Assessment and Mitigation of Air Pollutant Health Effects from Intra-urban Roadways: Guidance for Land Use Planning and Environmental Review

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I OVERVIEW – PREVENTING ROADWAY AIR QUALITY HAZARDS

Motor vehicles have been and will remain a major source of air pollution in the United States. While air pollutant emissions from motor vehicles are monitored and regulated on a regional basis, roadway air pollutant emissions vary significantly within a place or city meaning exposure is higher for those living near freeways and busy roadways.

Health research has consistently demonstrated that children living within 100-200 meters of freeways or busy roadways have poorer lung function and more asthma and respiratory symptoms than those living further away. Health effects, both chronic and acute, may result from exposure to both criteria air pollutants and mobile source air toxic. Health effects of air pollutant exposures may also involve synergistic effects among air pollutants, traffic noise and other traffic-related stressors.

In California, significant residential development is now occurring near freeways or busy arterial roadways. While infill development can reduce regional and global air pollution burdens, trends will increase exposure to air pollutants and their associated health burden for residents living in such developments.

In 2005, the California Air Resources Board issued guidance on preventing roadway related air quality conflicts, suggesting localities avoid placing new sensitive uses within 500 ft of many freeways. This guidance is advisory, and no existing federal and state regulations protect sensitive residential land uses from air pollution "hot spots" that occur near busy roadways. Federal and state agencies control air pollutants by regulating vehicle engine emissions on a "per mile" basis, generally ignoring impacts due to localized traffic intensity.

Good practice in planning and public health requires examining environmental hazards and potential health effects on a project-level basis and appropriate avoidance or mitigation. Furthermore, the California Environmental Quality Act (CEQA) requires the examination of potentially significant human health effects associated with environmental change. Preventative steps to avoid future land use air quality conflicts from busy roadways could include:

- Screening projects for exposure to high traffic volumes
- Examination of air quality exposure on a project-level basis
- Comprehensive health effects analysis involving identifying sensitive (receptors) populations, estimating exposure, and calculating health risks.
- Requirements to either avoid residential development or other sensitive uses at a site with relative high levels of vehicle air pollutants or building ventilation design improvements to filter outside air and locate air intakes away from pollution sources.
- Disclosure of exposure, health risks and included mitigations to future residents.

Guidance and regulations are needed to prevent health impacts associated with locating new residential uses near roadway air pollution hot spots. This document outlines a rationale and approach for the assessment and mitigation of air pollution health effects on sensitive uses from proximate roadway sources. Prevention of adverse air quality health effects requires a close coordination between public health, land use and transportation agencies. The table below outlines the key elements of a suggested program to evaluate and prevent roadway related effects at the project-level.

Programmatic Element	Description
Hazard Identification	Assess the cumulative vehicle volume on roadways within a 200 meter buffer of the sensitive site. The following sources may provide traffic data: • Caltrans Traffic Data (http://traffic-counts.dot.ca.gov/) • Local Public Works Departments • California Environmental Health Tracking Program's (CEHTP) spatial linkage web service to. (http://www.ehib.org/traffic_tool.jsp) • Environmental Impact Reports on projects in the area (Typically available from Departments of Planning) ***A potential hazard exists if average daily traffic volume exceeds the following thresholds*:*** 1. 100,000 vehicles / day within a 150 meter radius 2. 50,000 vehicles / day within a 100 meter radius 3. 10,000 vehicles /day within a 50 meter radius. **Note that the threshold of 100,000 vehicles with a 150 meter radius roughly corresponds to the CARB guidance avoiding sensitive uses. Thresholds for 100 meters and 50 meters are equivalent with regards to area traffic volume density.*
Exposure Assessment	Estimate concentration of PM 2.5 contributed by proximate roadway sources within a 150 meter radius of the project using physical based dispersion models using local data on vehicle volumes, vehicle types, emissions characteristics, meteorology. SFDPH recommends CAL3QHCR Line Source Dispersion Model with best available local meteorology. Other dispersion models may be appropriate as well.
Health Effects Assessment	If indicated quantify potential effects of roadway-related exposures to criteria and non-criteria pollutants on health outcomes using established risk assessment principles.
Action Threshold for Mitigation	Compare roadway contribution to annual average PM 2.5 concentration to an action threshold of 0.2 ug /m3 of PM 2.5.
Mitigation	***For sites with roadway contributions to PM 2.5 above the threshold concentration, prevent exposure or apply mitigations using the following hierarchy:*** 1. Relocate project outside hazardous zones around roadway of concern 2. Reroute or reduce traffic through circulation changes or traffic demand reduction. 3. Provide mechanical ventilation systems with best available supply intake air location; with fresh air filtration and building designs; and with reduced infiltration to mitigate particulate exposure.
Disclosure	For residents purchasing or renting property in proximity to hazardous roadway air pollution sources, provide information on exposure, hazards, and mitigations.

II BACKGROUND

The following sections provide the rationale for preventing air quality impacts from roadway sources though planning and the regulation of land uses. The section reviews vehicle pollutants, the epidemiology of roadway related health effects, intra-urban pollution variation, and sensitive populations.

