California Environmental Protection Agency

Air Resources Board

Roseville Rail Yard Study

Stationary Source Division
Release Date: October 14, 2004

State of California
AIR RESOURCES BOARD

Roseville Rail Yard Study

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Acknowledgements

The Air Resources Board staff wishes to acknowledge their appreciation for the information and data provided by the representatives of the organizations listed below.

Union Pacific Railroad Company: James Diel, Jon Germer, Jeff Hendrx, Richard Jacobs, Brock Nelson, G.L. Poff, Deb Schafer, Lanny Schmid, and Harry Syers.

Burlington Northern and Santa Fe Railway Company: John D. Chavez

National Railroad Passenger Corporation (Amtrak West): Denise Yaffe

Southwest Research Institute: Steven G. Fritz, P.E.

Air Quality Management Consulting: Robert G. Ireson, Ph.D.

General Motors, Electro-Motive Division: David E. Brann

General Electric Transportation Systems: David J. Ducharme and Vishwesh Palekar

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California Environmental Associates: Peter Okurowski

Placer County Air Pollution Control District: Tom Christofk, David Vintze and Todd Nishikawa

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Roseville Rail Yard Study Part I: Risk Characterization

Risk Characterization
for the Union Pacific Railroad's J.R. Davis Yard
Roseville, California

INTRODUCTION

The California Air Resources Board (ARB or Board) conducted a health risk assessment of airborne particulate matter emissions from diesel-fueled locomotives at the Union Pacific J.R. Davis Yard (Yard) located in Roseville, California. The results from that evaluation are presented in this report which is comprised of two parts. Part I, Risk Characterization for the Union Pacific Railroad's J.R. Davis Yard Roseville, California, provides a less technical and more easily understood explanation of health risk assessment results. It also is intended to explain what the risk assessment results mean and to put the results in perspective with other related environmental and public health risks. Part II, Health Risk Assessment for the Union Pacific Railroad's J.R. Davis Yard Roseville, California, provides a detailed assessment of the potential health risk near the Yard due to diesel particulate matter (diesel PM) emissions from locomotives.

BACKGROUND

The Placer County Air Pollution Control District (District) requested help from the ARB in determining the potential public health risks from diesel PM emissions due to locomotive activities at the J. R. Davis Yard (rail yard or Yard) in Roseville, California. Roseville is a rapidly growing area and development over the past several years has put more residences in close proximity to the rail yard. With an increasing population near the Yard, complaints regarding the rail yard operations and concerns about possible health risks have been raised. The rail yard is situated near the heart of Roseville, encompassing about 950 acres on a one-quarter mile wide by four-mile long strip of land that parallels Interstate 80. The Yard is bounded by commercial, industrial, and residential properties. The Yard is the largest service and maintenance rail yard in the West with over 30,000 locomotives visiting annually.

FINDINGS AND RECOMMENDATION

To summarize, the key findings of the study are:

- The diesel PM emissions in 2000 from locomotive operations at the Yard are estimated to be about 25 tons per year.
- Moving locomotives account for about 50 percent, idling locomotives account for about 45 percent, and locomotive testing accounts for about 5 percent of the total diesel PM emissions at the Yard.
- Computer modeling predicts potential cancer risks greater than 500 in a million (based on 70 years of exposure) northwest of the *Service Track* area and the *Hump*

and Trim area. The area impacted is between 10 to 40 acres. To provide some perspective on the size, an acre is about the size of a football field.

- The risk assessment show elevated concentrations of diesel PM and associated cancer risk impacting a large area. These elevated concentrations of diesel PM, which are above the regional background level, contribute to an increased risk of cancer and premature deaths due to cardiovascular disease and non cancer health effects such as asthma and chronic obstructive pulmonary disease. Potential cancer risk and the number of acres impacted for several risk ranges are as follows:
  - ✓ Risk levels between 100 and 500 in a million occur over about 700 to 1,600 acres in which about 14,000 to 26,000 people live.
  - ✓ Risk levels between 10 and 100 in a million occur over a 46,000 to 56,000 acre area in which about 140,000 to 155,000 people live.

- The magnitude of the risk, the general location of the risk, and the size of the area impacted varies depending on the meteorological data used to characterize conditions at the Yard, the dispersion characteristics, and the assumed exposure duration and breathing rate for the proposed population.

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- Given the magnitude of diesel PM emissions and the large area impacted by these emissions, short term and long term mitigation measures are needed to significantly reduce diesel PM emissions from the J.R. Davis Rail Yard.

RISK ASSESSMENT RESULTS

*A **risk assessment** is a tool used to evaluate the potential for a chemical or pollutant to cause cancer and other illnesses.*

A risk assessment uses mathematical models to evaluate the heath impacts from exposure to certain chemicals or toxic air pollutants released from a facility or found in the air. In order to perform the risk assessment, data was needed on the levels or concentrations of the diesel PM. At this time, there is no monitoring technique that allows scientists to directly measure diesel PM in the air. In order to estimate the concentrations of diesel PM, an emissions inventory was developed and an air dispersion model was then used to estimate the resulting concentration of diesel PM in the air. The air dispersion model uses a variety of information, such as the amount of pollutant emissions, weather or meteorology data, and the location and height of the emissions release, all of which can greatly affect the final results. A detailed description of how the risk assessment was done, including all of the supporting technical data and results, can be found in Part II of this report, *Health Risk Assessment.*

In a risk assessment, risk is expressed as the number of chances in a population of a million people who might be expected to get cancer over a 70-year lifetime. However, for informational purposes only, the risk is sometimes reported for other exposure times, such as a 30-year or a 9-year risk. The longer the exposure, the greater the risk will be. In this part, only the 70-year lifetime risk is presented. Information on risk levels associated with 30-year exposures are presented in Part II. This analysis focuses on potential cancer cases due to exposure to diesel PM emissions. However, there is a growing body of scientific data suggesting that exposure to fine particulate matter may be responsible for premature death and morbidity (illness) due to respiratory and cardiovascular disease. The sensitive subpopulations include people with pre-existing cardiovascular disease and respiratory disease, including asthma, particularly those who are also elderly. The overall noncancer mortality from diesel PM exposure may exceed the cancer mortality by a considerable amount. The levels of exposure to diesel PM from the estimated emissions of diesel PM at the Yard were calculated using two meteorological data sets (Roseville and McClellan) and for both urban and rural dispersion characteristics in the air dispersion model. Two meteorological data sets were used because there are no direct meteorological measurements at the yard, and there is some uncertainty about the representativeness of both the Roseville and McClellan data sets. The use of the two sets provides the best estimate of the expected range of levels or concentrations of diesel PM around the rail yard. Dispersion characteristics refer to the type of land use, such as whether there are buildings near-by or open fields. Both urban and rural dispersion characteristics were used because the land uses around the rail yard have properties of both. The predicted diesel PM concentrations near the Yard (within one mile) were estimated using urban dispersion characteristics, while diesel PM concentrations greater than one mile from the Yard were predicted using rural dispersion characteristics. This was done in order to simplify the presentation of the results while still providing a reasonable estimate of possible exposures. In the discussion below, the results based on the various predicted concentrations are presented.

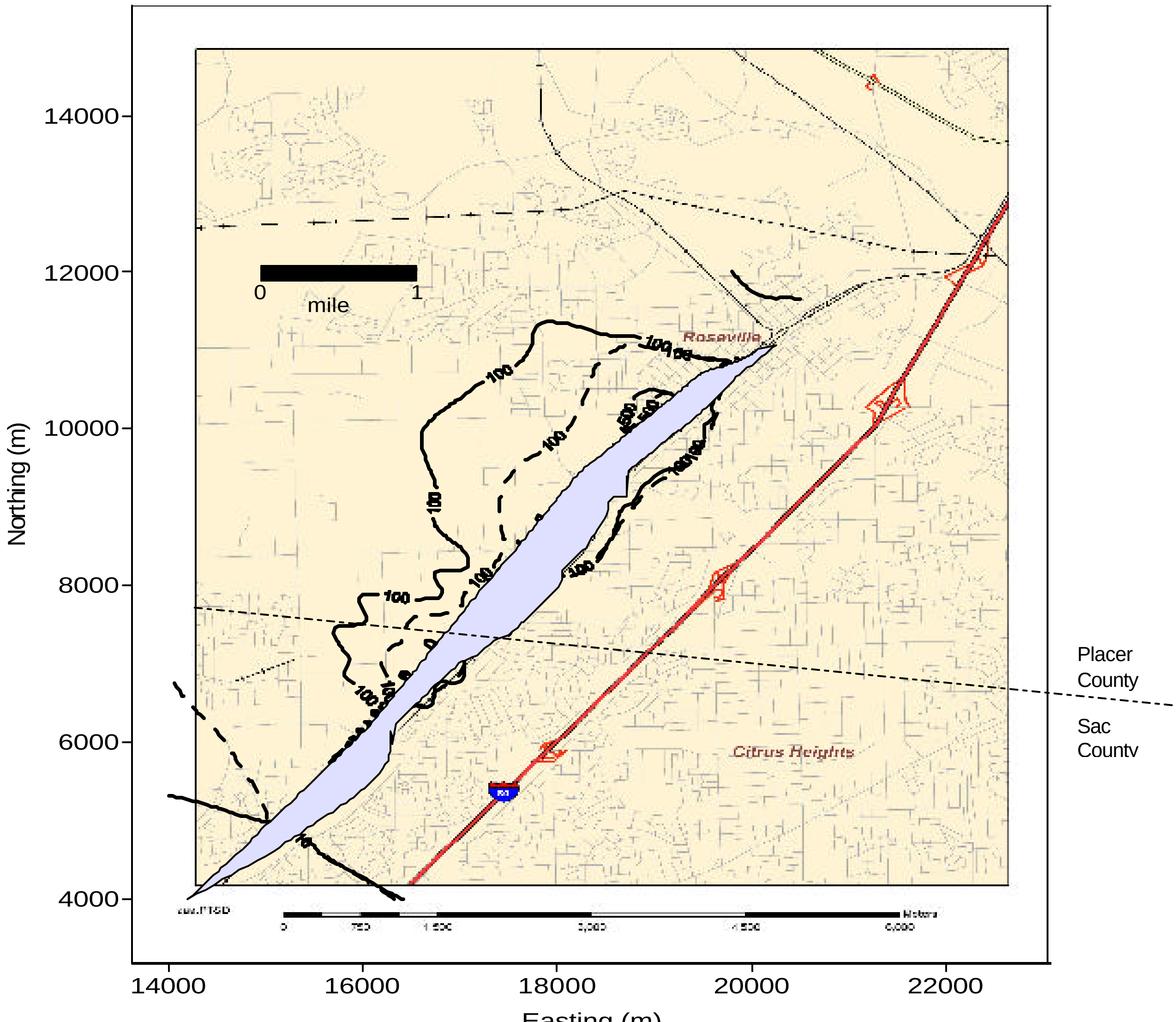
*For **cancer** health effects, the risk is expressed as the number of chances in a population of a million people who might be expected to get cancer over a 70-year lifetime. The number may be stated as "10 in a million" or "10 chances per million". Often times scientific notation is used and you may see it expressed as $1 \times 10^{-5.}$ or 10^{-5}. Therefore, if you have a potential cancer risk of 10 in a million, that means if one million people were exposed to a certain level of a pollutant or chemical there is a chance that 10 of them may develop cancer over their 70-year lifetime. This would be 10 new cases of cancer above the expected rate of cancer in the population. The expected rate of cancer for all causes, including smoking, is about 200,000 to 250,000 chances in a million (one in four to five people).*

Estimated Potential Cancer Risk

Figure 1 and Figures 2a and 2b present the estimated potential cancer risk levels due to diesel PM emissions at the Yard. For this analysis, staff elected to present the cancer risk data as risk concentration isopleths focusing on risk levels of 10, 25, 50, 100, and 500 in a million. Figure 1 focuses on the near source risk levels and Figure 2a and 2b focus on the more regional impacts. In each figure, the risk isopleths are overlaid onto a map of the Roseville area surrounding the Yard. The solid isopleth lines are based on the Roseville meteorological data and the dashed isopleth lines are based on the McClellan meteorological data.

Figure 1 shows the 100 and 500 in a million risk isopleths. As shown, the areas with the greatest impact have an estimated potential cancer risk of over 500 in a million. Depending upon the meteorological data set, and using urban dispersion characteristics, the areas exceeding 500 in a million ranges between 10 to 40 acres. The primary area with risks estimated above 500 in a million is shown in the center of Figure 1 toward the top of the Yard on the left. This off-site area is adjacent to the *Service Track* area which includes the maintenance shop. The high concentration of diesel PM emissions is due to the number of locomotives and the nature of activities in this area, particularly idling locomotives. The second area with risk estimates above 500 in a million is shown in Figure 1 just south of the county line and to the left of the Yard. This offsite area is adjacent to the *Hump and Trim* area. Based on the 2000 U.S. Census Bureau's data, between 500 and 700 Roseville residents live in these areas.

Figure 1
Estimated Cancer Risk from the Yard
(100 and 500 in a million risk isopleths)



Notes: Solid Line = Roseville Met Data; Dashed Contour Lines = McClellan Met Data; Urban Dispersion Coefficient, 80th Percentile Breathing Rate, All Locomotive's Activities [23 TPY], Modeling Domain = 6km x 8km, Resolution = 50m x 50m

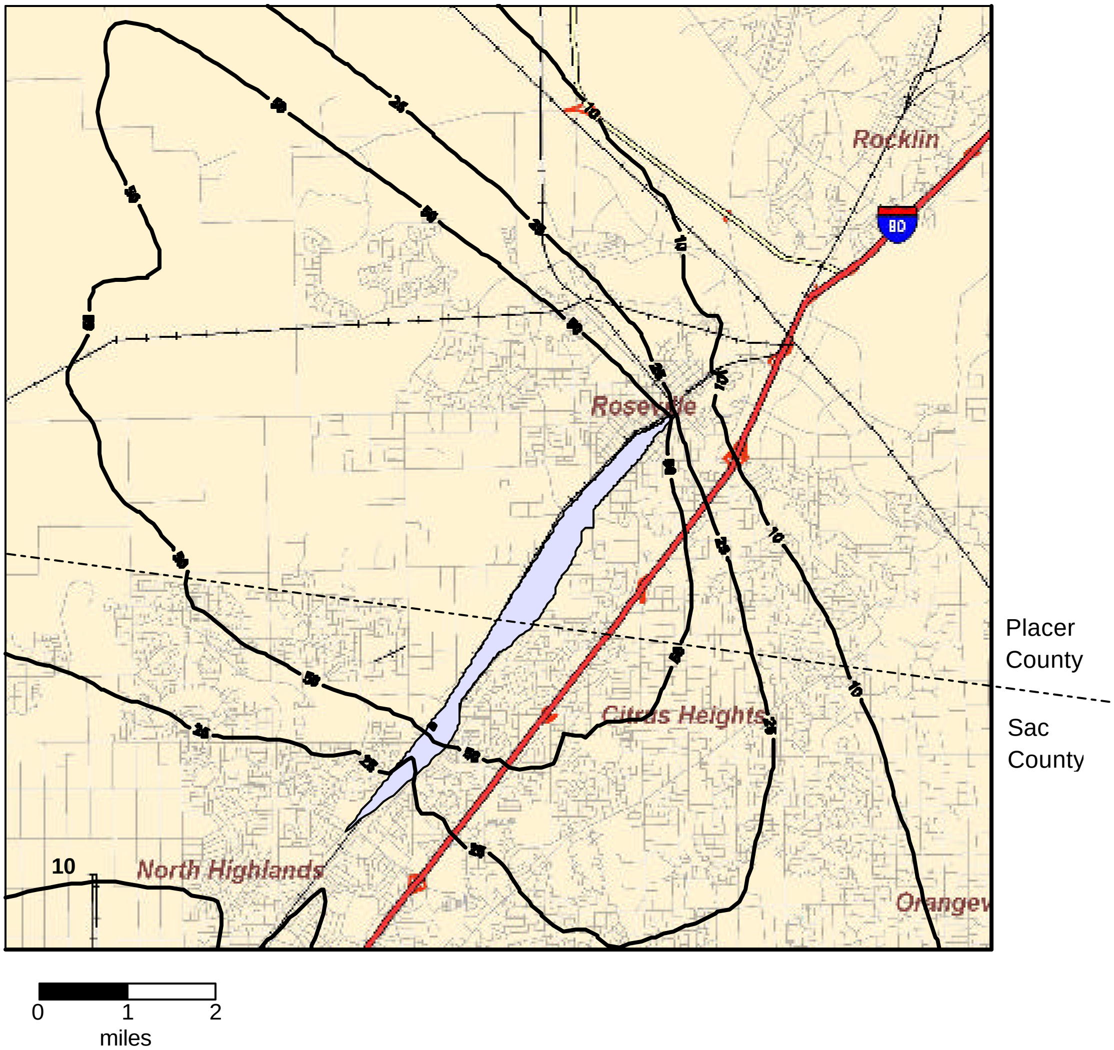
The second area of impact, with an estimated potential cancer risk of 100 to less than 500 in a million, ranges between 700 to 1600 acres. Again, the size of the area of impact is highly dependent upon the meteorological data set used. The area of impact is primarily to the north west of the Yard. Based on the 2000 U.S. Census Bureau's data, between 14,000 and 26,000 residents live in this area.

Figures 2a and 2b show the area where the predicted cancer risk exceeds 10, 25, and 50 in a million. Figure 2a displays the results using the Roseville meteorological data. As shown in figure 2a, the elevated risk levels are primarily to the northwest of the Yard (predominate wind direction) and decreases as the distance from the Yard increases. The largest area of impact has an estimated potential cancer risk of greater than 10 in a million. This area encompasses approximately 46,000 acres. The contour lines of 10 in a million are broken because the risk levels do not fall below 10 in a million within the model domain. In other words, the 10 in a million isopleth goes well beyond the boundaries of the figure. Based on the 2000 U.S. Census Bureau's data, about 140,000 people live in the 10 to 100 in a million isopleth shown on the figure and within the model domain.

Figure 2b shows the risk isopleths using the McClellan meteorological data. Again, the 10 in a million isopleth goes well beyond the boundaries of the figure. The area between the 10 and 100 in a million isopleth encompasses approximately 55,000 acres where an estimated 155,000 residents live.

What these results indicate is that the diesel PM emissions from the rail yard are widely dispersed out over the greater Roseville area at levels that pose a cancer risk concern. It is important to understand that these risk levels represent the predicted risk due to diesel PM above the existing background risk levels. For the broader Sacramento region the estimated background risk level from diesel PM is estimated to be 360 in a million for diesel PM and 520 in a million for all toxic air pollutants.

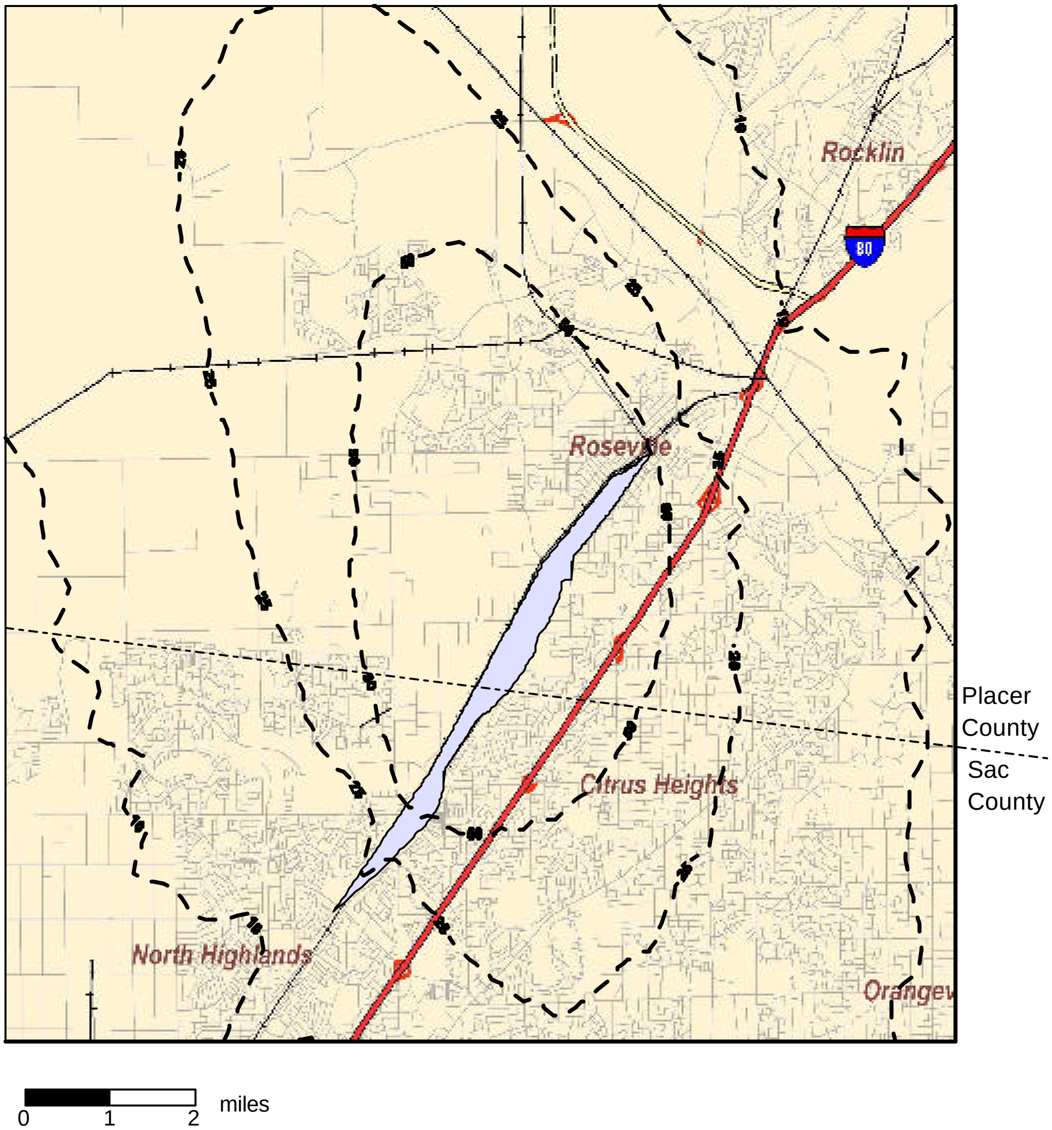
Figure 2a
Estimated Cancer Risk from the Yard Using Roseville Met Data
(10, 25, and 50 in a million risk isopleths)



Note: Roseville Meteorological Data, Rural Dispersion Coefficients, 80th Percentile Breathing Rate, All Locomotives' Activities [23 TPY], 70-Year Exposure

Figure 2b

Estimated Cancer Risk from the Yard Using McClellan Met Data
(10, 25, and 50 in a million risk isopleths)



Note: McClellan Meteorological Data, Rural Dispersion Coefficients, 80th Percentile Breathing Rate, All Locomotives' Activities [23 TPY], 70-Year Exposure

Risk Comparisons

To put the risk assessment numbers into perspective, it is helpful to view them in comparison to other risks due to exposure to air pollution. For example, the estimated risk from toxic air contaminants statewide, based on being exposed to an average annual concentration for 70 years is about 750 chances in a million. This number is based on an average concentration of toxic air pollutants measured by the ARB's monitoring network and the estimated risk for diesel particulate matter based on exposure estimates. The risk in various regions can vary considerably. For example, the average risk in some parts of the Los Angeles area are well over 1,000 chances in a million, while the average regional risk in a less industrialized area like Roseville, is closer to 500 chances in a million.

