operations, five are intermodal facilities, and one is a specialty yard.

**Table 1.** Characterization of Rail Yards Evaluated into Yard Types.

Facility ID	Classification	Maintenance	Intermodal	Specialty
Facility A	X	X		
Facility B				X
Facility C	X	X	X	
Facility D		X	X	
Facility E		X	X	
Facility F	X		X	
Facility G			X	
Facility H	X	X		
Facility I	X			

Table 2 summarizes the key emission-related activities at each type of rail yard. Table 2 is a generalization across all yards studied to date and is not specific to any of the individual yards.

**Table 2.** Emissions Sources Typically Occurring within Each Yard Type.

Category	Emissions Source	Yard Type			
		Classification	Maintenance	Intermodal	Specialty
Locomotives (Mobile Source)	Line Haul Locomotives	X	X	X	X
	Switch Locomotives	X	X	X	X
	Service Activities	S	X	S	S
	Maintenance Activities	S	X	S	S
Non-road Vehicles (Mobile Source)	Heavy Equipment	X	X	X	X
	Cargo Handling Equipment			X	
	TRUs (Container and Railcar)	S		X	S
	Specialty Equipment				X
	Miscellaneous, Other Non-Road	X	X	X	X
On-Road Vehicles (Mobile Source)	Yard Trucks, Worker Vehicles	X	X	X	X
	Commercial Delivery Trucks	X	X	X	X
	Drayage Trucks			X	S
Stationary Sources	Storage Tanks	S	X	S	S
	Space/Water Heating	X	X	X	X
	Solvents (Degreasers/Paints)	S	X	S	S
	IC Engines (Generators/Compressors)	S	S	S	S

X = Present at Facility, S = Situationally Present

## Locomotive Sources

Emissions from locomotives were determined from the combination of emission factors and activity data for each type of locomotive operation. Detailed historical data describing facility-specific locomotive characteristics and activity levels were collected and used to the extent available. Facility-specific data generally included the following:

1. Line haul locomotive schedules or records establishing the number of annual train events.
2. Activity data detailing operation time within the facility for through, arriving, and departing trains.
3. Operation time and assignment schedules for switch locomotives.
4. Operation time for maintenance and service activities, as well as counts of service events.
5. Operation time distribution by throttle notch setting for each type of activity.
6. Characterization of line haul and switch locomotives by certification Tier.
7. Presence of locomotive auxiliary power units (APUs) used for extended idling events (in place of locomotive idling) and conditions by which APU usage are permitted. (The Michigan yard permits extended idling events for locomotives at colder temperatures (at or below 40 degrees Fahrenheit) if needed for climate control. Monthly average diurnal temperature profiles were used to determine the frequency of annual hours below the temperature threshold.)
8. Idling events associated with locomotive refueling.

Emission factors for locomotives were specific to locomotive models and Tier and were compiled across multiple projects and resources including USEPA data collection resources.<sup>5</sup> Emission factors were detailed by throttle notch setting, so that emissions from notch-specific activities could be evaluated. Emission factors were corrected for California and Michigan Diesel fuel properties and sulfur levels.

## Non-Road Sources

Non-road sources at rail yard facilities cover operations from a broad range of equipment and off-highway vehicles, including those described below.

- Cargo handling equipment (CHE). This includes large non-road equipment specifically designed for general cargo handling operations including rubber tired gantry (RTG) cranes, forklifts, top picks, and yard hostlers.
- Specialty equipment. This includes equipment designed for unique cargo types, such as equipment used for automobile loading and unloading.
- Transportation refrigeration units (TRUs). These are auxiliary power devices for cargo containers and railcars, and are used to maintain climate control for perishable cargo.
- Other heavy equipment. This includes equipment used for tasks other than cargo handling, and includes man lifts, forklifts, skid loaders, cranes, rail maintenance equipment, and seasonal snow removal equipment.
- Other portable equipment. This includes generators, air compressors, pressure washers, steam cleaners, and welders.

The equipment specifications and activity data for facility-based non-road equipment, including engine model year, engine rating, annual activity levels, and total fuel consumption, when available, were collected for each yard. Due to the detailed nature of the data, these data were generally collected on-site through physical equipment inventories and records review.