Vehicle Related Air Pollutants

Engine exhaust, from diesel, gasoline, and other combustion engines, is a complex mixture of particles and gases, with collective and individual toxicological characteristics. Vehicle tailpipe emissions includes criteria air pollutants such as particulate matter and carbon monoxide, ozone precursor compounds such as nitrogen oxides (NO_x) and other hazardous air pollutants (e.g., air toxics) not regulated by EPA as criteria pollutants. Air pollutants associated with vehicle emissions are described in the table below.

Particulate matter (PM) represents a heterogeneous group of pollutants associated with vehicle emissions (WHO 2003). Collectively exposure fine particles are strongly associated with mortality, respiratory diseases and lung development in children, and other endpoints such as hospitalization for cardiopulmonary disease. Based on toxicological and epidemiological research, smaller particles and those associated with traffic appear more closely related to health effects (Schlesinger 2006). PM characteristics that may contribute to toxicity include: metal content; presence of polycyclic aromatic hydrocarbons and other toxic organic components. Other particulate matter characteristics that may be important to human health effects include: mass concentration; number concentration; acidity; particle surface chemistry; metals; carbon composition; and origin.

Motor vehicles aslo emit air toxics. EPA has identified six priority mobile source air toxics, including benzene, 1,3-butadiene, formaldehyde, acetaldehyde, acrolein, naphthalene, and diesel exhaust. Similarly, the California Air Resources Board (CARB) has identified 10 air toxics of concern, five of which are emitted by on-road mobile sources: benzene, 1,3-butadiene, formaldehyde, acetaldehyde, and diesel PM (California Air Resources Board, 2001).

Mobile source air toxics are known or suspected to cause cancer or other serious health or environmental effects. Benzene is of particular concern because it is a known carcinogen and most of the nation’s benzene emissions come from mobile sources. Diesel exhaust particulate matter (DPM) is a toxic air contaminant and known lung carcinogen resulting from combustion of diesel fuel in heavy duty trucks and heavy equipment.

Air Pollutants and Pollutant Mixtures with Important Motor Vehicle Sources

	Air Pollutant	Source	Health Effects
Criteria Pollutants	**Ozone**	Tropospheric ozone is formed in the atmosphere from chemical transformation of certain air pollutants in the presence of sunlight. Ozone precursors include vehicles, other combustion processes and the evaporation of solvents, paints, and fuels	Ozone causes eye irritation, airway constriction, and shortness of breath and can aggravate existing respiratory diseases such as asthma, bronchitis, and emphysema.
	Carbon Monoxide (CO)	Produced due to the incomplete combustion of fuels, particularly by motor vehicles	Exposure to high concentrations of CO reduces the oxygen-carrying capacity of the blood resulting in fatigue, impaired central nervous system function, and induced angina.
	Particulate Matter ***(PM_{10} and $PM_{2.5}$)***	Diverse sources including motor vehicles (tailpipe emissions as well as brake pad and tire wear, wood burning fireplaces and stoves, industrial facilities, and ground-disturbing activities	Impaired lung function, exacerbation of acute and chronic respiratory ailments, including bronchitis and asthma, excess emergency room visits and hospital admissions, pre-mature arteriosclerosis, and premature death.
	Nitrogen Dioxide (NO_2)	Combustion processes in vehicles and industrial operations	Increase the risk of acute and chronic respiratory disease and reduce visibility
	Sulfur Dioxide (SO_2)	Combustion of sulfur-containing fuels such as oil, coal, and diesel	Increased risk of acute and chronic respiratory
Non-criteria Pollutants	***Diesel exhaust***	Diesel engines	Probable human carcinogen (IARC Group 2A) Diesel engines also emit particulate matter criteria pollutants produced through combustion.
	Benzene	Gasoline engines	Known human carcinogen (IARC Group 1A)
	1,3 butadiene	Motor vehicle engines	Probable human carcinogen (IARC Group 2A)
	Benzo(a) pyrene	Motor vehicle engines	Probable human carcinogen (IARC Group 2A)

Epidemiology of Roadway Proximity Health Effects

Proximity to air pollution sources increases both exposure and hazards. With regards to roadway proximity effects, epidemiologic studies have consistently demonstrated that children living in proximity to freeways or busy roadways have poorer respiratory health outcomes (Delfino 2002). More recent research has found that health effects of roadway proximity may extend to coronary artery disease in adults. Several specific studies of roadway proximity health effects are briefly described below:

- A study of children in the Netherlands found that lung function declined with increasing truck traffic density especially for children living within 300 meters of motorways (Brunekreef 1997).
- Children in Erie County, New York hospitalized for asthma were more likely to live within 200 meters of heavily trafficked roads (Lin 2002).
- Among children living within 150 m of a main road in Nottingham, United Kingdom, the risk of wheeze increased with increasing proximity to the road (Venn 2001).
- In Oakland California, school children at schools in proximity to high volume roadways experienced more asthma and bronchitis symptoms (Kim 2004).
- In a low income population of children in San Diego, children with asthma living within 168 meters of high traffic flows were more likely than those residing near lower traffic flows to have more medical care visits for asthma (English 1999).
- In a study of Southern California School Children, living within 75 m of a major road was associated with an increased risk of lifetime asthma, prevalent asthma, and wheeze (McConnell 2006).
- In a study conducted in 12 southern California communities, children who lived with 500 meters of a freeway had reduced growth in lung capacity relate to those living greater than 1500 meters from the freeway (Guaderman 2004)
- In a study in Cincinnati, residence within 100 meters of stop and go bus and truck traffic predicted infant wheezing (Ryan 2005).
- In a study of German adults, residence within 200 meters of a major road predicted coronary artery calcification (Hoffman 2007). In the same population, residence within 150 meters of a major road predicted manifest coronary heart disease (Hoffmann 2007).

It is important to make clear distinction between specific roadway related health effects due to specific effects of particular air contaminants (e.g., diesel exhaust, benzene), health effects related to hot spots of criteria pollutants (e.g., fine particulate matter, carbon monoxide), and health effects due to the cumulative burden of roadway proximity. Unlike the epidemiological relationship between diesel exhaust and lung cancer hazard, at present, it is not possible to attribute the effects of roadway proximity on non-cancer health effects described above to one or more specific vehicle types or vehicle pollutants.

Intra-Urban Variation in Air Pollution Exposure due to Traffic

Within an area or place, exposure typically varies spatially with higher levels of exposure in proximity to sources of pollution. Roadways are important sources of intra-area variation for several air pollutants.

Several techniques have been employed to help estimate intra-urban variation in air pollutant concentrations dues to roadway sources; these techniques include pollutant monitoring, interpolation, land use regression, and dispersion analysis (Jerrett 2005).

Regional monitoring data conducted for NAAQS standards does not provide monitoring sufficient to adequately define for intra-urban exposure variation or hot spots due to traffic generated air pollutants. However, research in some locations based on measurements of shows that a significant share of spatial intra-urban air pollution variation in ambient levels of $PM_{2.5}$ is due to local traffic sources. For example, measurement of particulate matter along roads in different regions in the Netherlands has found that particle count is 40% higher 100 meters downwind of major traffic sources (Weijers 2004).

Land use regression techniques have been used to create a city-wide or region wide model of exposure based on land use and transportation characteristics (Ryan 2007). Researchers have created land use regression models for nitrogen dioxide validated in Alameda, San Diego, and Los Angeles have all found proximity to traffic to be key predictor of ambient nitrogen dioxide concentrations. A recent analysis in the New York City region found that traffic within 300-500 meters explained 37-44% of the variance of PM 2.5 (Ross 2007). Another analysis in the Los Angeles region found that traffic density within 300 meters along with industrial uses and government land predicted 69% of the variation in regional concentrations of $PM_{2.5}$ (Moore 2007).

Line source dispersion models are another available tool to predict variation of ambient concentrations of pollutants from traffic sources near roadways taking into account meteorological conditions, pollutant type, and other parameters (Jerrett 2005). One published study compared PM2.5 emissions predicted using the CALINE model against actual measures, finding an acceptable correspondence between measured and modeled levels for a suburban setting in Sacramento, California (Yura 2007).

A recent meta-analysis, based on 33 exposure studies, found significant spatial difference exist in multiple traffic related pollutants relative to proximity to busy roadways (Zhou 2007). The meta-analysis focused upon four pollutants; carbon dioxide, nitrogen oxides, particulates and ultrafine particulates. A variety of factors significantly influenced the spatial extent or the area of significant health impact associated with proximity to high traffic roadways. Such factors as background pollutant concentration, chemical reactivity (NO conversion NO2 and ultrafine coalescence to larger particulates), chemical inertness, meteorology, and health significance threshold all served to define the size of the spatial extent. The authors concluded that a 500 meter buffer around a high traffic roadway would be protective under most circumstances.

Roadway Air Pollutants in Infiltration into Indoor environments

Research shows consistent strong correlations between outdoor and indoor concentrations of traffic related air pollutants including constituents of particulate matter, such as benzene and PAHs, and volatile organic compounds, VOC's (Fishcer 2000). In one study, exposure in indoor environments to particulates, measured via light absorption, was 19-26% higher even when accounting for indoor sources such as appliances for cooking and heating (Wichmann 2005).

Sensitive Uses

The CARB Handbook puts the focus of its guidance on "land uses where sensitive individuals are most likely to spend time [including] schools and schoolyards, parks and playgrounds, daycare centers, nursing homes, hospitals, and residential communities." It is important to note, however, that air quality does not affect every individual in the population in the same way, and some groups are more sensitive to adverse health effects. Population subgroups sensitive to the health effects of air pollutants include the elderly and the young, population subgroups with higher rates of respiratory disease such as asthma and COPD, populations with other environmental or occupational health exposures that impact cardiovascular or respiratory diseases. Still, the focus on sensitive uses is appropriate because it not possible, within the context of planning, to distinguish sensitive uses with regards to population vulnerabilities

Environmental Justice Issues

Poverty confers a general susceptibility to the health effects of environmental stressors. For example, poorer residents may be more likely to live in crowded substandard housing and be more likely to live near industrial or roadway sources of air pollution. In California, the proportion of children of color living in high traffic density block is inversely related to median family income, and children of color are three times more likely to live in high-traffic areas than white children (Gunier 2003).