Top Ten Air Toxics*

Diesel particulate matter
1,3 Butadiene
Benzene
Carbon Tetrachloride
Formaldehyde
Hexavalent Chromium
Para-dichlorobenzene
Acetaldehyde
Perchloroethylene
Methylene Chloride

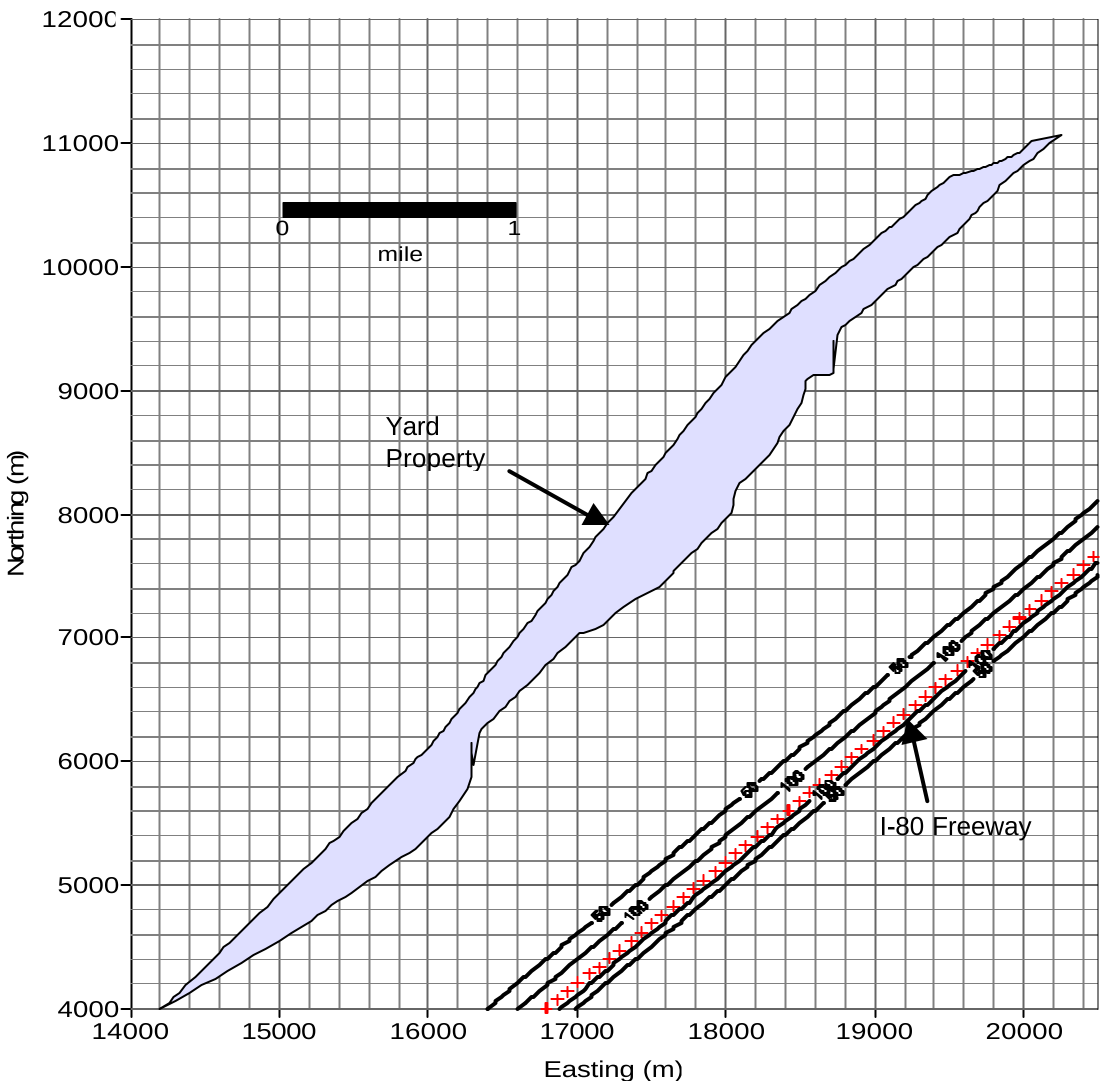
*These are the toxic air pollutants that contribute most to overall statewide risk that is measured in the ARB's monitoring network. Diesel PM is not measured, but is based on estimated values.

In addition, it may be helpful to compare the risk experienced by residents who live in close proximity to various types of facilities where many diesel engines are in use. Diesel PM is an air toxic that is released by a variety of sources. The typical risk from some of these diesel PM sources illustrate the "relative risk" when comparing activities. For example, a truck stop that has a high number of diesel trucks may result in an estimated risk as high as 200 chances in a million for nearby residents.[1] At a big distribution center where hundreds of diesel trucks operate, the risk could be as high as 750 chances in a million.[2]

To put this in a local perspective, the estimated risk from the diesel truck traffic on Interstate 80 in Roseville is shown in Figure 3. The amount of truck traffic driven daily on Interstate 80 is estimated to be about 10,000 heavy-duty diesel trucks per day based on 2002 activity data. The area of risk greater than 10 in a million is about one mile from the freeway (data not shown). The risk level at 300 feet from the edge of the freeway is about 100 in a million.[3]

[1] In July 2004, the ARB adopted an In-Use Diesel Truck Idling regulation that will reduce truck idling by 80 percent.
[2] In February 2004, the ARB adopted a Transport Refrigeration Unit (TRU) regulation that will reduce diesel PM emissions from TRUs by over 90 percent.
[3] The dispersion of diesel PM emissions was treated as an area source with urban dispersion coefficients using the USEPA ISCST3 model.

Figure 3
Estimated Risk from Diesel Truck Traffic on Interstate 80 at Roseville, CA



Note: Estimated Diesel PM Cancer Risk - 50/ and 100/million Contours from Freeway I-80 in Roseville (Roseville Meteorological Data, Urban Dispersion Coefficients, 80th Percentile Breathing Rate, EF = 0.293 g/v-mi [EMFAC2002, Y2004 Fleet], Diesel Truck Traffic = 10,000 vpd, 70-Year Exposure)

Uncertainty in Risk Assessment

The estimated diesel PM concentrations and risk levels produced by a risk assessment are based on several assumptions, many of which are designed to be health protective so that potential risks to individuals are not underestimated. Therefore, the actual risk calculated by a risk assessment is intentionally designed to avoid underprediction. There are also many uncertainties in the health values used in the risk assessment. Some of the factors that affect the uncertainty are discussed below.

When available, as is the case with diesel PM, scientists will use studies of people exposed at work to estimate risk from environmental exposures. The occupational exposures in these studies are usually much higher than environmental exposures encountered by the general public. In addition, scientists often do not have enough information to be able to predict how a chemical may affect any one person because we are unique and respond differently. Also the actual worker exposures to diesel PM were not measured but were derived based on estimates of emissions and duration of exposure. Different studies suggest different levels of risk. When the ARB's Scientific Review Panel (SRP)[4] identified diesel PM as a toxic air contaminant, they considered a range of inhalation cancer potency factors (1.3×10^{-4} to 2.4×10^{-3} $(\mu g/m^3)^{-1}$) and recommended that a risk factor of 3×10^{-4} $(\mu g/m3)^{-1}$ be used as a point estimate of the unit risk. From the unit risk factor an inhalation cancer potency factor of 1.1 $(mg/kg\text{-}day)^{-1}$ may be calculated.

As mentioned above, there is no direct measurement technique for diesel PM. For this analysis, an air dispersion model was used to estimate the concentrations that the public is exposed. The air dispersion models use a variety of information, all of which can affect the final results. All of these factors make up the “uncertainty” in the risk assessment.

[4] The Scientific Review Panel (SRP/Panel) is charged with evaluating the risk assessments of substances proposed for identification as toxic air contaminants by the Air Resources Board (ARB) and the Department of Pesticide Regulation (DPR). In carrying out this responsibility, the SRP reviews the exposure and health assessment reports and underlying scientific data upon which the reports are based, which are prepared by the ARB, DPR, and the Office of Environmental Health Hazard Assessment (OEHHA) pursuant to the sections 39660-39661 of the Health and safety Code and sections 14022-14023 of the Food and Agriculture Code. These reports are prepared for the purpose of determining whether a substance or pesticide should be identified as a toxic air contaminant.

Roseville Rail Yard Study Part II: Health Risk Assessment

Health Risk Assessment for the Union Pacific Railroad's J.R. Davis Yard Roseville, California

I. EXECUTIVE SUMMARY

At the request of the Placer County Air Pollution Control District (District), the California Air Resources Board (ARB or Board) conducted a health risk assessment of airborne particulate matter emissions from diesel-fueled locomotives at the Union Pacific J.R. Davis Yard (Yard) located in Roseville, California. Union Pacific Railroad Company (UP) assisted in the project by providing extensive information on facility operations and emissions.

The purpose of this Roseville Rail Yard Study Part II: Health Risk Assessment, is to provide a detailed assessment of the potential health risk near the Yard due to diesel particulate matter (diesel PM) emissions from locomotives.[5] The risk assessment included developing an inventory of diesel PM emissions at the Yard, conducting computer modeling to predict increases in the ambient air concentrations of diesel PM in the surrounding community due to locomotive activity, and assessing the potential cancer risks from exposure to the predicted ambient air concentrations of diesel PM. As a reminder, Part I of the Roseville Rail Yard Study, entitled "Risk Characterization" explains the results from the risk assessment in less technical and more easily understood terms. Part I also compares the predicted cancer risk from the Yard to other individual sources of diesel PM emissions, as well as to the overall cancer risk produced by airborne toxic compounds in California.

Presented below is a summary of the key findings of the study followed by an overview that briefly discusses how the exposure and risk assessments were performed to evaluate potential cancer risks from exposure to diesel PM from locomotive activities at the J.R. Davis Rail Yard. For simplicity, the overview discussion is presented in question-and-answer format. The reader is directed to subsequent chapters in Part II for more detailed information.

A. Summary of Findings

To summarize, the key findings of the study are:

- The diesel PM emissions in 2000 from locomotive operations at the Yard are estimated to be about 25 tons per year.
- Moving locomotives account for about 50 percent, idling locomotives account for about 45 percent, and locomotive testing accounts for about 5 percent of the total diesel PM emissions at the Yard.

[5] Diesel PM was identified as a toxic air contaminant by the ARB in 1998.

- Computer modeling predicts potential cancer risks greater than 500 in a million (based on 70 years of exposure) northwest of the *Service Track* area and the *Hump and Trim* area. The area impacted is between 10 to 40 acres.
- The risk assessment shows elevated concentrations (= 10 in a million) of diesel PM and associated cancer risk impacting a large area. These elevated concentrations, which are above the regional background level, of diesel PM contribute to an increased risk of cancer and premature deaths due to cardiovascular disease and non cancer health effects such as asthma and chronic obstructive pulmonary disease. Potential cancer risk and the number of acres impacted for several risk ranges are as follows:
  - ✓ Risk levels between 100 and 500 in a million occur over a 700 to 1600 acre area in which about 14,000 to 26,000 people live.
  - ✓ Risk levels between 10 and 100 in a million occur over a 46,000 to 56,000 acre area in which about 140,000 to 155,000 people live.

- The magnitude of the risk, the general location of the risk, and the size of the area impacted varies depending on the meteorological data (Roseville or McClellan), the dispersion characteristics (urban or rural), the assumed exposure duration (70 or 30 years) and the breathing rate (95^{th}, 80^{th}, and 65^{th} percentile).

B. Overview

1. What are exposure and risk assessments?

An exposure assessment is an analysis of the amount (concentration) of a substance that a person is exposed to during a specified time period. This information is used in a risk assessment to evaluate the potential for a chemical to cause cancer or other health effects. Mathematical models are used in both exposure and risk assessments to evaluate the potential health impacts from exposure to chemicals. The input to the mathematical models used to estimate potential health risk for substances emitted in to the air includes data and assumptions regarding:

- the magnitude and duration of the diesel PM emissions,
- the weather, (i.e. meteorology),
- human behavior patterns (i.e. the length of time someone is exposed), breathing rate, body weight
- and the toxicity of the substances.

The predicted concentrations and health impacts (e.g., cancer risk) presented in a site-specific health risk assessment are assumed to exist in excess of background concentrations or resulting health risks. For an individual person, cancer risk estimates are commonly expressed as a probability of developing cancer from a lifetime (i.e., 70 years) of exposure. Cancer risks are typically expressed as “chances per million”.

For example, if the cancer risk were estimated to be 100 chances per million, then the probability of an individual developing cancer would be expected to not exceed 100 chances in a million. If a population (e.g., 1 million people) were exposed to the same potential cancer risk (e.g., 100 chances per million), then statistics would predict that no more than 100 of those million people exposed are likely to develop cancer from a lifetime of exposure (70 years) due to diesel PM emissions from the Yard.

While there are inherent uncertainties in each of the variables, mentioned above, risk assessments are an effective tool to help assess an exposed populations relative risk from exposure to a toxic air contaminant. However, because there are inherent uncertainties in each of the variables that go in to a risk assessment, one needs to recognize that there is considerable uncertainty in estimating the risk for a specific individual or at a specific location. Generally, risk assessment results should not be considered as exact estimates of a specific individual's risk. Risk assessment results are best used to compare the relative risk between one facility and another and for comparing potential risks to target levels to determine the level of mitigation needed. They are also an effective tool for determining the impact a particular control strategy will have on reducing risk.

2. Why did ARB staff conduct an assessment of the J.R. Davis Rail Yard?

The ARB staff conducted an assessment of the J.R. Davis Rail Yard at the request of the Placer County Air Pollution Control District (District). After a recent expansion at the Yard, the District received a significant increase in noise and diesel exhaust emission-related complaints from residents of the City of Roseville that live near the J.R. Davis Rail Yard. To address the growing concerns of nearby residents and to better understand the diesel particulate matter (PM) emission impacts and the related health effects, and to determine if mitigation measures are needed, the District requested the ARB to prepare an exposure assessment of diesel PM emissions and its related heath impacts generated by activities at the J.R. Davis Rail Yard. To the ARB staff's knowledge, no comparable assessment of a similar facility has been prepared and reported in available literature.

3. Why is ARB concerned about Diesel PM?

Diesel engines emit a complex mixture of air pollutants, composed of gaseous and solid material. The visible emissions in diesel exhaust are known as particulate matter or PM, which includes carbon particles or "soot". In 1998, ARB identified diesel PM as a toxic air contaminant based on its potential to cause cancer, premature deaths, and other health problems. Health risks from diesel PM are highest in areas of concentrated emissions, such as near ports, rail yards, freeways, or warehouse distribution centers. Exposure to diesel PM is a health hazard, particularly to children whose lungs are still developing and the elderly who may have other serious health problems.

Health impacts from exposure to the fine particulate matter ($PM_{2.5}$) component of diesel exhaust have been calculated for California, using concentration-response equations from several epidemiologic studies. Both mortality and morbidity effects have been associated with exposure to either direct diesel $PM_{2.5}$ or indirect diesel $PM_{2.5}$, the latter of which arises from the conversion of diesel NO_x emissions to $PM_{2.5}$ nitrates. It was estimated that 2000 and 900 annual premature deaths resulted from exposure to either

1.8 $\mu g/m^3$ of direct diesel $PM_{2.5}$ and 0.81 $\mu g/m^3$ of indirect diesel $PM_{2.5}$, respectively, for the year 2000. The mortality estimates are likely to exclude cancer cases, but may include some premature deaths due to cancer, because the epidemiologic studies did not identify the cause of death. Exposure to fine particulate matter, including diesel $PM_{2.5}$ can also be linked to a number of heart and lung diseases. For example, it was estimated the 5,400 hospital admissions for chronic obstructive pulmonary disease, pneumonia, cardiovascular disease and asthma were due to exposure to direct diesel $PM_{2.5}$ in California. An additional 2,400 admissions were linked to exposure to indirect diesel PM (Lloyd. 2001)

4. Where is the J.R. Davis Rail Yard located and what locomotive activities occur there?

The Yard occupies about 950 acres, on a one-quarter mile wide by four-mile long strip of land that parallels Interstate 80, near the City of Roseville, California. Approximately two-thirds of the area of the Yard is located in Placer County with the remaining one-third in Sacramento County. Downtown Roseville and residential neighborhoods are located along the southern side of the Yard. On the northern side are residential areas as well as industrial zones. In the southeast, however, it is predominantly residential neighborhoods. As you move away from the Yard to the northwest, the area becomes more rural in nature. The J.R. Davis Rail Yard has been operating in the City of Roseville since 1905. At the Yard, trains are classified (locomotives and train cars are connected or taken apart) and locomotives undergo routine maintenance, servicing, and repair.

About 31,000 locomotives stopped at the Yard during the year in which UPRR collected statistics for the ARB. Another 15,000 locomotives used the Northside Tracks (through trains) during this period. These locomotives have very large diesel-fueled engines. Locomotive engines generally last 30 to 40 years. Because more effective emission standards for locomotive engines have only recently been promulgated by the U.S. Environmental Protection Agency (U.S. EPA), and are just now being phased in, emissions of both diesel PM and oxides of nitrogen (NOx) from locomotives remain very high relative to many other sources.

5. What are the diesel PM emissions from locomotive activities at the J.R. Davis Rail Yard?

The emissions of diesel PM from locomotive activities at the Yard in 2000 were estimated to be approximately 22 to 25 tons per year. About 50 percent of the diesel PM emissions are from locomotives moving through the different areas in the Yard, about 45 percent are from idling locomotives, and approximately 5 percent are from locomotives undergoing testing.

By area, the *Service Area* (the area around the maintenance shop) had the highest diesel PM emissions, about 8 tons per year. The *Service Area* is located at about the mid-point of the Yard on the northern side (See Figure II-1 on page 20). In the *Service Area*, the predominant source of emissions, about 75 percent of the total, is from idling locomotives. The *Hump Area* and *Trim Area* had the next highest emissions, with 7.5 tons per year diesel PM.

6. How were the diesel PM concentrations near the Roseville Rail Yard estimated?

ARB staff used the U.S. EPA approved computer model (ISCST3) to estimate the annual average offsite concentration of diesel PM resulting from locomotive activity at the Yard. The key inputs to the computer model were the diesel PM emissions information (both magnitude, timing, and location), the meteorological data (wind speed and direction), and the dispersion coefficients (rural or urban). The emissions inventory was developed working closely with Union Pacific Rail Road and the District. This inventory represents the most complete inventory for the J. R. Davis Yard and is based primarily on year 2000 data.

Two different sets of historical meteorological data were used in this analysis to estimate the dispersion and transport of diesel PM emissions from the Yard. One set, the Roseville meteorological set, was from a site about a mile from the Yard. The second set, the McClellan meteorological set, was from a site about 10 miles from the Yard. Since the area surrounding the Roseville Rail Yard has both urban and rural characteristics the modeling was also done using both the urban and rural dispersion coefficients. Based on current land use patterns near the Yard, ARB staff elected to use urban dispersion characteristics within one mile of the Yard and rural dispersion characteristics beyond one mile from the Yard.

7. How were the potential cancer risks from diesel PM estimated?

The potential cancer risks were estimated using standard risk assessment procedures based on the annual average concentration of diesel PM predicted by the model and a health risk factor (referred to as a cancer potency factor) that correlates cancer risk to the amount of diesel PM inhaled.

The methodology used to estimate the potential cancer risks is consistent with the Tier-1 analysis presented in the OEHHA, Air Toxics Hot Spots Program Risk Assessment Guidelines (September 2003). A Tier 1 analysis assumes that an individual is exposed to an annual average concentration of a pollutant continuously for 70 years.[6] A more refined risk assessment (Tier 2) can be performed when additional site specific information concerning the exposed population is available. However, in most cases, adequate site specific information about the exposed population was not available. This was the case in the Roseville Study. The cancer potency factor was developed by the Office of Environmental Health Hazard Assessment (OEHHA) and approved by the SRP as part of the process of identifying diesel exhaust emission as a toxic air contaminant (TAC). Diesel PM was identified as a TAC in 1998 after 10 years of extensive investigation.

[6]According to the OEHHA Guidelines, the relatively health-protective assumptions incorporated into the Tier 1 risk assessment make it unlikely that the risks are underestimated for the general population.