For the California facilities, non-road emission factors, except those for CHE, were obtained using CARB's OFFROAD2007 model. Emission factors for CHE and activity data assumptions for TRUs were taken from the CARB rulemaking documents and supporting tools for the CHE and TRU regulations.<sup>6,7</sup> In-use operation load factors were generally from CARB models and references. However, for two of the California facilities, equipment-specific load factors for yard hostlers were determined from available fuel consumption and operating hour data. These equipment and facility-specific load factors were found to be significantly lower than CARB default estimates.

For the Michigan facility, non-road emission factors were obtained by modeling the equipment characteristics in the USEPA's NONROAD2005d model. Since the completion of the inventory effort, this model has since been replaced by the NONROAD2008 model; however, there are no appreciable differences in non-road emission factor predictions between NONROAD versions 2005d and 2008 for the time periods evaluated.

For all facilities, the model-predicted non-road emission rates also relied upon ambient conditions (e.g., temperature) and fuel parameters (e.g., sulfur content) as model inputs that reflected local conditions.

### **On-Road Sources**

On-road source emissions were determined for employee-owned vehicles, facility-owned vehicles, vendor delivery vehicles, and drayage trucks using facility-specific modeling characteristics. Key facility data sources and parameters included the following:

1. Worker shift schedules,
2. Drayage truck gate counts,
3. Container lift counts,
4. Vendor delivery schedules ,
5. The distance traveled within each facility,
6. Proportions of travel on unpaved surfaces, and
7. Idling time estimates by type of vehicle activity.

For the California facilities, on-road emission factors were calculated using the CARB EMFAC2007 model. Emission factors are county or air basin specific and were developed by vehicle size class. Emissions were calculated separately for traveling and idling.

For the Michigan facility, traveling emission factors were estimated using USEPA's MOBILE6.2 model. Local inputs, including summer season gasoline RVP controls, were modeled based on information collected and reported in USEPA's National County Database, which is part of the National Mobile Inventory Model (NMIM). (NCD and NMIM are updated periodically by the USEPA. The versions used were dated May 2008.) Seasonal model runs (summer and winter) were completed to capture temperature variation effects. Idling emission rates were based on USEPA guidance.<sup>8</sup>

### **Stationary Sources**

There is a wide array of stationary emission sources at rail yard facilities. These include waste water treatment plants, fuel and waste oil storage tanks, stationary internal combustion (IC) engines (e.g., generators and compressors), and space and water heating equipment, as well as fugitive PM from vehicle operation, material handling, and sand tower activities.

For each facility, a detailed data collection effort was completed to compile the equipment and relevant source specifications for the emission calculations. Emission factors for stationary sources were generally from USEPA's AP-42 compilation document.<sup>9</sup>

## RESULTS

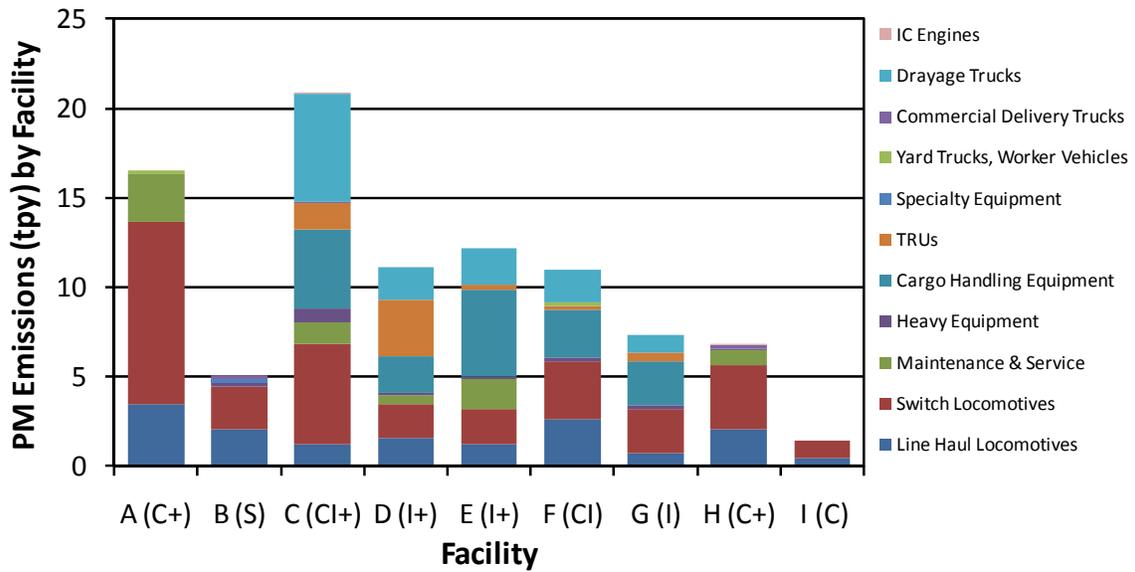
The emission inventory results for the nine rail yard facilities are shown in Figures 1-2 below. Of the nine facilities, eight are located in California (Facilities A through H) and one is located in Michigan (Facility I). All inventory results are reported in annual tons per year (TPY). Inventory results for Facility I represent calendar year 2007; results for the remaining eight facilities represent calendar year 2005. Inventory results are reported for PM and NOx. Only combustion PM was included; fugitive dust and brake/tire wear PM emissions were excluded.