II APPLICABLE POLICIES, REGULATIONS, LAWS, AND GUIDANCE

Federal and State Regulation of Criteria Air Pollutants

The USEPA identifies 6 criteria air pollutants that have important human health impacts; these include Ozone (O_3), carbon monoxide (CO), particulate matter (PM), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and lead. The Clean Air Act requires the EPA to develop specific public health and welfare-based exposure standards for the six criteria air pollutants and directing States to develop plans to achieve theses standards. Nationally, a network of air quality monitors provides information on ambient concentrations of criteria air pollutants. California has state standards for the six criteria pollutants that are more stringent than the federal standards.

Despite promulgation of National Ambient Air Quality Standards for criteria pollutants and implementation of air quality control plans, air pollutants continue to have significant impacts on human health. In part, these ongoing effects are due to non-attainment of air quality standards; however, exposure to air pollutants also results in health impacts even when levels are below existing standards (Johnson and Graham 2005).

Particulate matter is an example of a criteria air pollutant with documented health effects below the NAAQS criteria standards and even$PM_{2.5}$ levels measured below State AAQS are not optimally protective of public health. In fact, there is no scientifically known no-effects threshold for $PM_{2.5}$ suggesting the health benefits from incremental improvements. According to a cost-benefit analysis recently done by the USEPA, reducing the NAAQS for $PM_{2.5}$ by 1 ug per cubic meter from 15 to 14 would result in 1900 fewer premature deaths, 3700 fewer non-fatal heart attacks, and 2000 fewer emergency room visits for asthma each year (USEPA 2006).

Similarly, the 2002 State of California Air Resources Board Air Quality Standards Staff Report for Particulate Matter estimated that significant health effects benefits would accrue from reducing ambient $PM_{2.5}$ from current levels to natural background concentrations for every county in California (CARB 2002). The results of that health benefits analysis conducted for the California Standards is detailed in the table below.

Health Benefits of Reducing Ambient $PM_{2.5}$ to Natural Background Levels for California

Health Outcome	Estimated Benefits of Exposure Reduction
Mortality from Long Term Exposures in people over	9391premature deaths /year
Mortality from Short Term Exposures in all ages	4014premature deaths /year
Chronic Bronchitis	11,414 cases /year
COPD Hospitalizations	1241 hospitalizations /year
Pneumonia Hospitalizations	1791 hospitalizations /year
Cardiovascular Hospitalizations	3180 hospitalizations /year
Asthma Hospitalizations	950 hospitalizations /year
Acute Bronchitis in ages 8-12	32,923 cases/year
Asthma Attacks	344,532 cases/year
Work Loss Days	2,923,535

Federal and State Regulation of Mobile Source Air Toxics

Toxic air contaminants (TACs), including benzene and diesel exhaust, are a category of air pollutants not regulated under Federal Criteria air pollution rules but known to have adverse human health effects, ranging from birth defects to cancer. Toxic air contaminants from mobile Sources are primarily regulated by the Federal government. For example, in February 2007, EPA finalized a rule to reduce hazardous air pollutants from mobile sources (Control of Hazardous Air Pollutants from Mobile Sources, February 9, 2007). The rule will limit the benzene content of gasoline and reduce toxic emissions from passenger vehicles and gas cans and will be fully implemented by 2030.

The Clean Air Act of 1967 also allowed California to regulate vehicles sold within the State and to require those vehicles to meet more stringent emission standards. The California Air Resources Board is responsible for establishing emission standards for vehicles sold in California and has a variety of new programs directed at improving air quality through vehicle emission reduction.

- Amendments to California low emission vehicle regulations will extend passenger car emission standards to sport utility vehicles and pickup trucks.
- New on board diagnostic system regulations requires monitoring of all vehicle functions that may affect vehicle emissions.
- New heavy duty trucks and busses are being required to significantly reduce emissions of diesel particulates and nitrogen dioxide.
- Idling restriction for these large diesel vehicles are also being implemented to reduce exposure to school children and residents.
- The Air Resources Board has created a variety of incentive and grant programs to either upgrade vehicle emissions or remove vehicles from the statewide inventory.

US EPA Rules on Hot Spot Analysis for Transportation Projects

The US Environmental Protection Agency (EPA) currently requires qualitative hot spot analysis for particulate matter (PM) for new transportation projects in Federal nonattainment or maintenance areas for PM10 or PM2.5 (USEPA 2006). Requirements for quantitative hot spot analysis e.g., using dispersion modeling to determine concentrations at receptor locations) are pending EPA speciification of procedures for analysis. This rule does not apply to locating new sensitive uses adjacent to existing roadway pollution sources.