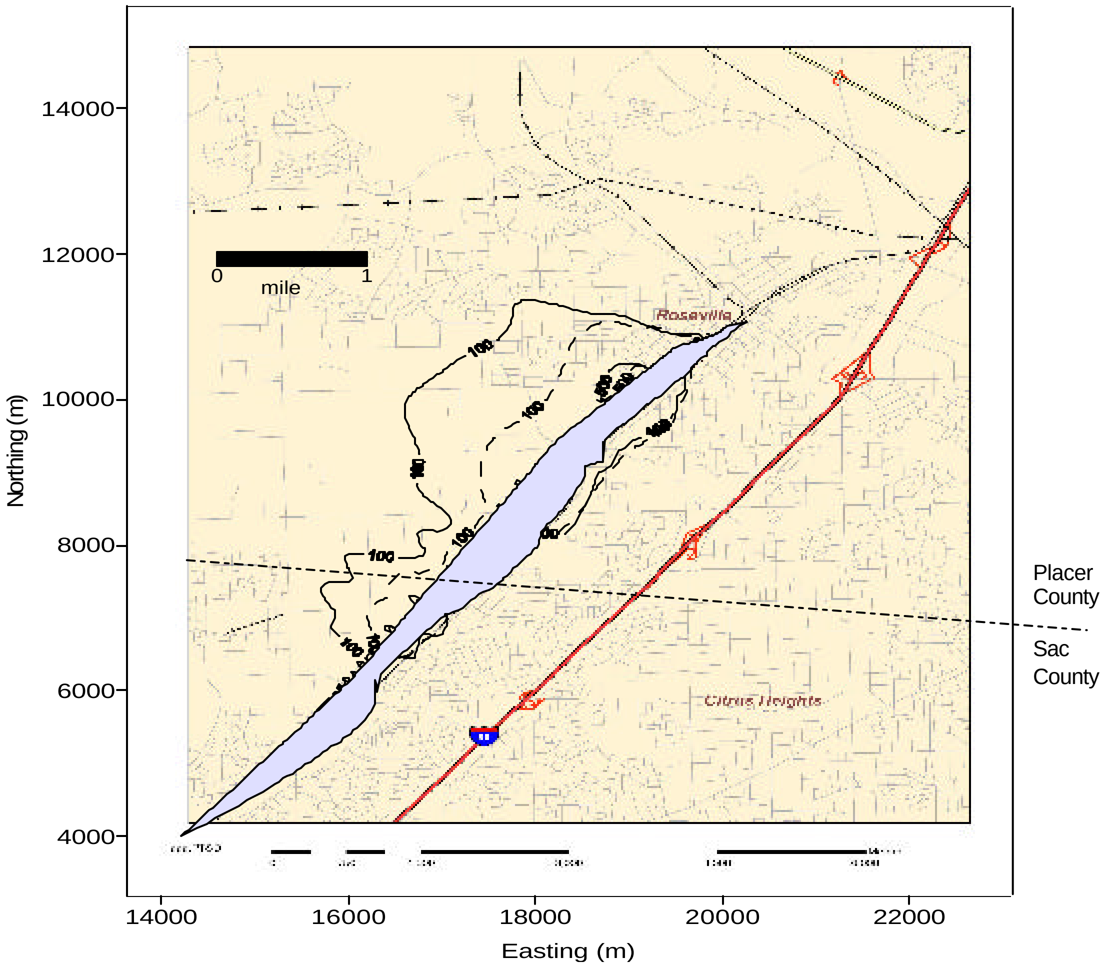
8. What are the results?[7]

The potential cancer risk from the estimated emissions of diesel PM at the Yard were calculated using two meteorological data sets (Roseville and McClellan) and for both urban and rural dispersion characteristics.[8]

Figure I.1 presents the predicted 100 and 500 in a million cancer risk isopleths for the two meteorological sets (Roseville and McClellan) using the urban dispersion characteristics. ARB staff believes that the urban dispersion characteristics are most appropriate for predicting the near source impacts from the Yard and the rural dispersion characteristics are most appropriate for predicting the area-wide impacts. The solid line represents the 100 or 500 in a million cancer risk isopleth using the Roseville meteorological data. The dashed line represents the 100 or 500 in a million cancer risk isopleth using the McClellan meteorological data. The area inside the isopleth has potential cancer risks estimated to be greater than 100 or 500 in a million depending on the isopleth. For example, the number of acres with predicted cancer risk levels at 100 in a million or more is approximately 1600 acres using Roseville meteorological data and 700 acres using McClellan meteorological data.

[7] All estimated cancer risks reported in the Executive Summary are based on the 80th percentile breathing rate that is the midpoint of the range of risk calculated in the risk assessment. The main body of Part II provides the more detailed information on the entire range of risk, which is calculated using the 65th to 95th percentile breathing rates.
[8] Dispersion coefficients are used in air dispersion models to reflect the land use (rural or urban) over which the pollutants are transported. The rural dispersion coefficient generally results in wider dispersion of the pollutant hence a larger "footprint" whereas an urban coefficient results in less dispersion of the pollutant and a smaller footprint. Because the area around the Yard contained both urban and rural land use types, the model was run with both dispersion coefficients.

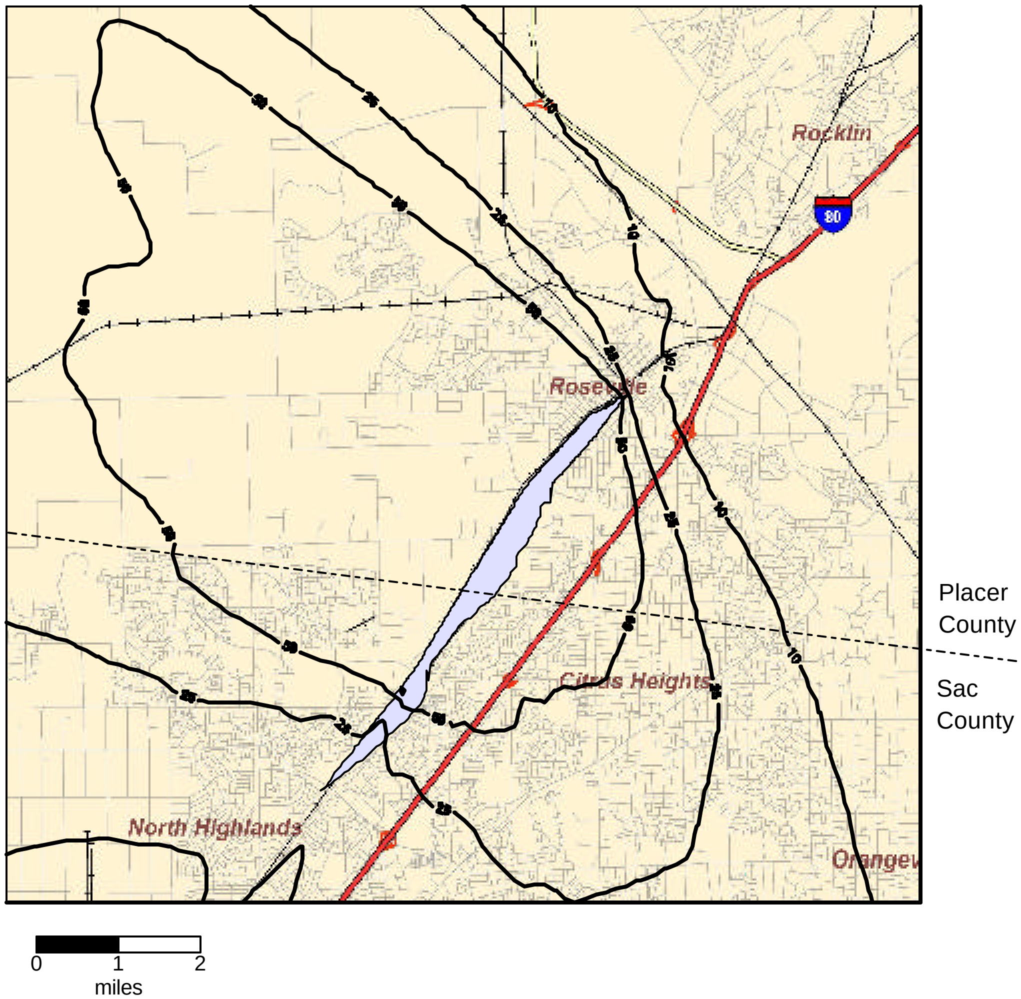
Figure I.1: Estimated Cancer Risk from the Yard (100 and 500 in a million risk isopleths)



Notes: 100/Million Contours: Solid Line – Roseville Met Data; Dashed Line-McClellan Met Data, Urban Dispersion Coefficients, 80th Percentile Breathing Rate, All Locomotives' Activities (23 TPY), 70-Year Exposure

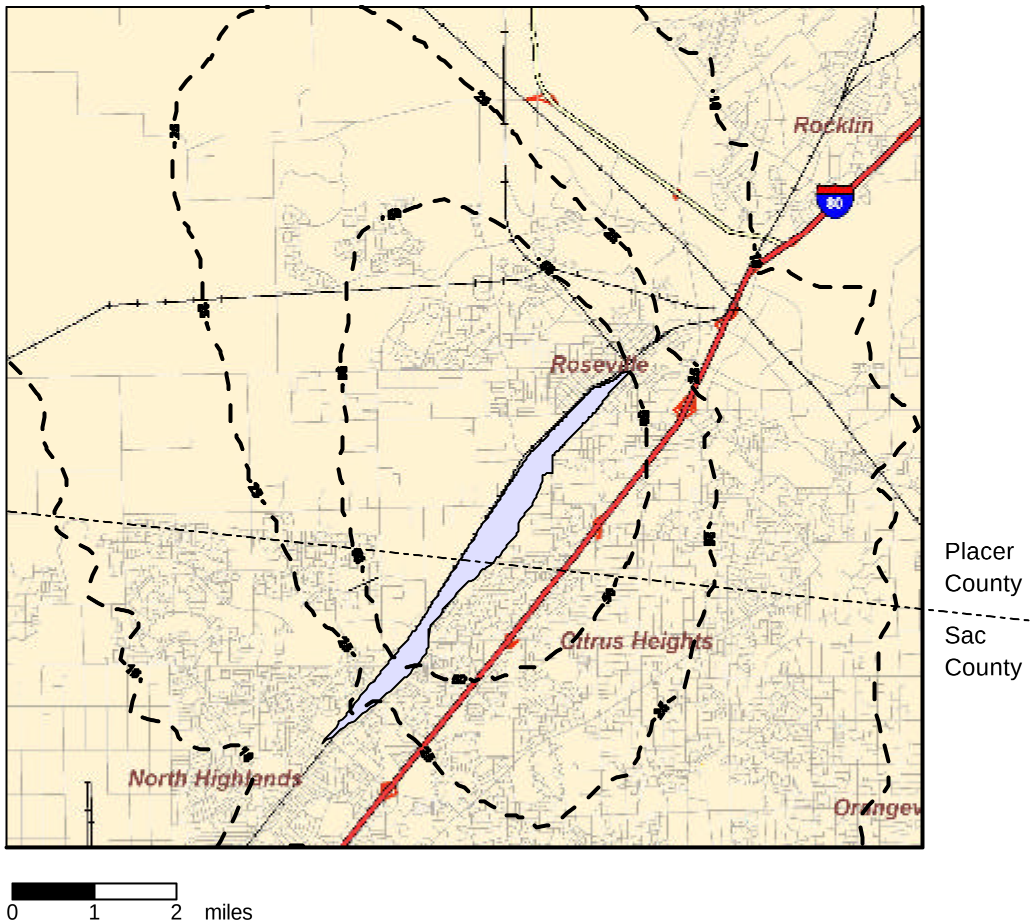
Figures I.2a and 1.2b present the potential risk for the two different meteorological data sets using the rural dispersion coefficient. As stated previously, staff believes that the rural dispersion characteristics are most appropriate for predicting the area-wide source impacts from the Yard. The isopleths for 10, 25, and 50 in a million potential cancer risk are shown. Figure 1.2a provides the estimated cancer risk isopleths using the Roseville meteorological data and Figure 1.2b the results using the McClellan meteorological data. As can be seen in the figures, the area in which the risks are predicted to exceed 10 in a million is very large, covering about a 10 mile by 10-mile area. The estimated number of acres, including areas outside of the modeling area, with a predicted cancer risk of 10 in a million or greater is in excess of 55,000 acres.

Figure I.2a: Estimated Cancer Risk from the Yard Using Roseville Met Data (10, 25, and 50 in a million risk isopleths)



Notes: Roseville Meteorological Data, Rural Dispersion Coefficients, 80th Percentile Breathing Rate, All Locomotives' Activities [23 TPY], 70-Year Exposure

Figure I.2b: Estimated Cancer Risk from the Yard Using McClellan Met Data (10, 25, and 50 in a million risk isopleth)



Notes: McClelln Meteorological Data, Rural Dispersion Coefficients, 80th Percentile Breathing Rate, All Locomotives' Activities [23 TPY], 70-Year Exposure

Using the U. S. Census Bureau's year 2000 census data, we estimated the population within the isopleth boundaries.[9] As shown in Table I.1, over 165,000 people live in the area around the Yard that has predicted risks of greater than 10 in a million. Also shown in Table 1.1 is the average risk level within each risk zone. For example the average risk within the ≥ 500 Roseville risk zone is 645 in a million.

Table I.1: Summary of Average Risk by Risk Zone and Acres Impacted

Meteoro-logical Data Source	**Risk Zone Based on Figures 1.1 and 1.2a and b Isopleth Boundaries** (70 Year Exposure)	Dispersion Characteristic	Average Risk Estimated Based on Years Exposed	Acres Impacted (rounded)	Estimated Year 2000 Population
			70 years		
Roseville	Risk ≥ 500	Urban	645	40	685
	Risk ≥ 100 and < 500	Urban	170	1,600	25,800
	Risk ≥ 10 and < 100	Rural	40	45,900	139,000
	Total			47,500	165,000
McClellan	Risk ≥ 500	Urban	630	10	460
	Risk ≥ 100 and < 500	Urban	156	700	14,200
	Risk ≥ 10 and < 100	Rural	28	55,500	155,000
	Total			56,200	169,000

Notes: Model domain for rural dispersion coefficient is 16km x 18 km with a resolution of 200m x 200m. For the urban dispersion coefficient the model domain is 6km x 8 km with a resolution of 50m x 50m. The 80th percentile breathing rate for adults was used.

Figures I.1 and I.2a and b are based on an exposure duration of 70 years. OEHHA guidelines recommend a 70-year exposure duration for a Tier 1 evaluation. The OEHHA guidelines also provide that a 30-year exposure duration may also be evaluated as supplemental information to show the range of cancer risk based on different residency periods. Table I.2 shows the equivalent risk level for 70- and 30-year exposure duration. Using this table, the 10 in a million isopleth line in Figures I.2 a and b would become 4.3 in a million if the exposure duration was 30 years for an adult.

Table I.2: Equivalent Risk Levels for 70 and 30-Year Exposure Duration

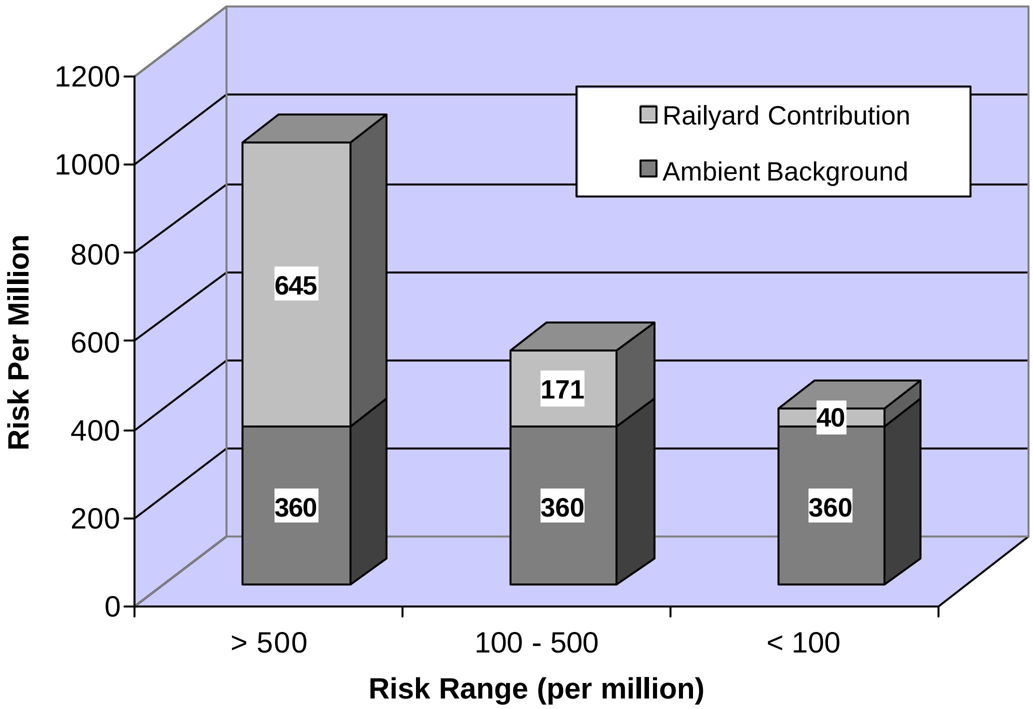
Exposure Duration (years)	Equivalent Risk Level (chance in a million)		
70	10	100	500
30	4.3	43	215

The estimated concentrations of diesel PM due to emissions from the rail yard are in addition to regional background levels of diesel PM. Although emissions from the rail

[9] To estimate the population, a GIS map of the model domain was overlaid with the 2000 census tract boundaries, and the percentage area of a given census tract within an isopleth was determined. The population of the census tract was then weighted with the percentage area of that census tract within the isopleth.

yard also contribute to the regional background, the measurable effect should be small. The regional background risk due to diesel PM emissions has been estimated to be 360 per million for the entire Sacramento Valley in the year 2000. Figure 1.3 provides a comparison of the predicted average potential cancer risk in various isopleths to the regional background risk from diesel PM. For example, in the greater than 500 isopleth or risk range, the average risk above the regional background is 645. Residents living in that area would have a potential cancer risk over 1,000. (645 per million due to rail yard emissions and 360 per million for regional background) (ARB 2004).

Figure 1.3: Comparison of Roseville Rail Yard Risks to the Regional Background Levels in the Sacramento Region for Diesel PM



Note: Roseville Meteorological Data, Urban Dispersion Coefficients for Risk Ranges of > 500 and 100-500, Rural Dispersion Coefficients for Risk Range of < 100.

9. Has monitoring been conducted to verify the model predictions.

No. Currently there is no specific measurement technique for directly monitoring diesel PM emissions in the ambient air. However this does not preclude the use of an ambient monitoring program to measure general air quality trends in a region. However, surrogate tests using elemental carbon can be very expensive. Since cancer risk is based on an annual average concentration, a minimum of a year of monitoring data would generally be needed. A monitoring study to validate the modeling results using elemental carbon would involve numerous monitors operating for at least a year. The cost of such a program is likely to be quite high, ranging from several hundred thousand to possibly several million dollars to complete. Past studies have used black carbon or elemental carbon measurements along with detailed emissions inventories to draw conclusions about the relative contributions of diesel PM emissions. As such, PM 2.5 elemental carbon monitoring can provide general information on combustion-related particulate matter in a region.

10. Have the diesel PM emissions at the Yard changed since 2000, the year for which the health risk assessment was conducted?

Without additional data, it is difficult to determine the emissions trends at the Yard since the year 2000. According to Union Pacific Rail Road, several actions have been taken to modify their locomotive fleet and operations at Roseville in ways that could decrease emissions associated with many locomotive activities. Some of the actions taken include replacing older locomotives with Tier 0 or better locomotives, installation of auto start-stop devices to limit idling, fuel efficiency improvements, modification of load test procedures, and operation efficiency improvements. While the exact diesel PM emissions benefits at the Yard have not been determined, UP indicates that they believe these efforts have resulted in actual emission reductions at the Yard. On the other hand, California has experienced a tremendous increase in the volume of cargo being moved through our Ports that could potentially result in additional rail traffic and diesel PM emissions. For example, based on fuel consumption data provided by the two Class 1 freight railroads operating in California, there was a 4 percent per annum increase in fuel consumption between 1998 and 2002. (BNSF & UP. 2004). Because of this, a more extensive analysis of the projected growth in activity and the impacts from emission reduction strategies is needed to determine if the emissions at the Yard have changed since 2000 and determine the degree to which emission reduction actions have offset the increased emissions due to growth in locomotive activities at the Roseville Yard.

II. INTRODUCTION

This report presents our evaluation of the potential air quality and public health impacts of diesel particulate matter (diesel PM) emissions from locomotive activities at the Union Pacific J.R. Davis Rail Yard (J.R. Davis Yard or Yard) located in Roseville, California. In this chapter, Air Resources Board (ARB) staff provides an overview of the report, the reasons for conducting the exposure assessment, a description of the J.R. Davis Yard, as well as the process used to develop for the exposure assessment.

A. Overview

Exposure or risk assessment is a complex process that requires the analysis of many variables to simulate real-world situations. Three steps were taken to perform the exposure assessment for the J.R. Davis Yard:

- Development of a diesel PM emissions inventory that reflects the amount of diesel PM released annually from locomotive activities at the Yard.
- Air dispersion modeling to estimate the ambient concentration of diesel PM that results from these emissions.
- Characterization of the exposures at nearby residences and estimation of increased potential cancer risk associated with long-term exposures to these concentrations.

The following chapters provide a description of each element of the exposure assessment. Detailed supporting information is included in the appendixes. Specifically, the following information is provided:

- the methodology used in developing the locomotive diesel PM emissions inventory for the J.R. Davis Yard;
- a summary of the estimated diesel PM emissions inventory for the J.R. Davis Yard;
- a discussion on the air dispersion modeling conducted to estimate ambient concentrations of diesel PM;
- the results of the air dispersion modeling and the sensitivity studies; and
- an estimate of the potential impacts (potential cancer risks) to nearby residences due to exposure to ambient concentrations of diesel PM from locomotive activities at the J.R. Davis Yard.

B. Purpose

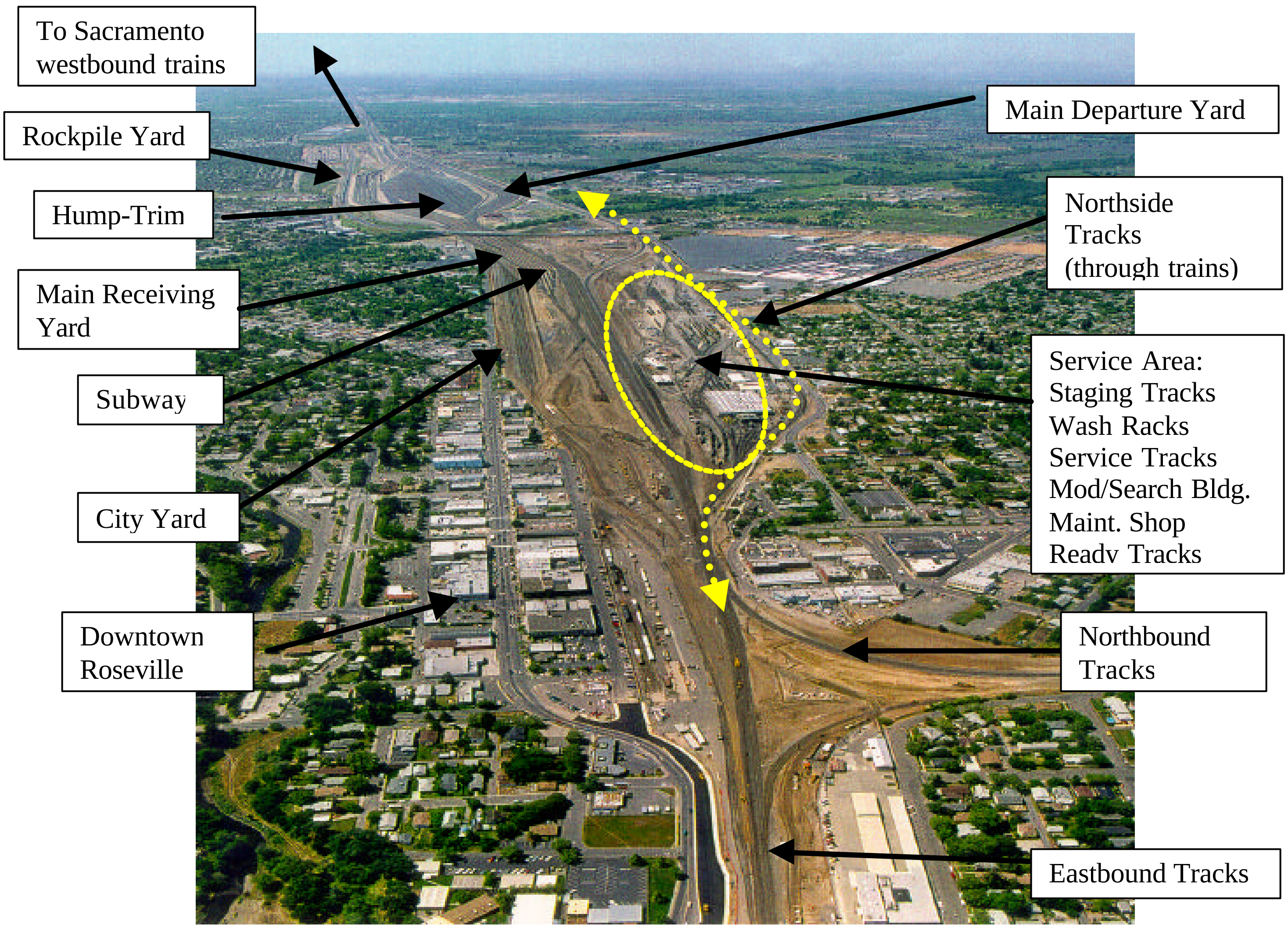
The ARB staff conducted this exposure assessment at the request of the Placer County Air Pollution Control District (District). After a recent expansion at the Yard, the District recognized a significant increase in noise and diesel exhaust emissions related complaints from residents of the City of Roseville that live near the J.R. Davis Yard. To address the growing concerns of nearby residents and to better understand the diesel PM emissions impacts, the District requested the ARB to prepare an exposure assessment of diesel PM emissions generated by activities at the J.R. Davis Yard. (Nishikawa. 2000) In response, the ARB agreed to work with the District to estimate the exposures associated with diesel PM emissions from current and future J.R. Davis Yard operations. (Kenny. 2000)

C. Description of the J.R. Davis Yard

The J.R. Davis Yard operates 24 hours a day, 7 days a week, and 365 days a year. It is Union Pacific's largest, most modern railroad classification yard in the Western United States. The J.R. Davis Yard serves as a classification,[10] maintenance, and repair facility for the Union Pacific Railroad (UPRR). Approximately 98 percent of Union Pacific's Northern California traffic moves through the J. R. Davis Yard.