The facility PM inventory results detailed by source category are presented in Figure 1. Only individual emission sources with greater than 0.05 TPY were included in the totals reported. Total facility PM emissions range from a low of 1.4 TPY to a high of 18.3 TPY. Key consistencies can be observed in these results when examined by the four yard type designations shown in Table 1.

- For yards that include maintenance and service activities (Facilities A, C, D, E, and H), the PM emissions from locomotives due to maintenance and servicing activities are a clear, but not dominant, portion of the total inventory. Maintenance and service related locomotive PM emissions are estimated at between 0.5 and 2.6 TPY, as compared with total PM emissions of between 6 and 21 TPY at the same yards.
- For classification yards (Facilities A, C, F, H, and I), the increased switch locomotive emissions are evident in these results. For each of these yards, the emissions from yard operations (ranging from 1.0 to 10.2 TPY) are more than those from line haul locomotive operations.
- For intermodal yards (Facilities C, D, E, F, and G), the emissions from non-road and on-road equipment activities represent between 35 and 76 percent of the total PM emissions. However, considerable variation in non-locomotive PM emissions from facility to facility is also present. Non-road PM emissions range from 3.1 to 6.7 TPY. On-road PM emissions range from 1.0 to 6.1 TPY. This variation is indicative of the types of cargo handled and other facility specific operations occurring at each Yard.
- For the single specialty yard (Facility B), the specialty equipment (motorized vehicular loading ramps) and other non-road and on-road sources operating at the facility represent about 14 percent of the total emissions
- For all rail yards, there is not a significant amount of combustion PM emissions from stationary sources.

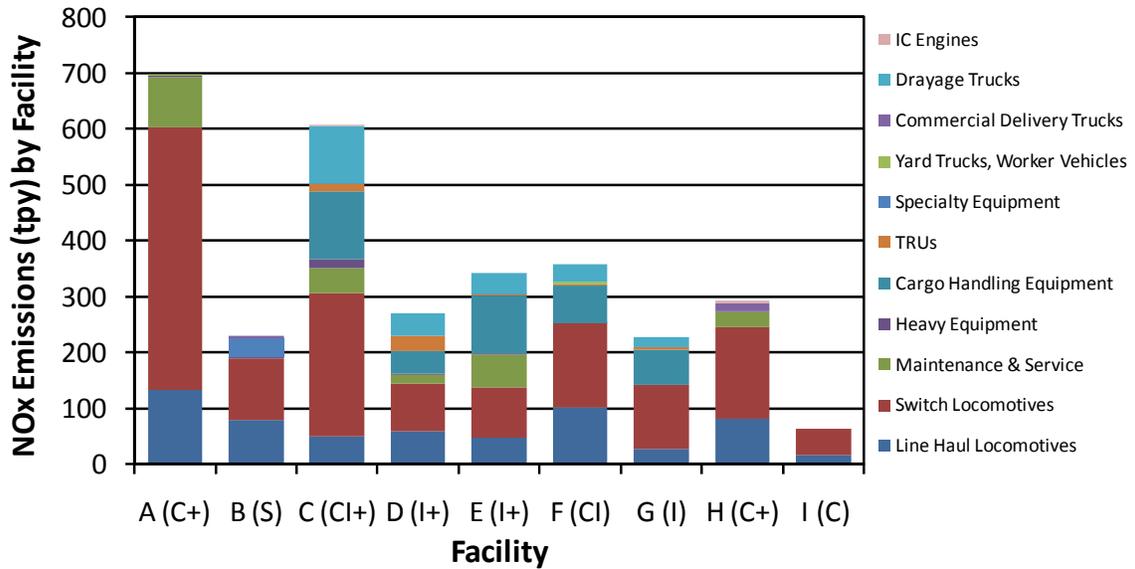
Figure 2 presents facility inventory results detailed by source category for NOx. Only sources with greater than 0.5 TPY were included in the NOx totals reported.