California Air Resources Board Guidance on Land Use-Air Quality Conflicts

The California Air Resources Board does not regulate local land use planning but rather air pollutant emissions from vehicles. However, because of the robust evidence relating proximity to roadways and a range of non-cancer and cancer health effects, the California Air Resource Board created guidance for avoiding air quality conflicts in land use planning in their *Air Quality and Land Use Handbook: A Community Health Perspective* (2005). In the guidance, CARB recommends not locating sensitive land uses, including residential developments, within 500 feet of a highway with more than 100,000 vehicles per day. CARB recommendations relevant to transportation-related land use-air quality conflicts are listed in the table below.

California Air Resource Board Guidance on Land Use-Air Quality Conflicts

Pollutions Source	**Recommendations**
Freeways and High Volume Roadways	*Avoid siting sensitive land uses within 500 feet of a freeway, urban roads with 100,000 vehicles/day, or rural roads with 50,000 vehicles/day.*
Distribution Centers	*Avoid siting sensitive land uses within 1,000 feet of a distribution center (that accommodates more than 100 trucks per day, more than 40 trucks with operating TRUs per day, or where T unit operations exceed 300 hours per week).* *Take into account the configuration of existing distribution centers and avoid locating residences and other sensitive land uses near entry and exit points.*
Rail Yards	*Avoid siting sensitive land uses within 1,000 feet of a major service and maintenance rail yar* *Within one mile of a rail yard, consider possible siting limitations and mitigation approaches*
Ports	*Consider limitations on the siting of sensitive land uses immediately downwind of ports in the most heavily impacted zones.* *Consult with local air districts for the latest available data on health risks associated with po emissions.*

California Environmental Quality Act

The California Environmental Quality Act CEQA requires an environmental impact report (EIR) where discretionary public agency decision have potentially adverse impacts on the environment (California Public Resources Code. § 21000). The regulations for CEQA specifically require that the EIR discuss "health and safety problems caused by the physical changes" (California Code of Regulations. §15126.2). CEQA standards also require an EIS whenever environmental effects of a project have the potential to cause substantial adverse effects on human beings, either directly or indirectly (California Code of Regulations. §15065). In evaluating significant impacts, CEQA explicitly requires consideration of potential environmental effects resulting from bring people in proximity to environmental hazards. (CCR §15126.2)

The Bay Area Air Quality Management District (BAAQMD) last updated guidance for project level environmental review in December 1999 and current guidance does not address the air quality issues presented in the CARB Air Quality and Land Use Handbook with respect to sensitive receivers.

Most cities do not have do not have specific guidance for the analysis of project-level land use air quality conflicts. However, many jurisidictions including San Francisco do have significance thresholds relevant to potential air quality and heath conflicts from roadways sources. The typical wording of San Francisco's significance threshold relevant to roadway proximity health effects is as follows:

> ***Implementation of the proposed project would have a significant effect on air quality if it would:… Expose Sensitive Receptors to Substantial Pollution Concentrations***

The recent environmental review of the Eastern Neighborhoods Community Plans in San Francisco concluded that rezoning in these areas would likely result significant environmental impacts to new residential uses because of the respiratory health effects of living near busy roadways SFDCP 2007. In this case, the Draft EIR also included innovative mitigations to require residential projects to analyze roadway pollution and mitigate effects on new residential uses through ventilation systems and building design.

General Plan Policies

Most cities in California have General Plans that include an Element developed to protect air quality. For example, the San Francisco's General Plan Air Quality Element establishes a goal of clean air planning to *reduce the level of pollutants in the air, to protect and improve public health, welfare and quality of life of the citizens of San Francisco and the residents of the metropolitan region*. The General Plan also recognized that the majority of air pollutants are generated on roadways from vehicle emissions. Policy 3.7 calls for calls for assessment of air quality hazards through modeling and prevention of new air quality hazards through building design

> **POLICY 3.7 Exercise air quality modeling in building design for sensitive land uses such as residential developments that are located near the sources of pollution such as freeways and industries.** *Project review and approval in the City should consider air quality implications. Certain land uses such as some types of industrial uses and freeways generally emit air pollutants that could be hazardous to human health, particularly that of sensitive receptors such as children, elderly and people with respiratory diseases. When reviewing new housing projects or other land uses to be used by sensitive receptors, location of industrial sites or other sources of air pollution should be considered in the design of the building to orient the air intake of the building away from the sources of pollution. Conversely, future industrial and other air polluting development should consider the existence of sensitive receptors in the vicinity.*

III ASSESSMENT OF AIR POLLUTION EXPOSURE AND HEALTH EFFECTS

In general, urban infill land use development can affect population health effects of air quality in two related ways.

- First, growth and development may result in new local area sources of air pollution through new transportation facilities, greater personal vehicle use, or increased demand for energy.
- Second, growth and development can bring a population in proximity to a pre-existing source of air pollution, like busy roadways, increasing exposure and hazard.