Figure II.1 is an aerial photo of the J.R. Davis Yard. Various areas within the Yard are identified the photo also shows the interface between the J.R. Davis Yard and the surrounding commercial and residential areas.

Figure II.1: Aerial Photo of J.R. Davis Yard



[10] Classification refers to the building and breaking down of trains.

The J.R. Davis Yard consists of approximately 950 acres situated on a one-quarter mile wide by four-mile long strip of land. Approximately two-thirds of the area of the J.R. Davis Yard is located in Placer County with the remaining one-third in Sacramento County.

A brief summary of the locomotive movements and activities within the J.R. Davis Yard that correspond to the labeled areas in Figure II.1 is provided below. Additional details are presented in Chapter III.

All arriving trains either go to one of the three receiving yards (Main *Receiving Yard, Rockpile Yard or City Yard*) or pass through the Yard on the *Northside Tracks*. For those trains arriving in one of the receiving yards, the locomotives are disconnected from the train and will follow one of two pathways. One pathway is to the *Subway*, which is used for rapid turn-around-fueling operations when full routine service is not required. The locomotives, which are coupled into groups of engines (known as consists), move from the *Subway* to either the *Main Departure Yard* or staging area for the *City Yard or Rockpile Yard.* The locomotives are connected to a train and depart from the Yard.

The other pathway, which the majority (approximately 75 percent) of arriving locomotives travel, has the locomotives moving from one of the receiving yards to the *Service Area* for service or maintenance prior to movement to the *Ready Tracks* where consists are formed. The newly formed consists will move from the *Ready Tracks* to either the *Main Departure Yard* or the staging area for the *City Yard or Rockpile Yard.* From here, the locomotives are connected to rail cars and depart the Yard.

The railcars disconnected from the arriving trains are taken to the H*ump and Trim* area by switcher locomotives for classification (building of trains). Likewise, the railcars are brought to the waiting locomotive (consists) in the departure yards by switcher locomotives for connection prior to leaving the Yard.

D. Development of the Exposure Assessment

To help facilitate and coordinate the collection and interpretation of the technical data necessary for the exposure assessment, a working group was formed with representatives from the ARB, the District and UPPR. The working group established goals and objectives for the project and identified timelines for deliverables of activity data and information on Yard operations. The working group met periodically to review data, identify data gaps and issues, and resolve technical issues.

The key tasks were:

- Develop a diesel PM emissions inventory for the yard
- Conduct air dispersion modeling using the diesel PM emissions inventory
- Conduct an assessment of potential cancer risk using the results of the dispersion modeling.

III. LOCOMOTIVE EMISSIONS CALCULATION METHODOLOGY AND ACTIVITY ASSUMPTIONS

In this chapter, ARB staff summarizes the methodology and development of the locomotive diesel PM emissions inventory for the J.R. Davis Yard. Additional details on the development of the emissions inventory are provided in Appendix B and C.

A. Emissions Calculation Methodology

An air emissions inventory was developed by determining the population and location of locomotives within the yard on an annual basis, establishing the activity (moving, idling, or testing) for the locomotives in each area, and applying emission factors specific to the locomotive model and activity. A simplified equation representing the emissions calculation is provided below with a short description of the approach used to determine the key inputs:

Emissions = ? (Locomotive Population) X (Activity) X (Emission Factor)

- *Locomotive Population*: The population of locomotives is a function of the number of trains arriving and departing the Yard on an annual basis. The number and type of locomotives visiting the Yard annually was determined from data provided by UPRR. UPRR provided detailed information for trains arriving, departing, and passing through the Yard for the period between December 1999 and November 2000. UPRR choose the second week of each month (seven consecutive days of operation) as a representative period from which to collect the data. The data was then extrapolated to represent an entire 1-year period.

- *Activity*: Locomotive activity is a function of what that locomotive is doing – moving at a certain notch throttle setting, idling, or undergoing maintenance testing. The annual, monthly, daily, and hourly locomotive activity in the Yard including locomotive movements and routes for arrival, departure, and through trains, locomotive service and testing activity (number, type, and duration of testing events were determined from the data provided by UPRR. For each activity and location, estimates of the notch setting, locomotive speed, and the time spent in each notch setting were determined.

- *Emission Factors*: The emissions rate for each locomotive is dependent on the locomotive model and what activity the locomotive is engaged in (idling, movement, testing). Emission factors were developed representing the diesel PM emissions rate at idle and at different notch settings for the locomotive models moving through the J.R. Yard. The emission factors for the locomotive models were obtained from the General Motors Electromotive Division (EMD), General Electric Transportation Systems, U.S. EPA's Locomotive Emission Standards Regulatory Support Document, April 1998, and locomotive emissions testing that was conducted by Southwest Research Institute for US. EPA (Fritz, 1995).

In the sections that follow, we provide additional details on the information gathered to support the development of the emissions inventory for the J.R. Davis Yard.

B. Locomotive Engine Population

During the period between December 1999 and November 2000, UPRR collected data for 1,453 individual trains and model information for 5,551 locomotives. This information was used to determine the total number, and the manufacturer and model of locomotives visiting the Yard on an annual basis.

As shown in Table III.1 Approximately 31,000 locomotives stop at the J.R. Davis Yard for service or fueling on an annual basis. Another 15,000 locomotives per year are through trains that use the *Northside Tracks*. The majority of the arriving locomotives, approximately 75 percent, are processed through the *Service Area* where they undergo routine service or maintenance. The other 25 percent are fueled at the *Subway* for rapid turn-around and eventual departure from the Yard.

TABLE III.I: Annual Average Locomotive Traffic at J.R. Davis Yard (Estimated for the Period 12/99 – 11/00)

	12/99 - 11/00	
	Locomotives	**Locomotives**
Arrivals/Departures	31,000	
to Service Area		21,500
to Subway		9,600
Northside Tracks (through trains)	15,000	
Totals	46,000	

Emissions data for all locomotive engine configurations are not available. Therefore, we grouped engines with similar configurations and emissions into classifications. Table III.2 identifies 11 locomotive model classifications that was considered representative of UPRR's locomotive inventory for J.R. Davis Yard.

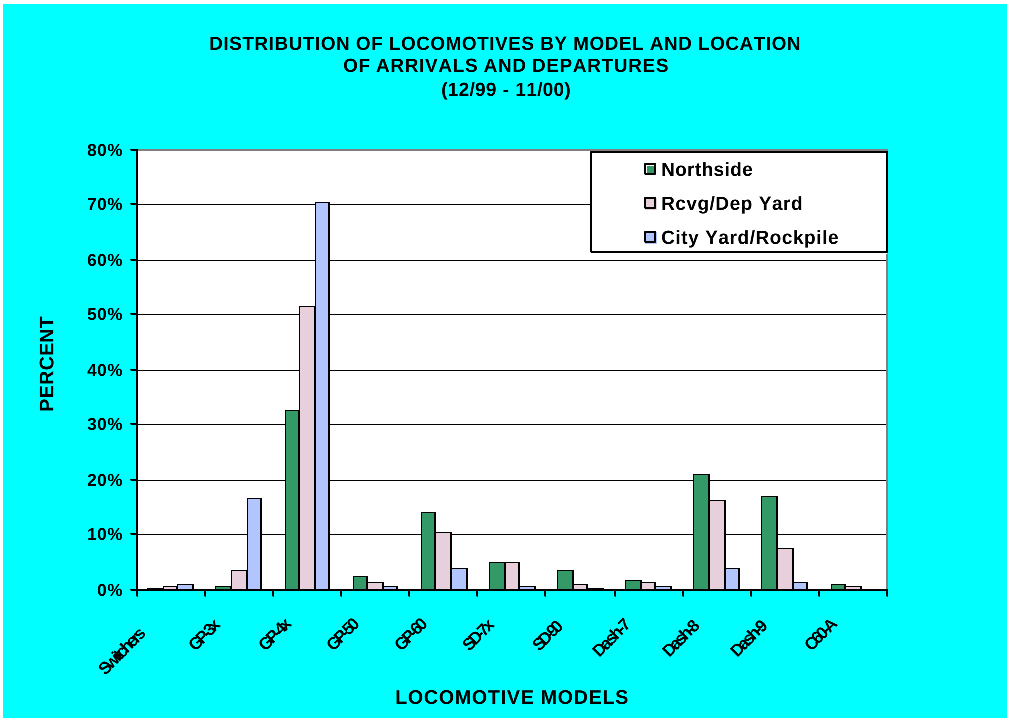
TABLE III.2: Locomotive Model Classifications at J.R. Davis Yard

Model Classification*	Engine Type	Locomotive Models Included in Classification
Switchers	EMD 12-645E	GP-15, SW1500, MP15AC
GP- 3x	EMD 16-645E	GP-30, GP-39
GP- 4x	EMD 16-645E3B	GP-40, GP-45, P42DC, F40PH
GP-50	EMD 16-645F3B	
GP-60	EMD 16-710G3A	
SD- 7x	EMD 16-710G3B	SD- 70, SD-75, SD70M, SD70MAC
SD-90	EMD 16V265H	
Dash-7	GE 7FDL, 12 cyl.	C36-7, B36-7, B30-7, B23-7, U36B
Dash-8	GE 7FDL, 12 or 16	C41-8, C39-8, B40-8, B39-8, B32-8
Dash-9	GE 7FDL, 16 cyl.	C44-9
C60-A (AC 6000)	GE 7HDL	

*EMD GP and SD series models using the same engines are listed with an "x" identifying multiple model numbers within the group.

As mentioned earlier, during the survey period, UPRR recorded locomotive model number for locomotives in each of the three major areas of the yard to allow determination of the fleet composition for each area. Figure III.1 presents the percent distribution of locomotives by locomotive model classification and location of arrival and departure trains. The most common locomotive classifications passing through the Yard are the GP-4X, GP-60, Dash-8, and Dash-9.

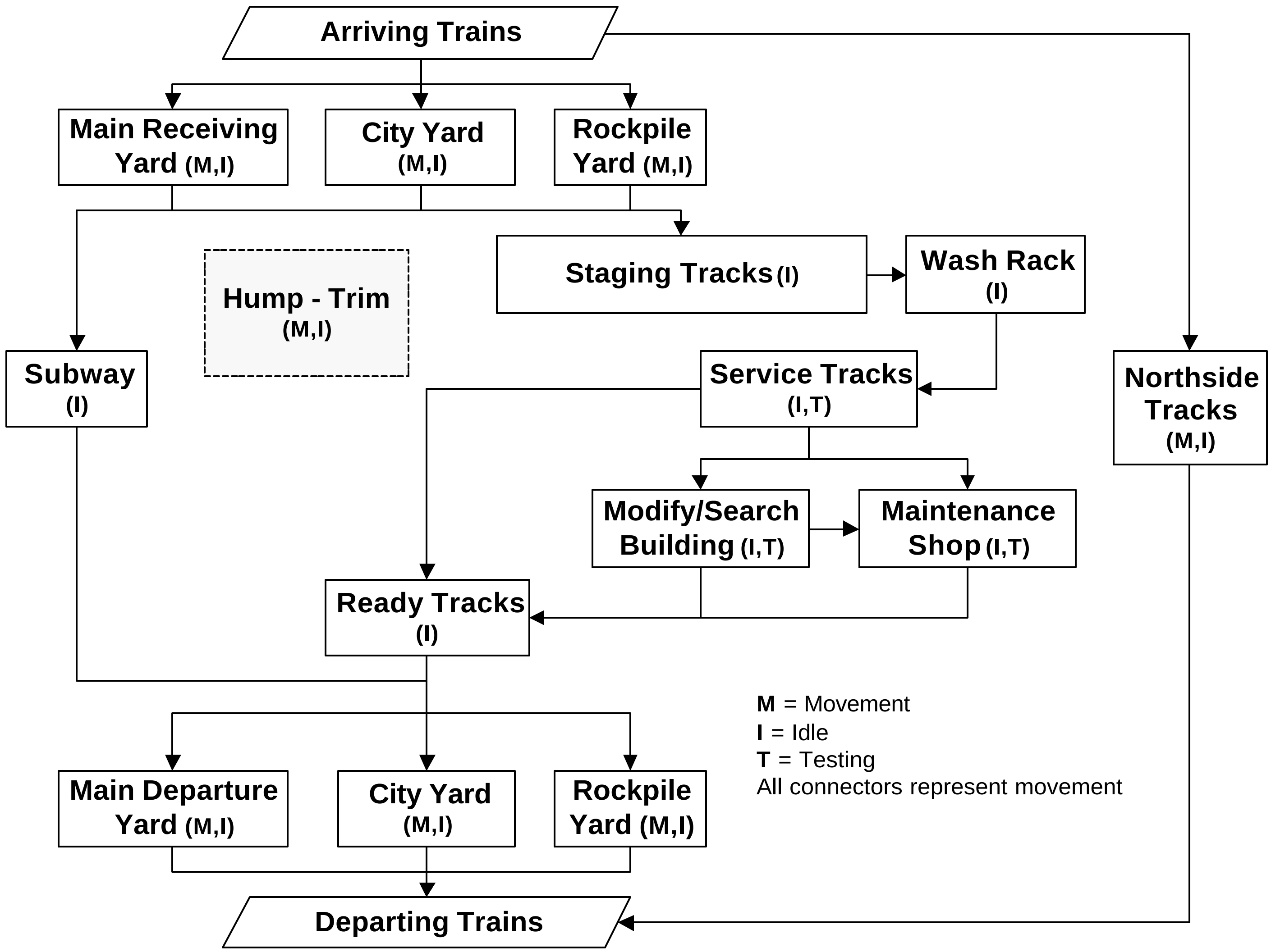
Figure III.1: Distribution of Locomotives at the J.R. Davis Yard



C. Locomotive Activity Assumptions

As shown in Figure III.2, all arriving trains either go to the receiving yards or pass through the Yard on the *Northside Tracks*.

Figure III.2: J.R. Davis Yard Locomotive Activity Schematic



For the locomotives arriving in one of the three receiving areas (*Main Receiving Yard, Rockpile Yard or City Yard*), after the locomotives are disconnected from the train, they will follow one of two pathways.

- One pathway is to the *Subway*, which is used for rapid turn-around-fueling operations. After the locomotives are refueled, the consist will move from the *Subway* to either the *Main Departure Yard* or staging area for the *City Yard or Rockpile Yard.*

- The other pathway, locomotives will move from the receiving yards to the *Service Area* for service and/or maintenance prior to movement to the *Ready Tracks* where consists are formed. The newly formed consists will move from the *Ready Tracks* to either the *Main Departure Yard* or staging area for the *City Yard* or *Rockpile Yard*.

In either pathway, the railcars disconnected from the arriving trains are taken to the *Hump Area* by switcher locomotives for sorting. These recoupled railcars are brought from the *Trim Area* to the departure yards by switchers and ultimately connected to locomotives. Finally, the newly formed train leaves the Yard via one of the departure yards.

Emissions from locomotives can result from locomotive movement along a track segment, idling in one area, or testing activities. As shown in Figure III.2, depending on where a locomotive is in the Yard and the activity that it is engaged in, different emissions levels are assigned to the locomotive.

UPRR provided descriptions of train and locomotive activities in the major areas shown previously in Figure III.2. The activities and locations include:

- Locomotive service activities (number, type, and duration of locomotive activities throughout the Yard.
- Estimates of duration or notch settings for locomotive movements in the Yard, and the nominal notch settings, speed, and distance profiles for departing, arrival, and through trains.

Based on this information, the number and model of locomotives on an hourly and daily basis were estimated for a year for each location in the Yard. Taking into account the estimates of average time spent in each area of activity, the maximum track speed limits between each area, and seasonal variation in activity, we allocated a locomotive "residence time" to each area of activity (including movements between each area).

Based on discussions with UPRR, we developed the following estimates of average times spent in each area:

- One-half to one hour in receiving yards prior to movement to either the *Subway* or *Staging Track* at the *Service Area.*
- Two hours in *Subway*.
- One hour in *Staging Track* (includes time in wash rack area).
- Three to four hours in *Service Tracks* area.
- Two to three hours in *Ready Track*s area.
- Two to four hours in departure yards prior to leaving the Yard.

The detailed assumption on actual locomotive activities in each of these areas are provided in Appendix C.

D. Locomotive Emission Rates

Locomotive engine emission rates were developed based on currently available data. The emission rate for a given locomotive engine will depend on the engine configuration and design, horsepower and the notch setting on the engine.[11] For the development of the diesel PM emissions inventory for the J.R. Davis Yard, ARB staff, in conjunction with UPRR representatives, evaluated available emission rate data. Emission factors for different locomotive models were obtained from the General Motors Electromotive Division (EMD), General Electric Transportation Systems, U.S. EPA's Locomotive Emission Standards Regulatory Support Document, April 1998, and locomotive emissions testing that was conducted by Southwest Research Institute for U.S. EPA (Fritz, 1995). Because emission factors were not available for all locomotive models ARB staff used engineering judgement to assign emission factors to the eleven model classifications for the locomotive engines at the J.R. Davis Yard.

For this analysis, all locomotives were assigned to one of the 11 locomotive model classifications discussed earlier. There was a wide range of emission rates depending on the model. For example, the PM emission factors for the idle mode ranged from about 16 g/hr to 228 g/hr. At a throttle notch of 2, the PM emission rate ranged from 76 g/hr to 201 g/hr. A summary of the emission factors at each notch setting for the different classification is provided in Appendix B.

[11] The power settings for locomotive engines are a series of discrete steady-state operating modes, or commonly referred to as notch settings. There are generally eight power settings (notches one through eight), in addition to low-idle, standard idle, and dynamic brake. These are the only engine power settings at which a locomotive can operate, and the engines can only provide power for propulsion in notch settings one through eight. Exhaust emissions data supplied by the engine manufacturers suggest that emissions can vary significantly by notch setting. One manufacturer's engine may be a relatively low emitter in one notch setting and be a relatively high emitter in another *(reference "Emissions Measurements, Locomotives, Steve Fritz August 1995)*.

IV. LOCOMOTIVE EMISSIONS ESTIMATES

In this chapter, we provide a summary of the diesel PM emissions inventory for the J.R. Davis Yard. Summaries are provided of the total emissions in various areas of the Yard, emissions attributed to different locomotive models and activities. Additional details on the emission inventory are provided in Appendix D.

A. Total Diesel PM Emissions and Distribution

To more easily characterize emissions of diesel PM that result from train or locomotive operations in the Yard, the diesel PM emissions were allocated into five areas based on specific train or locomotive operations. These areas are summarized in Table IV.1 and a detailed schematic and description of the area or activity represented by each area is also included in AppendixA.

Table IV.1: Description of Emissions for the J.R. Davis Rail Yard Diesel PM Emission Inventory

Area	***Description***
1	Movement to/from Yard boundary and receiving and departure yards (*Main Receiving Yard, Main Departure Yard*, *City Yard*, and *Rockpile Yard)* including movement on Northside tracks.
2	Movement/idling within the receiving and departing yards (*Main Receiving Yard, Main Departure Yard, City Yard*, *and Rockpile Yard,* including idling at the *Subway)*.
3	Service Area: Locomotive idling, testing, and movements in *Service Tracks*, *Wash Racks*, *Modsearch Building*, *Maintenance Shop*, and the *Ready Tracks* areas.
4	Hump and Trim operations – Movement of arriving rail cars to reclassification in *Hump Area*. Movement of reclassified cars to departure yards in *Trim Area*. Idling of tradeout locomotives during Hump operations.
5	Movement of locomotives between major locations in Yard (from *Main Receiving Yard*, *Main Departure Yard*, *City Yard*, and *Rockpile Yard* to either the *Subway* or *Staging Area*, and movement of locomotives from *Ready Tracks* or *Subway to Main Departure Yard* and *City Yard/Rockpile Yard* staging area).

Using the data provided by UPRR and the methodology described in Chapter III, the range of diesel PM emissions calculated for the Yard is approximately 22 to 25 tons per year.[12] The emissions ascribed to each area are provided in Table IV.2.

[12] The emissions were also calculated based on a train acceleration-based speed methodology. The results of this approach fell within the range of emissions presented in this chapter. See appendix D for additional details.