**Figure 1. PM Emissions by Source Category.**



C: Classification  
 S: Specialty  
 I: Intermodal  
 +: Maintenance and Service Operations

**Figure 2. NOx Emissions by Source Category.**



C: Classification  
 S: Specialty  
 I: Intermodal  
 +: Maintenance and Service Operations

For six of the California facilities, locomotive NOx emissions were not estimated in the original inventory reports. For these facilities, a “scaled locomotive” emission estimate was calculated. The California facilities reporting NOx emissions for locomotives were used to generate a NOx:PM ratio, by individual locomotive activity. These ratios were applied to the remaining California facilities where NOx results from locomotives were not reported. These scaled locomotive estimates were not part of the original inventory efforts and are provided here for comparison only; these values should not be used for other purposes. Key observations are noted below.

- For the three facilities where NOx emissions were reported, locomotive emissions ranged from 63 to 351 TPY for NOx.
- For non-road sources, the intermodal yards (C, D, E, F and G) have significant emissions due to cargo handling operations. For these facilities, NOx emissions from non-road equipment range from 67 to 151 TPY.
- For on-road sources, the intermodal yards (C, D, E, F and G) have significant emissions due to drayage truck activities. For these facilities, NOx emissions from on-road sources range from 19 to 104 TPY.
- For all the rail yards, the stationary sources are not large emitters of NOx.

## CONCLUSIONS

Rail yard emission inventory efforts require significant detailed data collection and processing due to the wide range of site-specific emission sources at these facilities. Results from nine separate facility-specific inventory efforts presented in this paper show considerable variation in total emissions and emissions by source category. Some consistency in inventory results can be observed across rail yard type (i.e., classification, maintenance and servicing, intermodal, and specialty yards).

The results of this paper are informative to document the size, scope, and variation of rail yard inventory estimates. As shown above, due to the unique nature of rail yard operations, a detailed site-specific inventory is necessary to determine emissions from a specific facility. The results reported herein are specific to the time period and facilities evaluated and should not be extrapolated to other locations or times.

## REFERENCES

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<sup>5</sup> “Locomotive Emission Standards, Regulatory Support Document.” United States Environmental Protection Agency Office of Mobile Sources, April 1998.

<sup>6</sup> “Staff Report: Initial Statement of Reasons for the Proposed Airborne Toxic Control Measure for In-Use Diesel-Fueled Transport Refrigeration Units (TRU) and TRU Generator Sets, and Facilities where TRUs Operate,” California Environmental Protection Agency, Air Resources Board, Stationary Source Division, October 2003.

<sup>7</sup> “Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Regulation for Mobile Cargo Handling Equipment at Ports and Intermodal Rail Yards,” California Environmental Protection Agency, Air Resources Board, Stationary Source Division, October 2005.

<sup>8</sup> “Idling Vehicle Emissions,” EPA420-F-98-014, U.S. Environmental Protection Agency, Office of Air and Radiation, April 1998.

<sup>9</sup> “AP 42, Fifth Edition, Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources,” Internet, web-based compilation document, <http://www.epa.gov/ttn/chief/ap42/index.html>, U.S. Environmental Protection Agency, Office of Air and Radiation.

## **KEY WORDS**

Emission Inventory

Locomotive

Non-Road

On-Road

Diesel