In general, pre-development assessment in areas potentially near hazardous air pollutions sources, such as busy roadways, should include at a minimum: (1) air quality modeling or direct measurement air pollutants under existing conditions; (2) modeling or estimation of future air quality conditions including changes associated with new or proposed uses; (3) identification of sensitive uses and exposed populations; and (4) where necessary, a health effects assessment as described above (BAAQMD 1999). Prevention of adverse air quality health effects requires a close coordination between land use and transportation systems planning. Specific mitigations include circulation changes or traffic demand reduction and filtration of ambient air.

The following assessment steps are designed to evaluate the increase in exposure associated with the specific change in traffic volume and type. Examples of air pollutant modeling and health risk assessment based on this approach are described in Appendix I.

Step 1: Hazard Identification

Prior to development approval, the developer should verify the intensity of area traffic in a 200 meter buffer using available sources of traffic data. The following sources may provide traffic data:

- Caltrans Traffic Data (http://traffic-counts.dot.ca.gov/)
- Local Public Works Departments
- California Environmental Health Tracking Program's (CEHTP) spatial linkage web service to. (http://www.ehib.org/traffic_tool.jsp) Within tool follow the following steps: (1) Select geocode address. (2) Enter address. (3) Select extract traffic metrics. (4) Enter radius in meters of buffer (150, 100, and 50 meters, as below. (5) Submit query. (6) Determine if sum of all unadjusted traffic volumes within buffer exceed potential hazard level.
- Environmental Impact Reports on projects in the area (Typically available from Departments of Planning)

A potential hazard exists if average daily traffic volume exceeds the following thresholds:

- 100,000 vehicles / day within a 150 meter radius
- 50,000 vehicles / day within a 100 meter radius
- 10,000 vehicles /day within a 50 meter radius.
- When heavy diesel bus and truck counts are available they shall be counted as equivalent to 22 vehicles when determining potential hazards (EMFAC, 2007).

The threshold of 100,000 vehicles with a 150 meter radius roughly corresponds to the CARB guidance avoiding sensitive uses. Thresholds for 100 meters and 50 meters are equivalent with regards to area traffic volume density.

Infill development is permissible in areas where the average daily traffic volumes are below these thresholds. Further analysis of hazards is generally not indicated if vehicle volumes fall below the above criteria.

Step 2: Exposure Estimation

Exposure modeling should occur for all sites a potential air quality hazard. As discussed above, assessment of air pollution using community wide monitoring data does not provide estimates of actual population exposure within a city and specifically within-area variation in air pollution hazards due to roadways. Exposure to roadway related air pollutants can be roughly estimated using distance or proximity to a pollution source as a proxy for exposure, however, this approach does not account for traffic characteristics, facility characteristics and meteorology. Exposure can be estimated using repeated measurements over representative traffic volume and meteorological conditions, but reliable exposure monitoring and evaluation requires multiple measurements over a period of multiple seasons.

For planning purposes, exposure can be more rapidly and efficiently estimated using Gaussian dispersion models based on physical characteristics of emissions, meteorology, link type (bridge, elevated, level, or canyon) and receptor horizontal and vertical location. A particular advantage of this technique is that line source regression models have also been used in health effects research relating roadways to adverse health outcomes and there is an established relationship between modeled exposures and health effects (Jerrett 2005).

The CAL3QHCR Line Source Dispersion Model Version 2.0, an enhanced version of CALINE3, is an example of a line source dispersion model that can be used to calculate exposure to an air pollutant at a development site due to roadway vehicle traffic (USEPA 2008). The USEPA recognizes CAL3CHCR as a preferred model for air quality modeling. The model further allows for the use of up to three years of hourly meteorological data in the calculation of receptor exposure. The Sacramento Metropolitan Air Quality District's (SMAQMD) in their recently upgraded CEQA guidance recommends CAL3QHCR should be used in assessment of roadway proximity health risks as the dispersion model to estimate PM_{10} concentrations at defined receptor locations by processing hourly meteorological data over a year, hourly emissions, and traffic volume (SMAQMD 2007).

This guidance suggest that prior to approval of a sensitive use in proximity to a busy roadway, development should model PM 2.5 concentrations attributable to existing and future area traffic for receptors at project site using the CAL3QHCR or anther equivalent methodology. Modeling should estimate both annual average and worst day (24-hour) exposure levels. Receptors may be located in a grid around a proposed development. Discrete receptors must be placed at a minimum at 6 receptors per acre and in the case of multiple storied buildings at ground, middle and rooftop locations which reflect potential worst case exposures. In addition receptors should be placed at the locations of all fresh air intakes. Discrete and grid receptors should encompass the perimeter of the project to include sensitive receiver locations closest to traffic. Suggested Data Sources for Model Parameters are listed below. A variety of graphic user interface programs exist for the CAL3QHCR model which simplify its use and implementation. One such modeling interface is the CAL-Roads View Interface Program produced by Lake Environmental (Lake Environmental 2006).