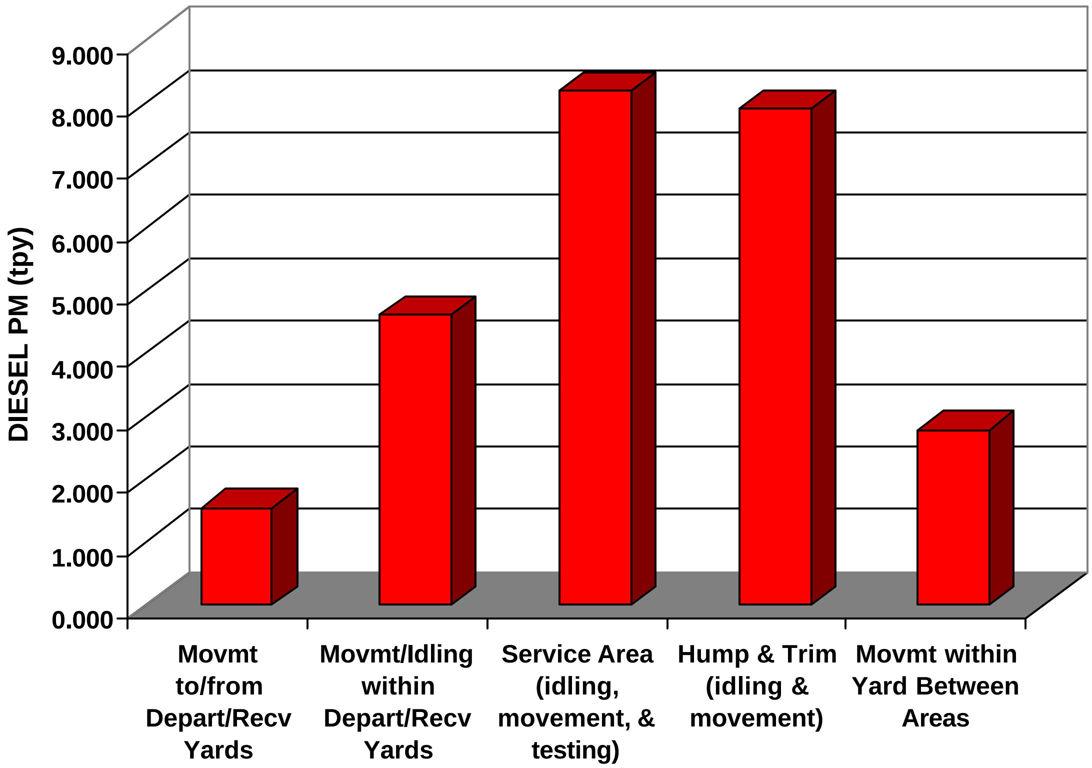
Table IV.2: Estimated Diesel PM Emissions for the J.R. Davis Rail Yard

Location	Total Diesel PM Emissions (tpy)*	Percent of Total
Area 1	1.5	6 - 7%
Area 2	4.6	18 - 21%
Area 3	7.8 - 8.2	31- 36%
Area 4	6.4 - 7.9	29 - 32%
Area 5	1.8 - 2.8	8 - 11%
TOTAL	22.1 - 25.0	

* Due to the uncertainties in locomotive operations in areas 3, 4, 5, and 6 a range of emissions was estimated based on different locomotive models and different potential notch settings.

The emissions estimates in Area 3 are associated with the *Service Area*. The emissions in this area comprise the largest percentage of emissions in the Yard, at approximately 31 to 36 percent of the total. The next highest emission source is the movement and idling of locomotives in the *Hump and Trim Areas* (Area 4) at 29 to 32 percent, followed by Area 2. Area 2 comprises the emissions from the movements of arriving and departing trains within the *Main Receiving* and *Departure Yards*, *City Yard* and *Rockpile Yard* (including idling of locomotives in these areas and at the *Subway*). About 18 to 21 percent of the emissions are from these activities. Figure IV.1 is a graphical depiction of the emissions contribution from the various activities in the Yard.

Figure IV.1: Contribution of Diesel PM by Activity in the Five Areas



Notes:
1. Graph represents high-end only

As shown in Table IV.3, emissions from the testing of locomotives comprise about 6 to 7 percent of the total emissions. The remaining emissions are divided approximately equally between idling and movement of locomotives in the Yard. Idling comprises a larger portion of the overall emissions in the S*ervice Area* (Area 3) and in Area 2, which includes the emissions in the receiving yards and the *Subway*.

Table IV.3: Allocation of Emissions within Each Area to Idling, Movement, and Testing Activities

Area	Diesel PM Emissions Tons per Year (tpy)			
	Total tpy	Idling tpy	Movement tpy	Testing Tpy
1	1.5	0	1.5	0
2	4.6	4.2	0.38	0
3	7.8 - 8.2	5.7 - 5.8	0.5 - 0.8	1.6
4	6.4 - 7.9	0.29 - 0.36	6.1 - 7.5	0
5	1.8 - 2.8	0	1.8 - 2.8	0
Total	22 - 25	10.2 - 10.4	10.3 - 13	1.6

B. Distribution of Emissions by Locomotive Model Groups and Activity

Tables IV.4A and IV.4B illustrate the distribution of diesel PM emissions by locomotive model classification and activity in pounds per day. As can be seen, the GP3X and GP4X locomotive classifications account for the largest emissions at 54 and 51 pounds per day respectively.

Table IV.4A and IV.4B presents two emissions totals for idling and movement of locomotives in the Yard. These emissions totals are due to the uncertainties in locomotive operations in Areas 3, 4, and 5. We've portrayed these differences in activities and the resultant emission totals as a low-end and high-end (i.e., a range in emissions.) The activities (and emissions) identified by Table IV.4A represent the low-end (22 tpy) and the emissions identified by Table IV.4B represent the high-end of our emissions range (25 tpy).

Table IV.4A: Total (Low-End) Annual Average Diesel PM Emissions (Lbs/Day)

TOTAL ANNUAL AVERAGE DIESEL PM_{10} EMISSIONS (LBS/DAY)				
Model	**Idling**	**[1]Movement**	**Testing**	**[1]Total**
Switchers	3.6	24.0	0.2	27.8
GP-3X	6.6	10.2	0.4	17.2
GP-4X	29.4	11.9	4.3	45.6
GP-50	0.5	0.4	0.3	1.2
GP-60	2.1	2.2	1.2	5.5
SD-7X	1.4	0.8	0.3	2.5
SD-90	1.0	0.5	0.1	1.6
DASH 7	0.5	0.3	0.1	0.9
DASH 8	7.6	3.9	1.1	12.6
DASH 9	2.8	1.8	0.8	5.4
C60-A	0.7	0.2	0.0	1.0
Totals	56.2	56.2	8.8	121
			TPY	22

1. Emissions represent idle + TN1

Trim set idling 100% switchers

Table IV.4B: Total (High-End) Annual Average Diesel PM Emissions (Lbs/Day)

TOTAL ANNUAL AVERAGE DIESEL PM_{10} EMISSIONS (LBS/DAY)				
Model	**Idling**	**[1]Movement**	**Testing**	**[1]Total**
Switchers	0.4	0.2	0.2	0.7
GP-3X	10.6	42.7	0.4	53.6
GP-4X	29.4	16.9	4.3	50.5
GP-50	0.5	0.6	0.3	1.4
GP-60	2.1	2.9	1.2	6.2
SD-7X	1.4	0.9	0.3	2.6
SD-90	1.0	0.5	0.1	1.6
DASH 7	0.5	0.3	0.1	0.9
DASH 8	7.6	4.1	1.1	12.8
DASH 9	2.8	2.1	0.8	5.7
C60-A	0.7	0.3	0.0	1.0
Totals	56.9	71.3	8.8	137
			TPY	25

1. Emissions represent idle + TN2

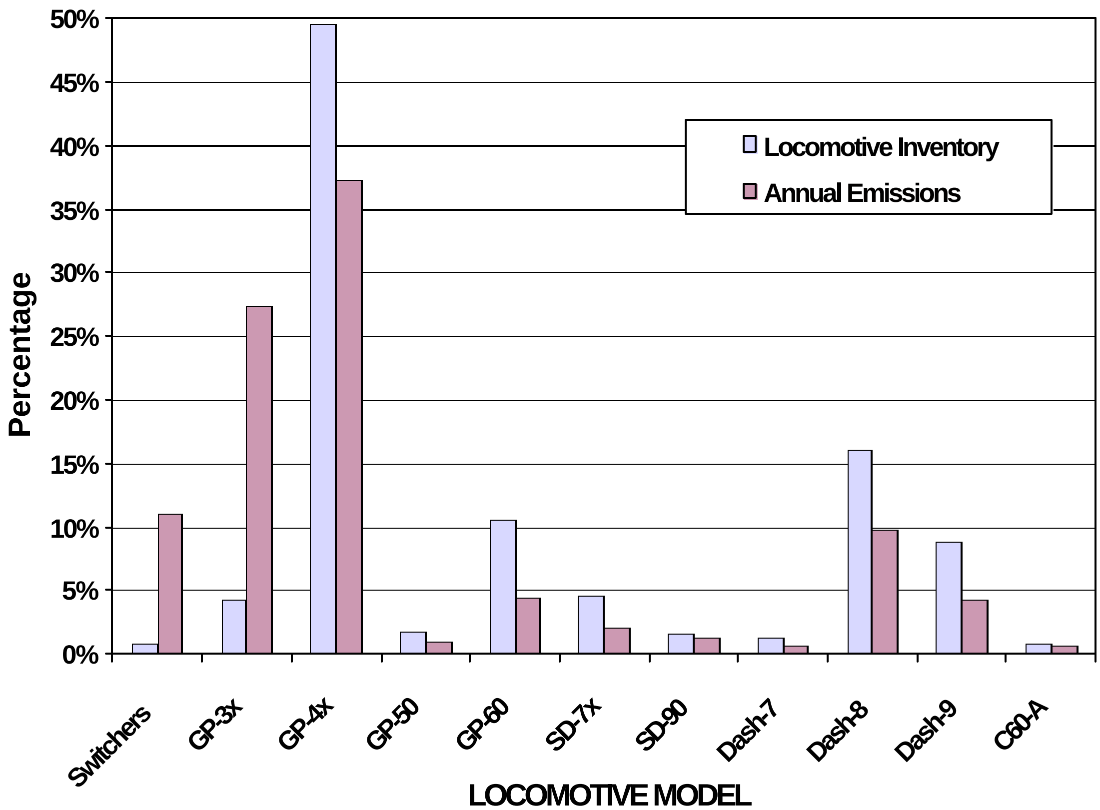
Trim set idling 100 % GP-3x

The differences between the low and high end emissions estimates are due to the assumptions used to estimate emissions in areas 3,4, and 5. For the low end estimate, we assumed locomotive movements in area 3 and 5 were done at notch 1. Notch 2 was assumed for the high end estimate. In area 4, *Hump and Trim*, either switchers or GP-3x locomotives can be used to classify rail cars. The low end estimate was based on assuming only switcher locomotives were used and the high end based on assuming only GP-3x locomotives were used for this activity.

Figure IV.2 presents the percent contribution by each locomotive model classification to the fleet inventory and to the total[13] diesel PM emitted within the Yard. A review of Figure IV.2 shows that switchers, GP-3x, GP-4x, and Dash 8 locomotive model groups contribute approximately 85 percent of the total diesel PM emitted within the Yard. These same model groups represent approximately 70 percent of the locomotive inventory for the Yard. The switchers and GP-3X model classifications account for approximately 5 percent of the locomotive inventory yet are responsible for over 35 percent of the total Yard emissions. This is because these locomotive models are dedicated to the *Hump and Trim* operations.

[13] Total diesel PM represents the average of the low-end and the high-end emissions totals for each locomotive model group.

Figure IV.2: Total Diesel PM Emissions and Locomotive Inventory at J.R. Davis Yard



C. Temporal Distribution of Diesel PM Emissions

The train and locomotive activities that occur in the J.R. Davis Yard occur continuously 24 hours a day. This same pattern of activity is repeated 7 days a week, 365 days a year. Figure IV.3 presents a graphic distribution of the total hourly average diesel PM emissions emitted at the Yard. To verify that the emissions were relatively constant throughout the day and year we investigated the temporal emissions profiles. As shown in Figures IV.3 and IV.4 below, the emissions are relatively constant over a 24-hour period and over the year. The peaks in the annual hourly average emissions are attributed to operational activities that occur at times of shift changes or maintenance activities.

Figure IV.3: Hourly Average Diesel PM Emissions at J.R. Davis Yard

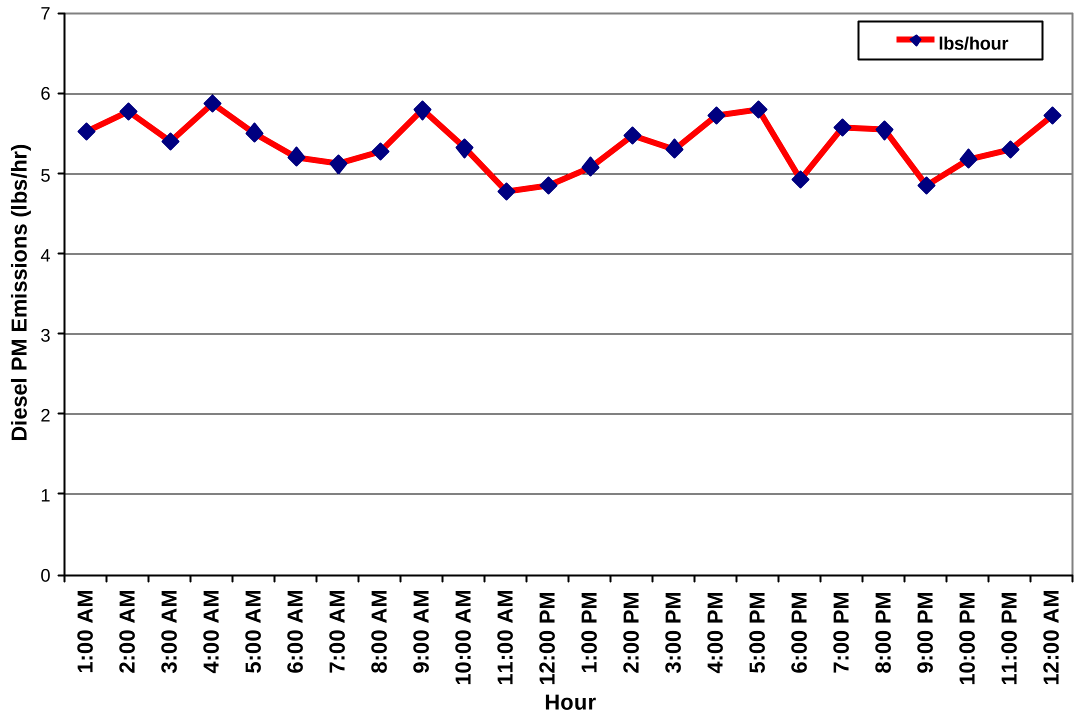
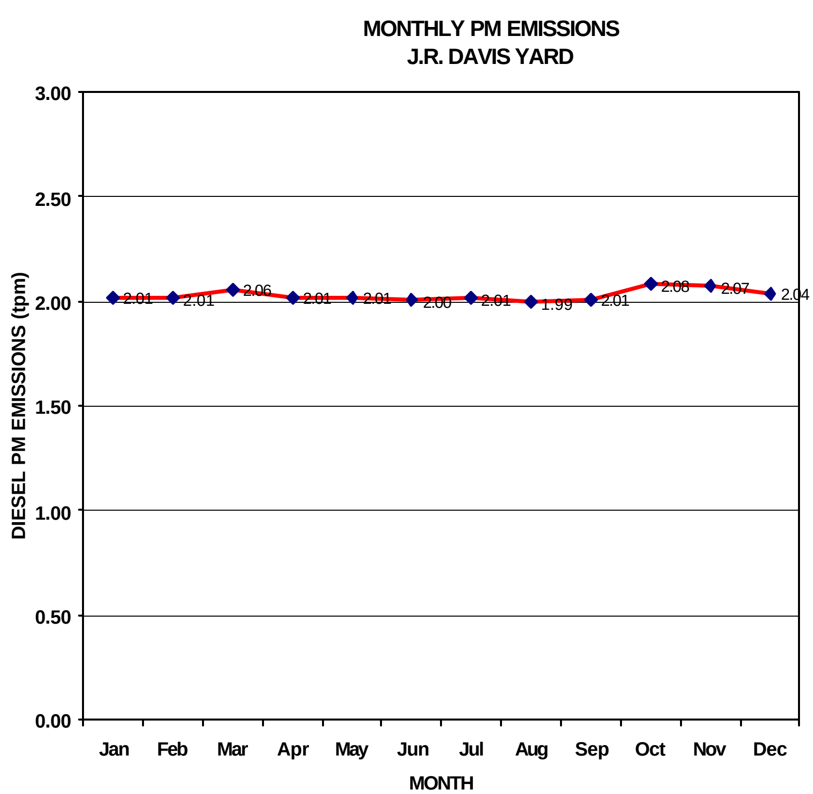


Figure IV.4: Monthly Diesel PM Emissions for J.R. Davis Yard



V. AIR DISPERSION MODELING OF J.R. DAVIS YARD

In this chapter, we describe the air dispersion modeling performed to estimate the downwind dispersion of diesel PM exhaust emissions resulting from the activities at the J.R. Davis Yard. A description of the air quality modeling parameters, including air dispersion model selection, emission source distribution, locomotive stack data, meteorological data selection, model receptor network, and building wake effects, are provided. Model input preparation, output presentation, and uncertainty and sensitivity analyses are also provided.

A. Air Dispersion Model Selection

Air quality models are often used to simulate atmospheric processes for applications where the spatial scale is in the tens of meters to the tens of kilometers. Selection of air dispersion models depends on many factors, such as, characteristics of emission sources (point, area, volume, or line), the type of terrain (flat or complex) at the emission source locations, and source receptor relationships. For the Yard, ARB staff selected the U.S. EPA Industrial Source Complex Model Short Term Version 3 (ISCST3, Version 00101) to simulate impacts at nearby receptors due to diesel PM emissions.[14] The ISCST3 model is a micro-scale, steady-state Gaussian plume dispersion model applicable for estimating impacts from a wide variety of emission release patterns (point, area, line, and volume) such as those found at the Yard for distances up to about 50 kilometers. The model may be used to predict annual average concentrations and account for the effects of building downwash as needed for the Yard. ISCST3 is also able to simulate the dispersion emissions generated from multiple sources and accommodate for both continuous and intermittent sources in flat and complex terrain. The application of ISCST3 follows guidance from the *U.S. EPA Guideline for Air Quality Methods (*40 CFR Part 51, Appendix W*)* (EPA Guidelines). The regulatory default options of ISCST3 were selected, which include (USEPA, 1995a&b):

- Stack-tip downwash (except for Schulman-Scire downwash)
- Buoyancy-induced dispersion (except for Schulman-Scire downwash)
- Final plume rise (except for building downwash)
- Treatment of calms
- Default for wind profile exponents
- Default for vertical potential temperature gradients
- Upper-bound concentration estimates for “super-squat” buildings

[14] ISCST3 Version 02035 was released after modeling studies had begun for the Yard. The changes between version 00101 and version 02035 include the correcting of problems with the SHRDOW emission factor, concatenation of multi-year meteorological files, the area source option of the TOXICS application, and a problem with COMPLEX terrain. Since our application of ISCST3 for the Yard does not use those options that were modified, it was not necessary to re-run the model with the new code.

B. Model Parameters and Adjustments

The emission sources from the locomotives in the Yard are characterized as either a point source or a volume source depending on whether the locomotive is stationary or moving. For stationary locomotives, including idling and load testing, the emissions are simulated as a series of point sources. Model parameters for point sources include emission rate, stack height, stack diameter, stack exhaust temperature, and stack exhaust exit velocity. For moving locomotives, the emissions are simulated as a series of volume sources to mimic the effects of initial dispersion due to plume downwash.

The emission rates for individual locomotive stacks are a function of locomotive type, notch setting, activity time, duration, and operating location. Stack parameters, for the 11 locomotive model classifications at the Yard including stack height, diameter, exhaust temperature, and exhaust velocity, were obtained from the General Motors, Electro-Motive Division and UPRR. Detailed information on the stack parameters is presented in Appendix B. Since the stationary locomotives were not uniformly distributed throughout the Yard, the locations of individual locomotive emission sources which were used for the model inputs were determined based on the detailed locomotive distribution and activity information provided by UPRR (see Appendices C and D).

For "through-trains" and movement of locomotives within the Yard, the emissions are simulated as a series of volume sources with adjusted initial plume release height. Key model parameters for volume sources include initial lateral (σ_{yo}) and vertical (σ_{zo}) dimensions of volumes and source release height. The initial lateral dimensions are estimated by dividing the adjacent source separation distance by a standard deviation of 2.15 as recommended in the ISCST3 User's Guide. Since some rail lines are curved, the source separation distances are not uniform within the Yard.

To consider potential buoyant effects from the exhaust of "through-trains" the volume release heights are adjusted based on a sensitivity study for each of the 11 locomotive model classification. Due to the diurnal variations of ambient air temperature, the adjustment in volume release height are treated separately for daytime (6 am to 6 pm) and nighttime (6 pm to 6 am). Appendix G presents the calculations for the adjustments. The initial vertical dimension of each volume source was determined by dividing the adjusted source height by a standard deviation of 2.15 as recommended in the ISCST3 User's Guide.

C. Emission Sources and Terrain Characterization

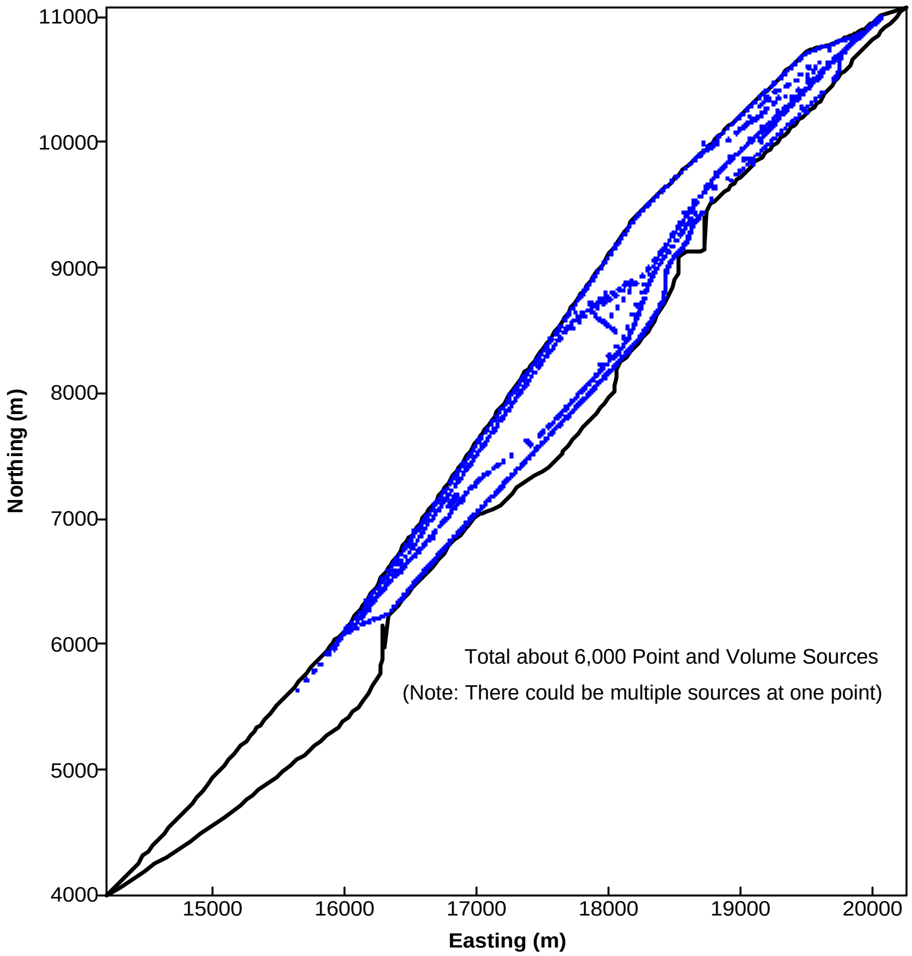
The Davis Yard emissions inventory is a critical input to the ISC3T model. To distribute the emissions into individual emission sources suitable for modeling, the Yard was divided into the following areas:

- *Main Receiving Yard*
- *Rockpile Yard*
- *Subway*
- *Staging Tracks*
- *Service Tracks*
- *Main Departure Yard*
- *Northside Tracks*
- *Ready Tracks*
- *Hump Operation*
- *City Yard*
- *Mod/Search Building*
- *Maintenance Shop*
- *Trim Operation*

For each area, there are numerous rail lines with lengths of several hundred meters to several kilometers. For simplicity, it is assumed that the emissions are emitted from certain rail lines and locations. For example, there are seven rail lines over three kilometers long in the *Main Receiving Yard*. In this case, we assumed that the emissions are generated from individual points along the center rail line. The coordinates for these emission sources were obtained from the confidential digitized two-dimensional associative electronic map (AUTOCAD format) provided by the UPRR. The distance between the two adjacent sources ranges from 50 to 150 meters. Since each locomotive type has different emission rates, notch settings, and stack data; for each point, there could be a maximum of 99 stacks (11 locomotive types x 9 settings). Figure V.1 presents a graphical representation of each emitting source evaluated in the modeling exercise. Note that in Figure V.1, each point could represent a maximum number of 99 independent point sources.

Local terrain variations are not considered for sources and receptors in the modeling domain. The local terrain is relatively flat.

Figure V.1: The Distribution of Emission Sources within the Yard



D. Meteorological Data

The ISCST3 model requires hourly meteorological data as input. The critical meteorological parameters include wind speed, wind direction, atmospheric stability, ambient temperature, and mixing height. These parameters have significant impact on the modeling predictions. Wind speed determines how rapidly the pollutant emissions are diluted. It also influences plume rise, thus affecting downwind concentrations of pollutants. Under low wind conditions, the plume's initial buoyancy and inertia will cause the emissions to go higher into the air than during high wind conditions. Wind direction determines where pollutants will be transported.

Atmospheric stability determines the rate of mixing in the atmosphere and is typically characterized by the atmospheric vertical temperature profile. The difference of ambient temperature and the stack exhaust exit temperature determines the initial buoyancy. In general, the greater the temperature difference, the higher the plume rise. Mixing height defines the vertical depth of the atmosphere through which pollutants are allowed to mix by dispersion processes. The greater the mixing height, the larger the volume of atmospheric available to dilute the pollutant concentration.

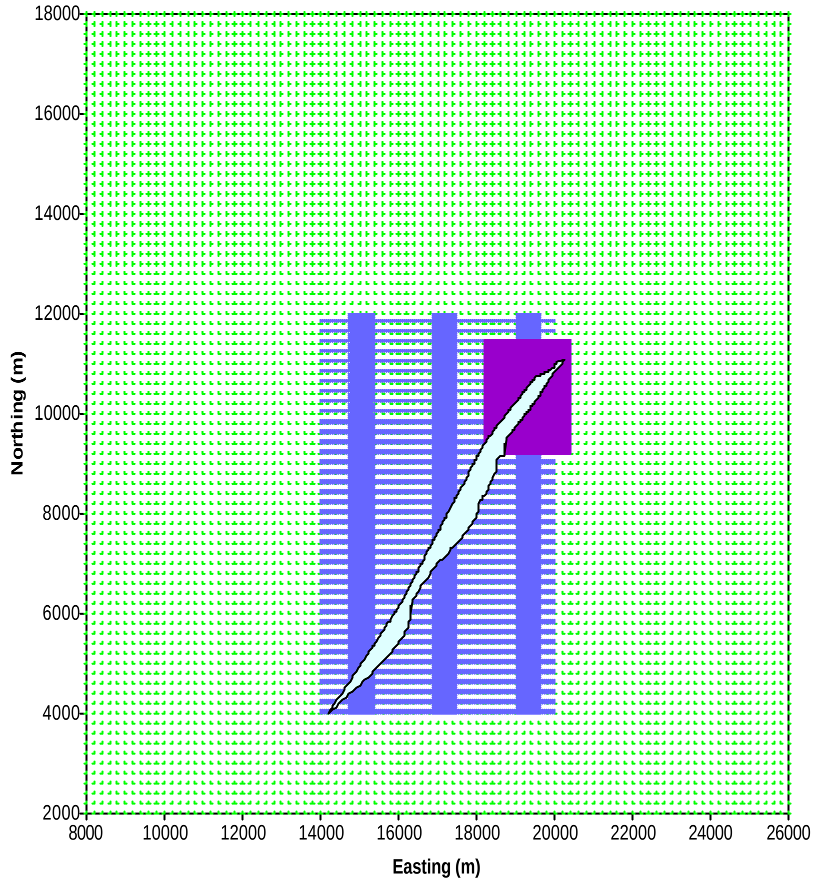
Meteorological data should be selected on the basis of spatial and temporal representativeness. The spatial representativeness of the data is dependent upon the proximity of meteorological monitoring site to the facility location. The temporal representativeness of the data is a function of the yearly variations in weather conditions. The ARB air quality monitoring (AQM) station at Roseville is within one mile of the Yard. The most recent year of meteorological data for this site is 1999. Although the use of five years of meteorological data is strongly recommended by U.S. EPA and CARB, one year (1999) of representative meteorological data was thought to be sufficient based on an analysis of five years of data, which indicated that there were little variations between the years. Even though the ARB AQM station at Roseville is near the Yard, it has limitations. The wind speed collected at this station is a vector averaged wind speed. U.S. EPA Guidelines specify scalar winds speeds should be used for Gaussian plume modeling. Scalar average winds are generally greater than vector averaged winds and as a result, there may be a bias in the estimated concentrations.

Because of the limitation in the Roseville AQM meteorological data discussed above, the meteorological data for 1996 from McClellan AFB was also selected and used as a sensitivity study. McClellan AFB is about 10 miles southwest of the Yard. Although further from the Yard than the Roseville AQM data, the McClellan AFB data are scalar averaged wind speeds. The detailed procedures of meteorological data preparation and the QA/QC are presented in Appendix F. The statistically analysis and windrose plots for the meteorological data are also presented in Appendix F.

E. Model Receptors

Receptors are the locations where concentrations are estimated by the model. A Cartesian grid receptor network is used in this study where an array of points are identified by their x (east-west) and y (north-south) coordinates. This network is convenient to identify the emission sources within the Yard with respect to the receptors in the nearby residential areas. Initial screening analyses indicate that higher off-site potential cancer risks should be located adjacent to the *Service Area* (or Area 3 which includes the *Staging Tracks*, *Service Tracks*, *Mod/Search Building*, *Maintenance Shop*, and *Ready Tracks*). To better define concentrations in this area, a fine grid receptor network of 20m x 20m is used in the modeling domain of 1km x 1km surrounding the *Maintenance Shop Area*. A medium grid receptor network of 50m x 50m is selected for the modeling domain of 6km (easting) x 8km (northing), which covers the whole Yard and the surrounding residential areas. A coarse receptor network of 200m x 200m is selected in the large modeling domain of 18km x 16 km, which covers the whole the City of Roseville and part of the County of Sacramento. Figure V.2 shows the grid receptor networks of fine (20m x 20m), medium (50m x 50m), and coarse (200m x 200m). Note that the receptors within the Yard are included in the network, but the risks from these on-site receptors are excluded from final risk analyses.[15] As stated above, all receptors are assumed to be at the same base elevation as the emission sources (i.e., flat terrain).

Figure V.2: Distribution of Receptors around the Yard [Black(Purple) for 20m x 20m, Dark Gray(Blue) for 50m x 50m, and Light Gray(Green) for 200m x 200m]



F. Building Wake Effects

If pollutant emissions are released at or below the "Good Engineering Practice" (GEP) height as defined by EPA Guidance (USEPA, 1985), the plume dispersion may be affected by surrounding facility buildings and structures. The aerodynamic wakes and eddies produced by the buildings or structures may cause pollutant emissions to be mixed more rapidly to the ground, causing elevated ground level concentrations. The ISCST3 model has the option to simulate the effects of building downwash. To do so,

[15] Due to the complexity of operations within the yard, a number of simplifying assumptions were made in preparing model inputs. For example, the emissions of moving locomotives were represented by emissions at a fixed location. For this study, such simplifications are intended to estimate off-site concentrations only.

"direction-specific" building dimensions for each emission point need to be input. The direction-specific building dimensions represent the building width perpendicular to the wind direction (PBW) along with the building height (BH), and they are prepared by the Building Profile Input Program (BPIP). The BPIP calculates 36 pairs of BH and PBW values for input to ISCST3 (USEPA, 1995c).

In this study, two types of building or structures are considered: locomotives and actual buildings in the *Mod/Search Building* and *Maintenance Shop Area*. For each locomotive, it is assumed that the stack is on top of the locomotive roof. It also is assumed that each locomotive has the same physical height, length, and width.

G. Model Inputs

ISCST3 requires four types of inputs: control, source, meteorological, and receptor. Control inputs are required to specify the global model options for the model run. The control options include dispersion coefficients (rural vs. urban), averaging time, pollutant type, exponential decay, terrain, and receptor elevations. The regulatory default option as described previously is also control input.

Source inputs require source identification and source type (stack, area, volume, or open pit). Each source type requires specific parameters to define the source. For example, the required inputs for a point source are emission rate, release height, exhaust exit temperature, exhaust exit velocity, and stack diameter. In addition, other parameters for building downwash, variable emission rates, dry and wet deposition can be specified.

The requirements for meteorological and receptor inputs have been discussed in the Meteorological Data and Model Receptors. Table V.1 lists the model options used in ISCST3. In order to generate the inputs for the large number of sources needed to simulate emissions at the Yard, several Fortran programs were developed.

Table V.1: Modeling Input Parameters and Description

Modeling Parameters	Values or Description
Model Used	ISCST3(Version 00101)
Source Type	Point and Volume
Dispersion Setting	Urban and Rural
Receptor Height	1.5 m
Stack Information*:	
Stack Diameter	Dependent upon locomotive type
Stack Height	Dependent upon locomotive type
Stack Exhaust Temperature	Dependent upon locomotive type and notch setting
Stack Exhaust Flow Rate	Dependent upon locomotive type and notch setting
Emission Rate	Dependent upon locomotive type, notch setting, location, and operation time
Time Emissions Emitted	24h/d with variable emission rate, 365d/y
Meteorological Data	Roseville (1999) and McClellan AFB (1996)
Release Height	Dependent upon source type, locomotive type, and operation time
Building Downwash	Yes for stack sources
Modeling Domain	1km x 1km, 6km x 8km, 18km x 16km

*Detailed stack information is provided in Appendix B.

H. Model Output Presentation

The concentrations of diesel PM estimated by the modeling are presented as 2-D isopleths and zone averages. The 2-D isopleths are used to display the plume ranges and to visualize the rate at which the diesel PM concentrations change with distance. Zoned average concentration is introduced to quantitatively determine concentrations in specific areas. The point of maximum impact (PMI) in the vicinity of the Yard (outside of the yard fence) was first identified and a series of circles with different radii $r_1,\ldots.,r_N$ centered at the PMI was drawn. The zoned average concentration located between r_1 and r_2 is calculated as the follows:

$$Zoned\ average\ concentration = \frac{\sum_{i=1}^{N} R_i A_i}{\sum_{i=1}^{N} A_i} \qquad (1)$$

where R_i is the diesel PM concentration in the grid cell i in the ring-shaped region defined by $r_1 < r < r_2$, and A_i is the corresponding area, N is the number of grid cells in the ring-shaped region of $r_1 < r < r_2$. The N varies and increases with radium r. Note that the concentrations of diesel PM within the Yard are omitted from the zone average. This was done to minimize modeling artifacts because in certain cases the distance between the receptor and the assumed source location have been simplified.

I. Uncertainty and Sensitivity Analysis

There are two kinds of uncertainties: inherent and reducible. Inherent uncertainty is caused by the model's (e.g., ISCST3) inability to accurately simulate a complex wind flow field. Air dispersion models simulate pollutant transport in the air with known conditions that are input to the models (e.g., wind speed, mixing height, and emission release characteristics). However, there are variations in the transport, such as the turbulent flow in the air, which are not simulated by the models. As a result, deviations in pollutant concentrations estimated by the models may occur. Nevertheless, inherent uncertainty is beyond our study scope. Reducible uncertainty is a result of uncertainties in the input values of the known conditions, which include source characteristics (emissions, stack parameters, etc.) and meteorological inputs.

Uncertainties of emission estimates may be attributed to many factors such as locomotive engine type, throttle setting, level of maintenance, operation time, and emission factor estimates. Evaluating individual uncertainties is difficult and may in itself introduce new uncertainties. We conducted sensitivity studies to evaluate how the uncertainty of model input parameters affect the estimated concentrations. The sensitivity studies are conducted by considering variations in the following parameters:

emission rate, stack exhaust temperature, stack exhaust velocity, meteorological data selection, and dispersion coefficient selection. The ranges of the parameters for the sensitivity studies are defined as follows:

Emission rate:	Base case ± 20%
Stack exhaust temperature:	Base case ± 50K
Stack exhaust velocity:	Base case ± 50%
Meteorological data:	Roseville and McClellan AFB
Dispersion coefficient:	Rural vs. Urban

The impacts of these variables on the resultant concentrations and exposures are discussed in Chapter VI.

VI. EXPOSURE ASSESSMENT OF J. R. DAVIS YARD

In this chapter, we briefly describe the Office of Environmental Health Hazard Assessment (OEHHA) guidelines on health hazard risk assessment and how we used the guidelines to characterize potential cancer risks associated with exposure to diesel exhaust from the Yard. We also present detailed air dispersion modeling results for the Yard and discuss the results from sensitivity studies conducted to provide perspective on the uncertainties in the modeling results.

A. OEHHA Guidelines

The Air Toxics Hot Spots Program Risk Assessment Guidelines: The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments (OEHHA guidelines) published as a final draft by OEHHA in 2003[16], (OEHHA 2002a and ARB 2003) outlines a tiered approach to risk assessment, providing risk assessors with flexibility and allowing for consideration of site-specific differences. Tier 1 is a standard point-estimate approach that uses a combination of the average and high-end point-estimates. Tier 2 utilizes site-specific information for risk assessment when site-specific information is available and is more representative than the Tier 1 point-estimates. Tier 3 is a stochastic approach for exposure assessment when the data distribution is available. Tier 4 is also a stochastic approach but allows for utilization of site-specific data distribution.

The OEHHA guidelines require that all health hazard risk assessments use Tier 1 evaluation for the Hot Spots Program. For Tier 1, OEHHA recommends that two values, one representing an average and another representing a defined high-end value, be used for key exposure pathways (e.g., breathing rate). The average and high-end of point-estimates are defined in terms of the probability distribution of values for that variate. The mean (65^{th} percentile) represents the average values for point-estimates and the high end (95^{th} percentile) represents the high-end values for point-estimates from the distribution identified in OEHHA (2000).[17] In addition to using an estimate of average and high-end consumption rates, potential cancer risk evaluations for 9, 30, and 70-year exposure durations can be utilized. Nevertheless, all hazard risk assessments must, at a minimum, present the potential risks based on a 70-year exposure.

B. Exposure Assessment

Exposure assessment is a comprehensive process that integrates and evaluates many variables. Three variables can have significant impacts on the results of a health risk assessment – emissions, meteorological conditions, and human exposure information. The emissions affect the risk levels linearly, as emissions increase so does the risk.

[16] The final guidelines were augmented on October 9, 2003 with the "Air Resources Board Recommended Interim Risk Management Policy for Inhalation-Based Residential Cancer Risk."

[17] The 65^{th} percentile breathing rate is 271 L/kg-day and the 95^{th} percentile breathing rate is 393 L/kg-day, which differ by approximately 30 percent.

Meteorological conditions can have a large impact on the resultant ambient concentration of toxic pollutant with higher concentrations found along the predominant wind direction and under calm wind conditions. The key variables in human exposure are a person's proximity to the emission plume, how long he or she breathes the emissions (exposure duration), the person's breathing rate, and body weight. The longer the exposure time, the greater the potential risk.

To examine the potential cancer risks associated with exposure to diesel exhaust emissions from locomotive activities in the J. R. Davis Yard, we used the Tier-1 methodology presented in the OEHHA guidelines. The OEHHA guidelines, and this assessment, use health and exposure assessment information that is contained in the Air Toxics Hot Spot Program Risk Assessment Guidelines, Part II, Technical Support Document for Describing Available Cancer Potency Factors (OEHHA 2002b); and the Air Toxics Hot Spot Program Risk Assessment Guidelines, Part IV, Technical Support Document for Exposure Analysis and Stochastic Analysis (OEHHA 2000). We assumed nearby residents would be exposed to diesel exhaust PM for 70 years. The potential cancer risk is estimated by multiplying the inhalation dose by the cancer potency factor (CPF) of diesel PM (1.1 $(mg/kg\text{-}d)^{-1}$). Additional details on the risk characterization are provided in Appendix I.

C. Risk Characterization

Risk characterization is defined as the process of producing a quantitative estimate of risk, including a discussion of its uncertainty. The risk characterization process integrates the results of air dispersion modeling and relevant toxicity data (i.e., diesel exhaust PM Cancer Potential Factor) to estimate potential cancer or noncancer health effects associated with contaminant exposure.

For this study, exposures are assumed to occur through the inhalation pathway only. The potential cancer risks are characterized based on the 80^{th}, mean (65^{th}) and 95^{th} percentile breathing rates. Noncancer chronic health effects are not evaluated in this study because inhalation cancer risk due to diesel exhaust emissions from the Yard outweighs the noncancer chronic health impacts from diesel PM. Currently, there is no acute reference exposure level to quantify the (short-term) one-hour health impacts. Diesel PM risk is evaluated by the inhalation pathway only. There is not an oral slope factor to assess the risk from pathways other than inhalation. It is important to note that no background or ambient diesel PM concentrations are incorporated into the risk quantification. In the following sections, we present predicted cancer risk levels using two different meteorological data sets and dispersion coefficients.

To characterize the risk, three modeling domains were used in this modeling exercise: fine (1km x 1km, or 0.6mi x 0.6mi with a resolution of 20m X 20 m), medium (6km x 8km, or 4mi x 5mi with a resolution of 50m X 50m), and coarse (18km x 16km, or 11mi x 10mi with a resolution of 200m X 200m). The risks are presented graphically as 2-D isopleths and zoned averages.[18] The 2-D isopleth contours were used to display the

[18] As discussed in Chapter V, for this risk assessment, the concept of zoned average risk was introduced to help portray the risk from the Yard. Zoned average risk represents the average risk in a given area, in

risk's plume ranges with distances in all wind directions. This approach is a deviation from the traditional approach of focusing on cancer risk at the point of maximum impact or at the maximum exposed individual. Staff elected to use this alternative approach due to the complexity of the modeling, the need for numerous simplifying assumptions, and the uncertainties with respect to the location of emission sources (the exact location of idling locomotives is often unknown). We also provide a discussion on the relationship of risk with downwind distance, and the temporal and spatial effects of risks associated with activities in the Yard.

1. Estimated Exposures[19]

The potential cancer risk from the estimated emissions of diesel PM at the Yard were calculated using two meteorological data sets (Roseville and McClellan) and for both urban and rural dispersion characteristics.[20] Figures VI.1a and b present the potential risk for the two meteorological data sets using the rural dispersion coefficient. Staff believes that the rural dispersion characteristics are most appropriate for predicting the area-wide impacts i.e. those impacts further away from the yard, and the urban dispersion characteristics are most appropriate for predicting the near source impacts from the Yard.

For simplicity, only the isopleth for 10 in a million potential cancer risk is shown in each figure. In Figure VI.1a the solid line represents the 10 in a million cancer risk isopleth using the Roseville meteorological data and in figure VI.1b the dashed line represents the 10 in a million cancer risk isopleth using the McClellan meteorological data. Inside the isopleth the potential cancer risk is estimated to be greater than 10 in a million. Outside the line the potential cancer risk is estimated to be less than 10 in a million. As can be seen in the figure, the area within which the risks exceed the district's significant risk threshold of 10 in a million is very large, extending about 8-10 miles in the North-South direction.