Model Parameter	Data Source and Typical Assumptions
Traffic data	Average hourly traffic volume (AADT/24hours).
Vehicle Emissions rates	California Air Resources Board EMFAC 2007. Emission in grams/mile is calculated by weighting known automobile, truck, and other type percentages.
Traffic speed	25mph local, 30 mph arterial, 55mph freeway
Temperature and Humidity	Area Annual Average (e.g., 50% relative humidity, and 50 degrees F)
Surface meteorology	Best available 3 year meteorology from BAAQMD
Number of Receptors	Minimum six receptors per acre. Grid receptor in Calroad. Receptors set at expected exposure heights.

Step 3: Threshold Evaluation for Action and Mitigation

In this protocol, PM 2.5 serves as a proxy for pollutant exposures from vehicles, and PM 2.5 is not the only pollutant of concern associated with vehicles or vehicle proximity. No federal, state, or local agency has adopted a health-based standard for evaluating roadway related pollution hot spots related to particulate matter. Based on available research, SFDPH therefore provides the following threshold to trigger action or mitigation.

> **0.2 ug /m3 of PM 2.5 annual average exposure from roadway vehicles within a 150 meter buffer of a sensitive receptor**

The rationale for this threshold is enumerated below:

- A threshold of 0.2 ug / m3 represents about 8-10% of the intra-urban range of PM 2.5 ambient concentration based on available and reliable monitoring data in San Francisco.
- A change in ambient concentration of PM 2.5 by 0.2 ug /m3, independent of other vehicle pollutants would result in significant forecasted health impacts.
    - Based on a recent study of intra-urban pollution in Los Angeles, a 0.2 ug /m3 increase in PM 2.5 would result in a 0.28% increase in non-injury mortality or an increase of about twenty-one excess death per 1,000,000 population per year from non-injury causes in San Francisco (Jerrett 2005). This effect is well above the one-in-a-million lifetime *de minimus* risk threshold for premature death considered insignificant by most regulatory agencies (Asante-Duah 2002).
    - Applying the health effects assessment methodology and Concentration Response Functions in the CARB Staff Report on AAQS for PM published in 2002. A 0.2 ug /m3 increase in PM2.5 affecting a population of 100,000 adults would result in about 20 extra premature deaths per year (CARB 2002). This effect is well above the one-in-a-million lifetime *de minimus* risk threshold for premature death considered insignificant by most regulatory agencies (Asante-Duah 2002).

- A 0.2 ug /m3 increase in PM2.5 would also result in ~160 days per year with respiratory symptoms, 108 days with work limitations, and 577 days with minor activity limitations in the same adult population.

Step 4: Health Effects Analysis

If estimated exposure from near traffic sources is below the 0.2 ug/m3 Pm 2.5 action level for mitigation or if traffic exposures are fully mitigated, this guidance considers development permissible and completion of *Step 4: Health Effects Analysis* is not needed. Health effects analysis may still be desirable even where exposure levels are below the above action threshold to inform stakeholders or decision-makers. Health effects analysis may also be important to inform or motivate additional mitigations.

Forecasting heath effects associated with changes in exposure requires a concentration-response function, estimates of exposure, and baseline incidences of health effects. Concentration-response functions are equations that relate a change in the incidence of an adverse health outcome to the change in an ambient concentration of a pollutant and are typically based on regression analyses from epidemiological studies (WHO 2001). This approach has been used by the US Environmental Protection Agency and the State of California Air Resources Board for Particulate Matter in standard setting for particulate matter (CARB 2002).

Estimating Health Effects from Roadway PM 2.5 Concentrations

This guidance suggests predicting traffic-related PM 2.5 exposure effects on excess mortality from all non-injury causes based on a recent intra-urban air pollution and health study in Los Angeles. Simply stated, estimating excess mortality from a roadway source involves multiplying an estimate of PM2.5 exposure from existing and new traffic sources expressed in ug/m^3 (using CAL3QHCR as described above or an equivalent exposure model) times the crude incidence of mortality from non-injury causes times an effect measure for PM2.5 and mortality.

$$\textbf{Excess Mortality}_{\text{Traffic Attributable PM 2.5}} = (\textbf{Concentration}_{\text{Traffic Attributable PM 2.5}})\ (\textbf{Incidence}_{\text{Non Injury Mortality}})\ (\textbf{Relative Risk}_{\text{PM2.5}})$$

The relative risk (effect measure) in this formula, 0.014, is derived from the study by Jerrett et al. (2005) showed that every 1.0 ug /m3 increase in PM 2.5 results in a 1.4% increase in annual mortality incidence from all non-injury causes. The dose response relationship is consistent with other epidemiologic studies and can be extrapolated to other urban settings to provide a rapid estimate of health effects associated with intra-urban variation in PM 2.5 exposures. California Vital Statistics data or local county public health departments are sources of baseline crude mortality rates for specific categories of causes. The case study in the appendix provides an example of the application of this method.