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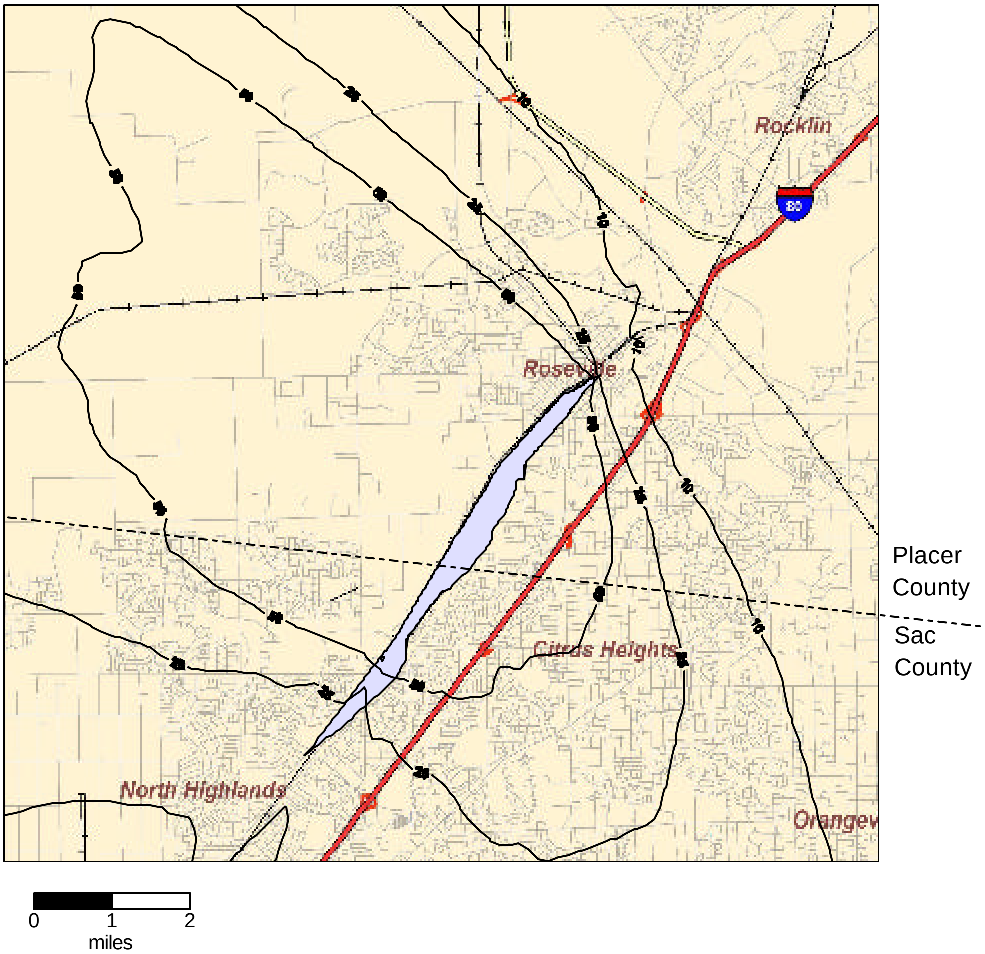
this case, concentric rings were drawn around the point of maximum impact in the outside of the yard fence and the risk within the rings were averaged to generate a "zoned average concentration."

[19] The results based on the 80th percentile breathing rates are presenting in this subsection and those for the mean and 95th percentile breathing rates are provided in Appendix H.

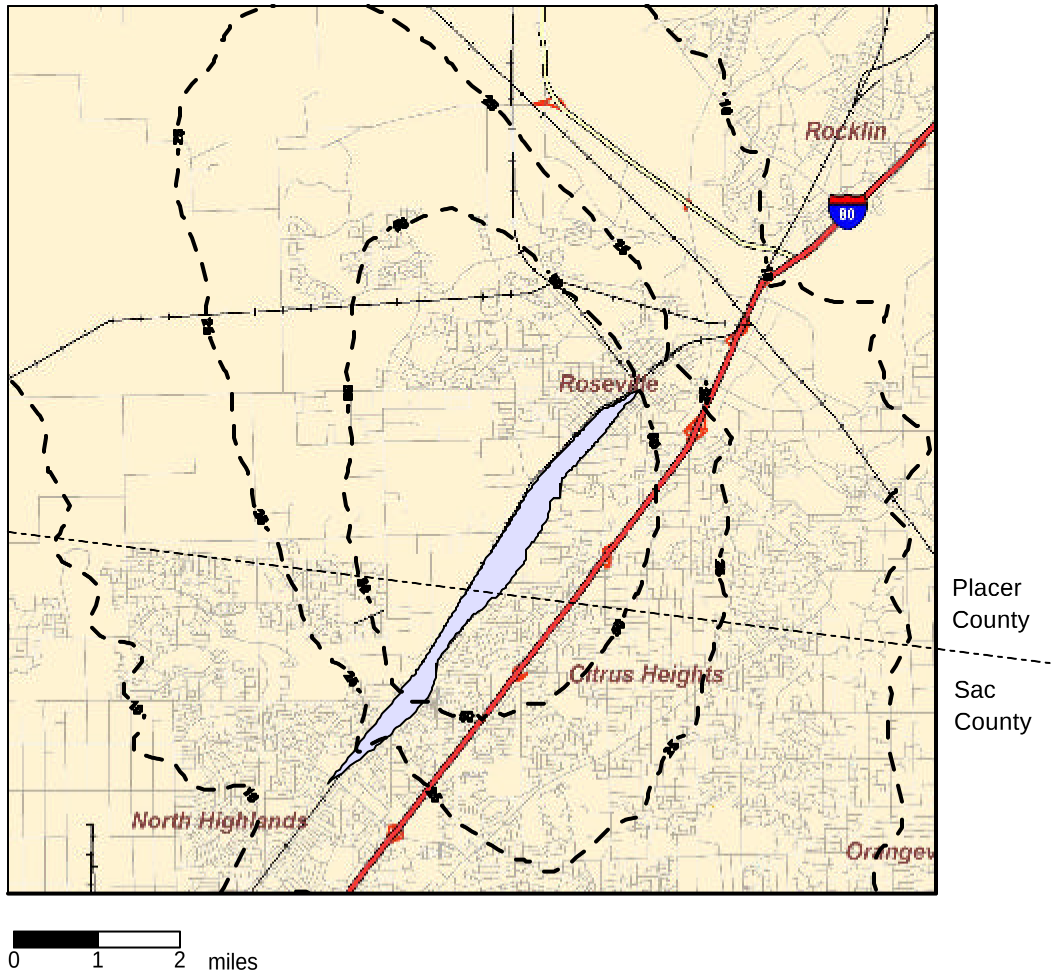
[20] Dispersion coefficients are used in air dispersion models to reflect the land use (rural or urban) over which the pollutants are transported. The rural dispersion coefficient generally results in wider dispersion of the pollutant hence a larger "footprint" whereas an urban coefficient results in less dispersion of the pollutant and a smaller footprint. Because the area around the Yard contained both urban and rural land use types, the model was run with both dispersion coefficients.

Figure VI.1a: Estimated Cancer Risk from the Yard Using Roseville Met Data (10, 25, and 50 in a million isopleths)



Note: Roseville Meteorological Data, Rural Dispersion Coefficients, 80th Percentile Breathing Rate, All Locomotives' Activities [23 TPY], 70-Year Exposure

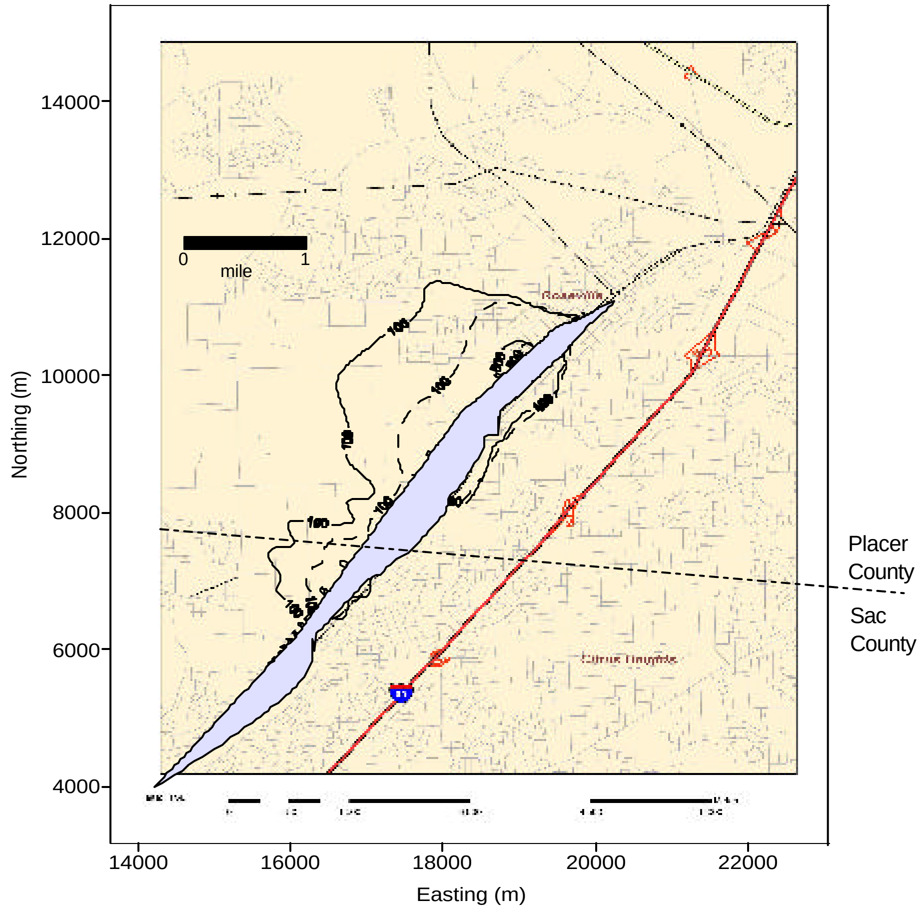
Figure VI.1b: Estimated Cancer Risk from the Yard Using McClellan Met Data (10, 25, and 50 in a million isopleths)



Note: McClellan Meteorological Data, Rural Dispersion Coefficients, 80th Percentile Breathing Rate, All Locomotives' Activities [23 TPY], 70-Year Exposure

Figure VI.2 presents the 100 and 500 in a million cancer risks contour lines (isopleth) for the two meteorological sets (Roseville and McClellan) using the urban dispersion characteristics. Staff believes that the urban dispersion characteristics are most appropriate for predicting the near source impacts from the Yard. The solid line represents the 100 and 500 in a million cancer risk isopleths using the Roseville meteorological data. The dashed line represents the 100 and 500 in a million cancer risk isopleths using the McClellan meteorological data. The area inside the isopleth has potential cancer risks estimated to be greater than 100 or 500 in a million.

Figure VI.2: Estimated Cancer Risk from the Yard (100 and 500 in a million risk isopleths)



Notes: 100/Million Contours: Solid Line – Roseville Met Data; Dashed Line – McClellan Met Data, Urban Coefficients, 80th Percentile Breathing Rate, All Locomotives' Activities [23 TPY], 70-Year Exposure

As can be seen by these figures, the magnitude and the extent (size of area) of the predicted cancer risk levels are highly dependent on the meteorological data selected, and the use of urban or rural dispersion coefficients. However, in either case the potential cancer risk level is significant. Additional details for the isopleths are provided in Table VI.1. As is shown, a very large area, between 47,500 and 55,500 acres have predicted concentrations of diesel PM that result in a risk of greater than or equal to 10 in a million, the District's threshold for significant risk. About 9,000 acres have PM concentrations that result in risks between 10 and 100 in a million, about 700-1,600 acres have risks between 100 and 500 in a million, and approximately 10-40 acres could have risks of greater than 500 in a million[21].

[21] Modeling inputs placing idling emissions at specific locations (e.g., at the west end of the Departure Yard), may cause modeling artifacts that are not representative of actual conditions. Such artifacts appear as high estimated concentrations in localized areas near the Yard boundary that is less than 100m across. Since such idling emissions actually occur at locations along a longer section of the track, the peak off-site concentrations may be lower.

Table VI.1 provides information on the average risk with the three risk zones based on two exposure durations as well as the number of acres in each of the risk zones. For example, in the ≥ 100 and < 500 risk zone (see Figure VI.2) the average cancer risk in that area is 170 in a million assuming a 70-year exposure duration and 73 in a million assuming a 30 year exposure duration. The number of acres estimate to be in this risk zone is in the last column is 1600.

It should be noted that the 70-year exposure duration is recommended in the OEHHA guidelines for a Tier 1 evaluation. A 70-year exposure ensures a conservative risk estimate is predicted and is a "historical benchmark for comparing facility impacts on receptors and for evaluating the effectiveness of air pollution control measures." The OEHHA guidelines also provide that a 30-year exposure duration may also be evaluated as supplemental information to show the range of cancer risk based on different residency periods. However, the OEHHA guidelines also caution that as the exposure duration decreases the uncertainties can increase since the cancer potency factors are derived from long term studies (OEHHA 2002a).

Table VI.1: Summary of Average Risk by Risk Zone and Acres Impacted

Meteoro-logical Data Source	**Risk Zone Based on Figures VI.1 and VI.2a and b Isopleth Boundaries** (70 Year Exposure)	Dispersion Characteristic	Average Risk Estimated Based on Years Exposed		Acres Impacted (rounded)
			70 years	30 years	
Roseville	Risk ≥ 500	Urban	645	275	40
	Risk ≥ 100 and < 500	Urban	170	73	1,600
	Risk ≥ 10 and < 100	Rural	40	17	45,900
	Total				47,500
McClellan					
	Risk ≥ 500	Urban	630	270	10
	Risk ≥ 100 and < 500	Urban	156	67	700
	Risk ≥ 10 and < 100	Rural	28	12	55,500
	Total				56,200

Notes: Model domain for rural dispersion coefficient is 16km x 18 km with a resolution of 200m x 200m. For the urban dispersion coefficient the model domain is 6km x 8 km with a resolution of 50m x 50m. The 80th percentile breathing rate for adults was used.

The OEHHA guidelines require that for health risk assessments, the cancer risk for the maximum exposed individual or at the point of maximum impact (PMI) be reported. The PMI is the offsite location closest to the emission source that shows the highest modeled concentration of diesel PM, or highest risk. The maximum off-site diesel PM cancer risks from the Yard range from 900 to 1,000 in a million based on the urban dispersion, 80th percentile breathing rate, and 70 years of exposure. The location of the PMI varies, depending upon the meteorological data set (McClellan or Roseville), air dispersion coefficients (urban or. rural) and how the emissions are allocated in the Yard.

The estimated concentrations of diesel PM due to emissions from the Yard are in addition to regional background levels of diesel PM. Although emissions from the Yard also contribute to the regional background, the measurable effect should be small. The regional background risk due to diesel PM emissions has been estimated to be 360 per million for the entire Sacramento Valley in the year 2000. In those areas around the Yard, the potential risks can be significantly above the regional background levels. For example, within the ≥ 500 Roseville risk zone, the average risk is 645 in a million due to emissions only from the Yard. Taking into consideration both the regional background emissions and the Yard impacts, residents living in that area would have a potential cancer risk over 1,000 (645 per million due to Yard emissions and 360 per million for regional background). (ARB 2004).

2. Variation of Diesel PM Concentration with Time of Day

Since meteorological conditions and emissions vary with time, the hourly contributions to annual average diesel PM concentration exhibit diurnal and seasonal patterns. Figures VI.3 (a & b) present the diurnal contributions to the concentrations over a year with different receptor distances in the predominant wind direction for Roseville meteorological data with rural and urban dispersion coefficients, respectively. The receptors used in the Figures VI.3 (a & b) are selected in the predominant wind direction at the distances of 200, 500, 1000, and 5000 meters from the Yard boundary near the *Service Area*. Although the hourly emission profile does not show much variation over a period of 24 hours (see Chapter IV, Section B), the hourly contribution to annual average concentration exhibit strong diurnal effects and the effects are greater closer to the Yard boundary.

Figure VI.4 shows the bimodal contribution to the concentration for daytime (6am to 6pm) and night-time (6pm to 6am) emissions as a function of downwind distance. As seen in Figure VI.4, the contribution to the concentration for receptors, kilometers away is greatest for nighttime conditions. This phenomenon is not surprising because the vertical dispersion is relatively strong during the daytime due to warming of the ground by the sunlight and causes unstable atmospheric conditions. In addition, a sensitivity study (the results not shown here) indicated that there is greater plume rise and as a result the PMI is located further downwind during the nighttime conditions. This condition helps us to better understand why the risk does not decrease as rapidly with distance from the source as with other conventional sources such as a freeway for example. In the freeway example, the diurnal emissions reduce the contribution to annual average from nighttime situations.

The monthly contribution to the concentration is shown in Figure VI.5 for various downwind receptor distances. The summer season has higher contributions to annual average, predominantly for shorter receptor distances. This is likely due to the longer daylight hours during the summer time, which results in more unstable atmospheric condition due to solar radiation. This in turn results in less plume buoyancy. Temporal annual average diesel PM concentration variations for McClellan AFB meteorological data exhibit the similar patterns and can be found in Appendix H (see Figures H5-H8).

Figure VI.3a: Diurnal Contribution to Annual Avg. Conc. Vs. Receptor Distance (Annual Average: 1.74 mg/m^3 at 200m, 1.18 mg/m^3 at 500m, 0.80 mg/m^3 at 1km, and 0.25 mg/m^3 at 5km. Roseville Met Data, Rural Dispersion Coefficient)

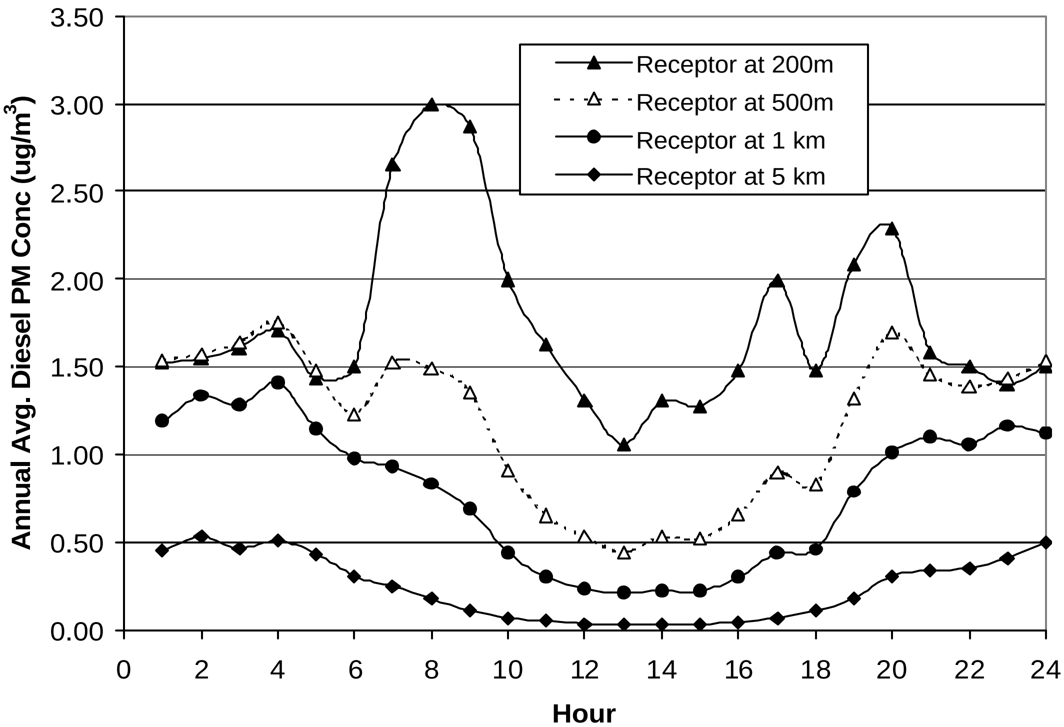


Figure VI.3b: Diurnal Contribution to Annual Average Conc. vs. Receptor Distance (Annual Average: 1.55 mg/m^3 at 200m, 0.80 mg/m^3 at 500m, 0.40 mg/m^3 at 1km, and 0.09 mg/m^3 at 5km. Roseville Met Data, Urban Dispersion Coefficient)

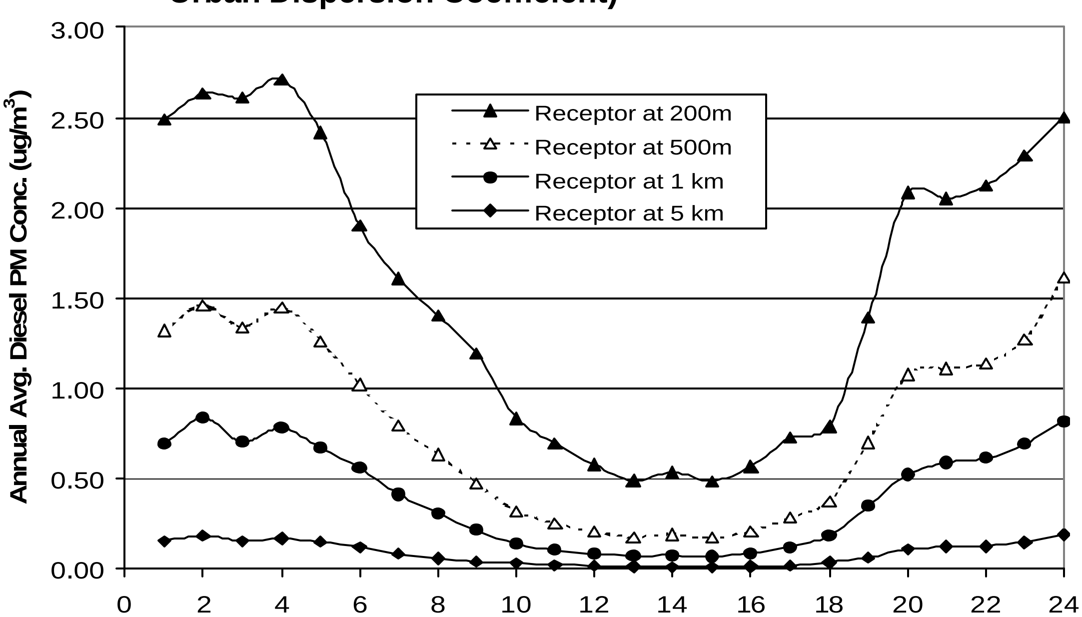


Figure VI.4: Contribution to Annual Avg. Conc. (%) from Day Time (6am – 6pm) and Night Time (6pm – 6am) Emissions vs. Receptor Distance (Roseville Meteorological Data (1999))

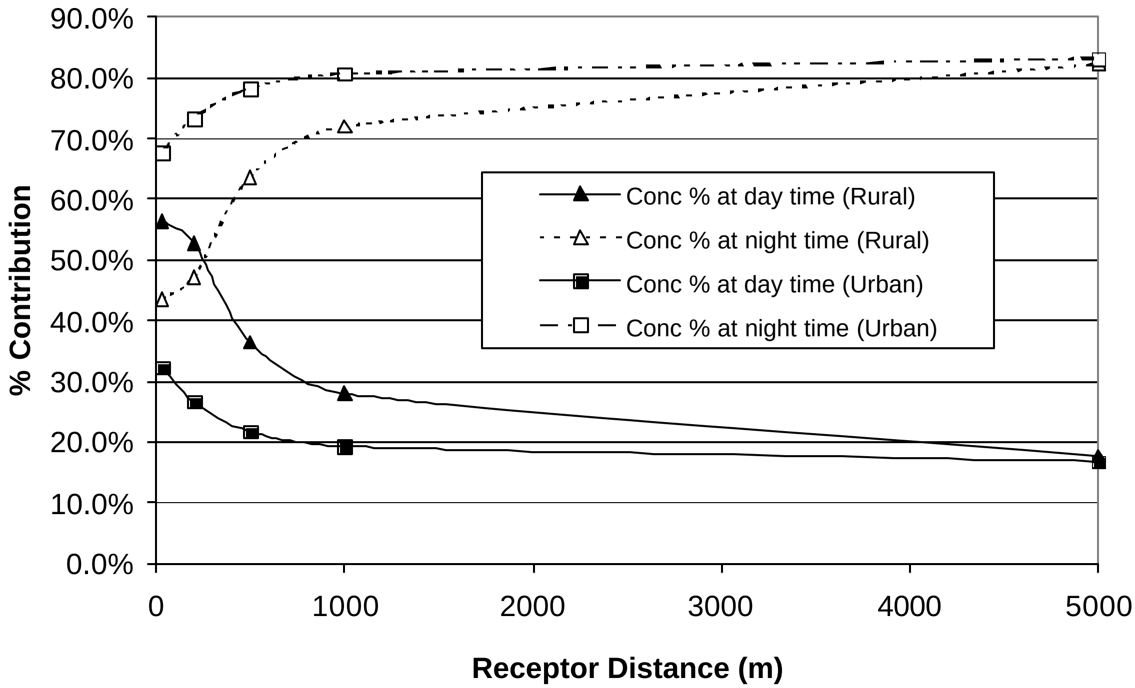


Figure VI.5a: Monthly Contribution to Conc. for Various Receptor Distances (Roseville Meteorological Data, Rural Dispersion Coefficient)

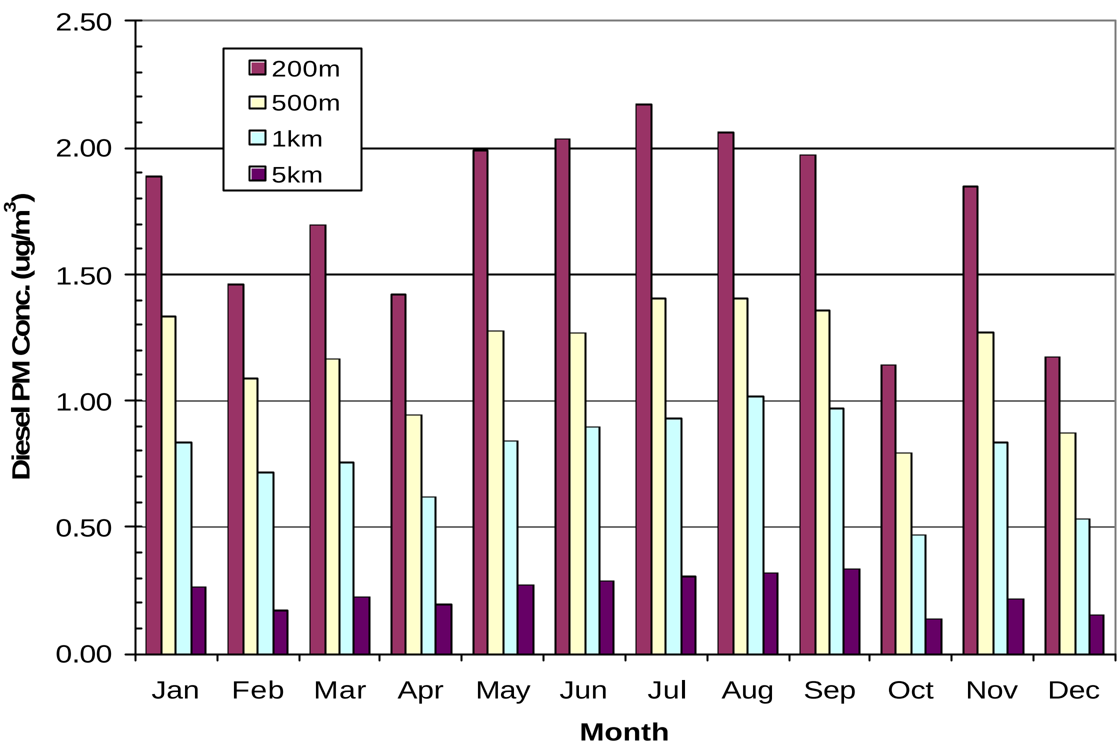
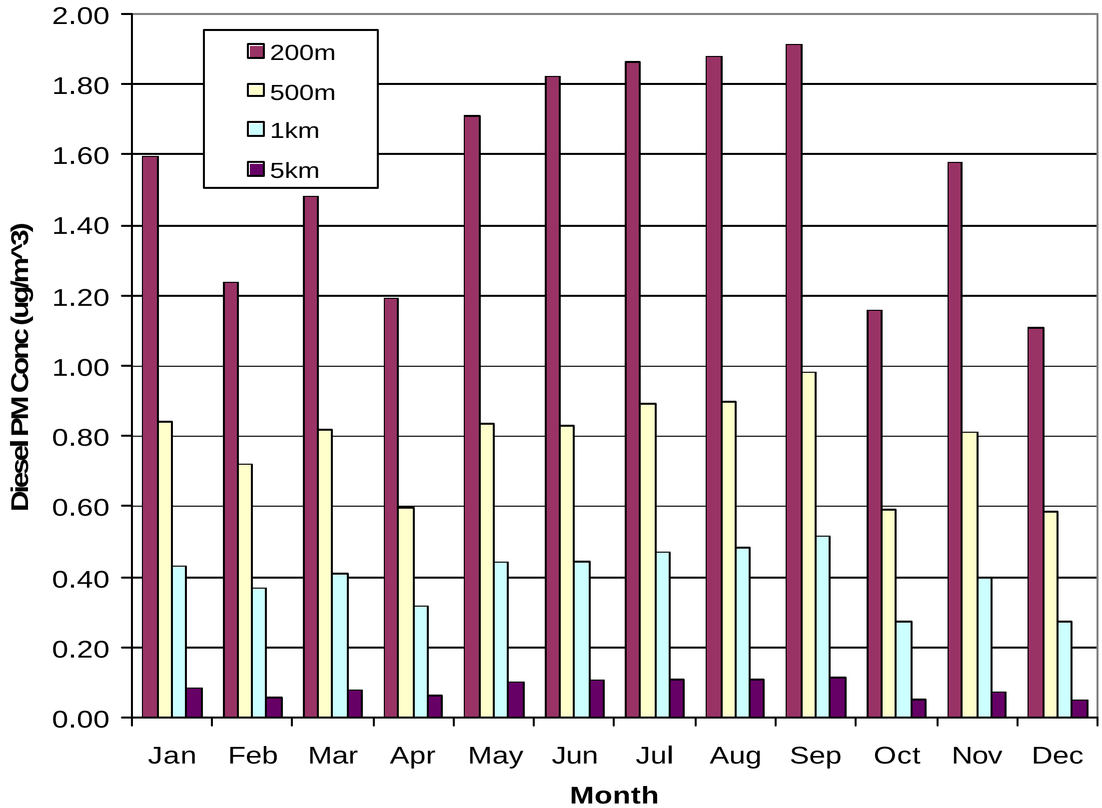


Figure VI.5b: Monthly Contribution to Conc. for Various Receptor Distances (Roseville Meteorological Data, Urban Dispersion Coefficient)



3. Risk Associated with Movement and Idling Activity

In this section we take a closer look at the impacts associated with two types of sources within the Yard, movement activity and idling activity. As stated in Chapter III, there are three kinds of activities in the Yard: movement, idling, and testing. The emissions for these activities are approximately 10.3, 10.5, and 1.6 tons per year, respectively. For simplicity of discussion, we include the emissions of testing into the idling activity. The modeling results for the movement and idling activities are presented in Appendix H (see Figures H9 and H10).

Based on the analysis, there are two relatively small offsite areas where the estimated risk exceeds 500 cases in a million. The first is adjacent to the *Service Area* and the second is adjacent to the *Hump and Trim* area. It is possible that the 500 in a million estimates adjacent to the *Hump and Trim* operation are an artifact of how emissions from the *Ready Track* were modeled. However, without additional field observation and analysis, ARB staff cannot make a definitive finding. However, we do not believe that this additional work would significantly change the results or conclusions of the report.

4. Risk Associated with Individual Activities/Areas

As documented in Chapters III and IV, the locomotive activities occur in many areas of the Yard, e.g., the *Northside Tracks*, *Main Departure Yard*, *Main Receiving Yard*, *City Yard*, *Rockpile Yard*, *Subway*, *Service Area* (*Staging Tracks, Service Tracks, Mod/Search Building, Maintenance Shop and Ready Tracks*), and *the Hump and Trim Operations*. We conducted individual air dispersion modeling runs for all Diesel PM emissions resulting from locomotive activities in these areas. Each activity has a different contribution to the overall cancer cases per million (risks) attributed to emissions of diesel PM from locomotives within the Yard.

The greatest contribution to risks is due to emissions in the *Service Area*, where cancer risk levels are estimated to exceed 500 in a million in the residential area nearby the *Service Area* (see Figure H-11 in Appendix H). Three factors help explain these estimates:

1. Diesel PM emissions generated at the *Service Tracks* and *Ready Tracks* account for about 31 to 36 percent of the total diesel PM emissions within the Yard.
2. The areas where the emissions are generated within the *Service Area* are relatively small (concentrated source of emissions) and located close to the Yard boundary.
3. The predominant emissions activity in this area is idling, which results in localized areas of elevated concentration because of lower plume rise caused by lower exhaust temperature and lower exhaust exit velocity.

The second largest contributor to estimated risk is locomotive activity in *the Hump and Trim Operations* area, which account for about 29 to 32 percent of total diesel PM emissions emitted within the Yard. The offsite locations adjacent to the *Hump and Trim Operations* (Area 4) are predicted to have 70-year cancer risk levels exceeding 500 cases per million (see Figure H12 in Appendix H).

The emissions from departure yards and receiving yard, (Area 2), contribute to the third largest risk impact offsite. The risk greater than or equal to 100/million extends to about one mile in the downwind direction (see Figure H-13 in Appendix H). The total emissions from *Main Departure Yard* and *Main Receiving Yard* account for about 18 to 21percent of total diesel PM emitted within the Yard.

While a comparison of emissions (Chapter 4, Table IV.2) and the estimated risks associated with the three main contributors of emissions and risk (Areas 2, 3, and 4) are similar in magnitude, the potential health impacts are at different offsite areas and the modeling domains are different.

D. Uncertainty, Variability, and Model Sensitivity

To better understand the extent of uncertainty and variability in the modeling results, we conducted sensitivity studies using variable values for the modeling parameters, including modeling domain and resolution, emission rate, stack exhaust temperature and flow rate, meteorological data selection and dispersion coefficients, and building downwash. To reflect the uncertainties and variabilities, the modeling results are presented as spatial average range.

1. Modeling Domain and Resolution

As stated in the previously, three modeling domains are used in this modeling exercise: fine (1km x 1km, or 0.6mi x 0.6mi), medium (6km x 8km, or 4mi x 5mi), and coarse (18km x 16km, or 11mi x 10mi). The first domain (fine) is used to capture the levels of elevated concentration around the *Service Area* where there are the busiest activities. The second domain (medium) covered the whole Yard and nearby residential areas. The third domain (coarse) is utilized to include the estimated risk for in the whole City of Roseville and part of the County of Sacramento. Three modeling resolutions are used for the fine, medium and coarse domains: 20m x 20m, 50m x 50m, and 200m x 200m, respectively. The modeling domain average risks presented here for the purpose of comparing of variables only. Table VI.2 summarizes the effects of the modeling domain on the spatial average risks, Table VI.3 summarizes the effects of the modeling resolution on the spatial average risks. As expected, the smaller the modeling domain, the larger the spatial average risk. On the other hand, as the modeling resolution increases (moves from coarse to medium to fine), the spatial average risks are increased by less than 5 percent. The effect of modeling resolution on the spatial average risk is not significant.

Table VI.2: Effect of Modeling Domain on Spatial Averages

Met. Data	Disp. Option	Risk in Domain 1 (1km x 1km)	Risk in Domain 2 (4mi x 5mi)	Risk in Domain 3 (11mi x 10mi)
Roseville	Rural	360 – 530 (1.280)	110 – 160 (0.384)	40 – 55 (0.135)
Roseville	Urban	285 – 410 (1.000)	55 – 80 (0.191)	15 – 22 (0.053)
McClellan	Rural	300 – 430 (1.050)	80 – 115 (0.278)	27 – 40 (0.094)
McClellan	Urban	180 – 260 (0.625)	35 – 50 (0.123)	11 – 16 (0.039)

Note: (1) The values in the parenthesis are diesel PM concentrations, in $\mu g/m^3$, and
(2) The modeling resolutions for domain 1, domain 2 and domain 3 are 20m x 20m, 50m x 50m, and 200m x 200m, respectively.

Table VI-3. Effect of Modeling Resolutions on Spatial Average Risks in the Domain of 4mi x 5mi (Unit in Potential Cancer Cases per Million)

Met. Data	Disp. Option	Average Risk (50m x 50m)	Average Risk (200m x 200m)
Roseville	Rural	110 – 160 (0.384)	105 – 155 (0.374)
Roseville	Urban	54 – 79 (0.191)	52 – 75 (0.181)
McClellan	Rural	77 – 112 (0.270)	75 – 105 (0.254)
McClellan	Urban	35 – 50 (0.121)	33 – 48 (0.116)

Note: The values in the parenthesis are spatial averaged diesel PM concentrations, in $\mu g/m^3$.

2. Effects of Uncertainty in Diesel PM Emissions

Uncertainties of emission estimates can be attributed to many factors, which include variations in locomotive engine type, throttle setting, number of locomotives, operation time, and emission factor. Assessing or evaluating individual uncertainties is difficult and may itself introduce new uncertainties. From the perspective of modeling inputs, if locomotive engine's stack diameter, height, exhaust temperature, and exhaust velocity are fixed, uncertainties related to the factors mentioned above can be incorporated into a lumped modeling input parameter – emission rate.

As explicitly stated in the Gaussian plume dispersion equation, which is used for this analysis with ISCST3, the downwind concentration is linearly proportional to the emission rate. This means that uncertainty of the estimated concentrations resulting from uncertainty of emission rates can be estimated by linearly scaling the model outputs. For example, if the emission rate increases or decreases from the base case by 20 percent, the estimated risks due to emissions from the Yard can be scaled by 20 percent. Correspondingly, the spatial average risks in the fine modeling domain (4mi x 5mi) for base case $\pm$ 20% are about 130 – 190 and 90 - 130 cases per million, respectively, based on Roseville meteorological data with the rural dispersion coefficients and the 65th to 95th percentile breathing rate.

3. Effects of Stack Data

The stack data includes stack height, stack diameter, stack exhaust temperature, and stack exhaust exit velocity. The stack height and diameter are a function of locomotive type and they are considered to be constant. The stack exhaust temperature and exhaust exit velocity are a function of locomotive type and throttle setting. Generally speaking, the lower the exhaust temperature and the lower the exhaust exit velocity, the higher the estimated concentrations at downwind receptors. In order to investigate the sensitivity of the effects of exhaust temperature and exhaust velocity on the diesel PM concentrations and risks, we conducted four sensitivity studies. The modeling conditions, the spatial average risks, and the maximum diesel PM concentrations at the PMI are listed in Table VI.4.

Table VI.4: Effect of Exhaust Temperature and Velocity on Spatial Average Risks

Case	Variable	Spatial average risk and Diesel PM Concentration.	Compared with base case	Diesel PM Concentration at PMI μg/m^3	Compared with base case
Base	Base T, V	105 – 155 (0.372)	-	3.72	-
1	T-50K	123 – 179 (0.416)	+11.8 %	5.12	+37.6 %
2	T + 50K	104 – 151 (0.351)	-5.6 %	3.14	-15.6 %
3	V – 50%	130 – 189 (0.440)	+18.2 %	4.74	+27.4 %
4	V + 50%	96 – 139 (0.323)	-13.1 %	3.00	-19.3 %

Note: (1) Roseville meteorological data with rural dispersion coefficients is used,
(2) The modeling domain = 4mi x 5mi and modeling resolution = 200m x 200m, and
(3) T = exhaust temperature, V = exhaust velocity, Q = emission rate.
(4) Diesel PM concentrations and locations of PMIs are a function of stack exhaust temperature and velocity.

As expected, when we reduce the exhaust temperature or exhaust velocity (cases 1 and 3), the estimated diesel PM concentration and risks increases. Conversely, the reverse is true when the exhaust temperature or velocity increases. In addition, variation in stack temperatures and velocity can affect the location of the PMI. The effects of changing exhaust temperature and exhaust velocity on the concentration of diesel PM at the PMIs are the same as the spatial average diesel PM concentrations or risks. Nevertheless, changing exhaust temperature and velocity has a greater effect on the diesel PM concentration and risks at the PMI than on the spatial average risks. In other words, stack exhaust data poses more effects on the nearby receptors than on the far-away receptors in the predominant downwind direction.

4. Effects of Meteorological Data

The modeling results using Roseville and McClellan AFB meteorological data have been presented and discussed in Section C of this chapter. The general finding is that the estimated risks based on the McClellan AFB meteorological data show lower spatial average risks and has relatively steep slope of risk change with the downwind distance. The spatial average risk within the fine modeling domain (1km x 1km) is about 430 potential cancer cases per million, which is lower than that based on the Roseville meteorological data (530 cases per million), based on 95th percentile breathing rate and the rural dispersion coefficients. For the modeling domain of 4mi x 5mi, the spatial average risk based on the McClellan AFB meteorological data is about 110 cases per million, which is lower than the risk based on the Roseville meteorological data (160 cases per million) for the same modeling domain.

Intuitively this makes sense because the annual average wind speed from the Roseville meteorological data is lower than the average speed from the McClellan AFB. Based on the Gaussian model formulation, the downwind concentration is inversely proportional to the wind speed. The annual average wind speeds for the Roseville and McClellan AFB meteorological data sets are 2.39 and 3.52 m/s, respectively.

The dispersion coefficients have a significant effect on risks. The proper selection of dispersion coefficients is difficult for this analysis. As we can see from Table VI.2, the rural dispersion coefficients produce about a 28 percent greater spatial average risk than the urban dispersion coefficient in the fine domain (1km x 1km). By selecting both urban and rural dispersion coefficients and evaluating the results for both, we can bracket the appropriate dispersion conditions in the modeling domain.

5. Effect of Building Downwash

The sensitivity study on building downwash indicated (data not shown) that the buildings located in the Diesel Shop area do not have significant effect on the spatial average risk (less than 1 percent). The effect of building downwash resulting from the locomotive dimensions on the spatial average risks is about 10 percent based on Roseville meteorological data with the rural dispersion coefficients in the modeling domain of 4mi x 5mi.

E. Summary of Modeling Results

The estimated offsite diesel PM concentrations and associated potential cancer risk due to locomotive activities at the J.R. Davis Yard in Roseville are significant. The magnitude and the extent (size of area) of the predicted cancer risk levels are highly dependent on the meteorological data selected, and the use of urban or rural dispersion coefficients.

We conducted four base-case modeling simulations, i.e., Roseville and McClellan AFB meteorological data coupled with rural and urban dispersion coefficients. Computer modeling predicts potential cancer risks greater than 500 in a million (based on 70 years of exposure) northwest of the *Service Track* area and the *Hump and Trim* area. The area impacted is between 10 to 40 acres. Potential cancer risk and the number of acres impacted for several risk ranges are as follows:

- Risk levels between 100 and 500 in a million occur over about 700 to 1,600 acres in which about 14,000 to 26,000 people live.
- Risk levels between 10 and 100 in a million occur over a 46,000 to 56,000 acre area in which about 140,000 to 155,000 people live.

The magnitude of the risk, the general location of the risk, and the size of the area impacted varies depending on the meteorological data (Roseville or McClellan), the dispersion characteristics (urban or rural), the assumed exposure duration (70 or 30 years) and the breathing rate (95^{th}, 80^{th}, and 65^{th} percentile).

Even though hourly emissions from locomotive activities in the Yard did not have much variation, the simulated risks exhibit strong temporal pattern. The daytime (6am to 6pm) activity contributes most to risks at nearby receptors. The nighttime (6pm to 6am) activity contributes most to risk for the far-away receptors. For seasonal variations of the risks, the summer season contributes most for receptors nearest the Yard.

Diesel PM emissions from the Yard are split between idling (including load testing) and movement approximately, 12 tpy and 10 tpy, respectively. Individually, idling emissions contribute most to offsite risks for receptors near the *Service Area* (Area 3) and receptors near the *Hump and Trim Operations* (Area 4). Estimated risks attributed to emissions from movement are distributed to receptors near the boundary throughout the whole Yard and therefore have less of a “hot spot” impact.

The simulated risks also exhibit spatial variations. Among the twelve activity areas within the Yard, it is estimated that *Service Area* contributes the most to the estimated risk for residential receptors near the Yard. The *Hump and Trim Operations*, *and Departure* and *Receiving Yards* (*Main Receiving* and *Departure Yards*, *City Yard*, *Rockpile Yard*, and idling in *Subway*) are identified as the second and third largest contributors to the estimated cancer risks to the nearby residential receptors.

The model sensitivity to various modeling input parameters, including diesel PM emission rate, exhaust temperature, exhaust flow rate, meteorological data selection, dispersion coefficient selection, and building downwash, were investigated.

Uncertainty and variability of emission estimates are a direct result of many factors, such as locomotive engine type, throttle setting, operation schedule, and emission factor. The uncertainty in the emission rate is linearly related to the concentration and subsequently, the risk.

The lower the exhaust temperature and stack exhaust velocity, the higher the risk. For the modeling domain of 4mi x 5mi and Roseville meteorological data with rural dispersion coefficients, if the exhaust temperature is decreased by 50 Kelvin or increased by 50 Kelvin, the domain spatial average risk is increased by 10 percent or decreased by 5 percent, respectively. Similarly, if the stack exhaust velocity is decreased by 50 percent or increased by 50 percent, the corresponding domain spatial average risk would increase by 18 percent or decrease by 13 percent, respectively.

The selection of meteorological data and choice of dispersion coefficients effect the estimated concentrations and risk. For the modeling domain of 4mi x 5mi, the spatial average risk resulting from the most conservative selection (Roseville meteorological data with rural dispersion coefficients) is about three times higher than that resulting from the most dispersive selection (McClellan AFB meteorological data with urban dispersion coefficients). Since the most ideal choice of meteorological conditions are not available, the above selections are believed to bracket the most ideal selections.

The effect of building downwash from the buildings in the *Service Area* on the spatial average risk is negligible (less than 1 percent). Including downwash effects due to the dimensions of the locomotives increases the spatial average risk by about 10 percent for the Roseville meteorological data with rural dispersion coefficients in the modeling domain of 4mi x 5mi.

The sensitivity studies are useful to evaluate the effects of uncertainties and variabilities in the model inputs on the estimated downwind concentrations, and subsequently risks. The modeling techniques used to evaluate downwind concentrations of diesel PM emissions are based on the best available information and following OEHHA Risk Assessment guidelines. Where uncertainties arise, sensitivity studies are used to establish a range of possible downwind concentrations. To derive more refined estimates of potential risk, more site-specific data may be used.

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