Estimating Health Effects from Mobile Source Air Toxics

Estimating health effects, including cancer risks, from mobile source air toxics can be complimentary to the estimation of health effects from PM 2.5 described above. A common means of assessing cancer risk is to multiply an estimate of exposure to each carcinogenic substance by a Unit Risk Factor (URF) for that substance. This produces an estimate of excess risk of cancer over a lifetime of exposure. For example, to estimate excess cancer risk from diesel particulate matter exposure from a roadway source on a sensitive use, one would use PM 10 as a conservative estimate of diesel vehicle exhaust emissions. Using EMFAC 2007 to estimate PM 10 emissions and modeling those emissions in CAL3QHCR an annual diesel exposure can be approximated. Multiplying this exposure by the an inhalation cancer risk unit risk factor (URF) diesel exhaust ($3.0 \times 10^{-4.}$ $ug/m^3)^{-1}$ in order to produce an estimate additional lifetime cancer probability.

Excess Lifetime Cancer Risk $_{\text{Traffic Attributable DPM}}$ = (Traffic $_{\text{DPM}}$) (Unit Risk Factor $_{\text{DPM}}$)(1 million population)

Using this method, a roadway contribution of DPM of 1 ug/m^3 translates into risk of 300 excess cancers per one million people exposed over a lifetime ($300 = 1 \times 3.0 \times 10^{-4} \times 10^6$). Examples of the application of Unit Risk Factors are provided in the modeling examples in the Appendix on page 27.

A similar approach may be taken for other air toxics using an appropriate modeling tool for exposure from a roadway source. The table below enumerates unit risk factors for human cancer risk for several priority mobile sources assigned by the California Office of Environmental Health Hazard Assessment (OEHHA).

If health effects on cancer incidence are estimated, analytic protocols should follow the State of California guidance documented in OEHHA's Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessment (2003). If cancer risks are estimated, a risk of one in a million as stipulated in the Hot Spots Program (AB 2588) may be used as a thresholds for significant hazards and effects should be estimated for each USEPA priority Mobile Source Air Toxics

OEHHA Unit Risk Factors (expressed in $(mg/m^3)^{-1}$) for USEPA priority Mobile Source Air Toxics

Pollutant	**OEHHA URF**
Acetaldehyde	2.7×10^{-6}
Acrolein	N/A
Benzene	2.9×10^{-5}
1,3-Butadiene	1.7×10^{-4}
Formaldehyde	6.0×10^{-6}
DPM	3.0×10^{-4}

IV MITIGATION OF ROADWAY—SENSITIVE USE AIR QUALITY CONFLICTS

The California Air Resource Board, Air Quality and Land Use Handbook: A Community Health Perspective (2005) made recommendations to avoid locating sensitive land uses, including residential developments, within specific distances of certain known sources of toxic air contaminants (CARB 2005). Specific CARB recommendations for the location of residential uses relative to air pollution sources are listed in the table above. This guidance anticipates that some cases sensitive uses will be proposed or considered within the exclusion zone recommended by CARB and thus provides an approach to air quality assessment and mitigation within recommended zones of exclusion.

Mitigations to prevent impacts on air pollution exposures from roadway sources should follow comprehensive air quality assessment. This guidance recommends that the approach to mitigation should follow the following hierarchy:

1. **Changing Vehicle Circulation or Reducing Traffic**
2. **Locating Sensitive Uses To Minimize Exposure**
3. **Providing Ventilation Systems To Mitigate Roadway Exposures**

Tier 1: Changing Circulation or Reducing Traffic Volumes

Reducing the volume of traffic on streets programmed for residential or mixed-use residential use could significantly decrease the impacts of roadways on air pollution exposure. Circulation changes that would re-route through traffic around proposed new residential and mixed-use residential areas would reduce or displace the location of air pollution hot spots. Re-routing heavy duty truck and freight routes away from residential and mixed use residential areas could have a similar air quality benefit with regards to diesel emissions exposure. In considering circulation changes, it is important to prevent re-routing traffic or heavy duty truck and freight routes to other areas with existing or proposed sensitive uses.

Lowering traffic volumes via a comprehensive area wide traffic demand reduction program could also reduce exposure. The Metropolitan Transportation Agency, the Bay Area Air Quality District, and the South Coast Association of Governments are resources for the identification and evaluation of TDM measures. Vehicle emissions programs such as URBEMIS also allow a planner to estimate the effectiveness of a package of TDM measures on trip generation (URBEMIS 2008).

Tier 2: Locating Sensitive Uses To Minimize Exposure

Exposure analysis may suggest that pollutant concentrations vary across a project site. In this case, results from the exposure analysis can be used to situate sensitive uses within the lowest exposed areas available. If concentrations are below action levels or other levels of concern, further mitigation may not be indicated.

Tier 3: Providing mechanical ventilation systems with fresh air filtration.

When reducing traffic or locating residential uses in the areas of the project not impacted by roadway air pollutants is not feasible, residential uses should incorporate mechanical ventilation systems with ambient air filtration to mitigate exposure particulates and other pollutants of concern. The design of ventilation mitigations to protect sensitive uses from higher levels of pollution from mobile roadway sources should follow hazard and exposure assessment.

If the project anticipates operable windows or other sources of infiltration of ambient air, this guidance recommends that the development install a central HVAC (heating, ventilation and air conditioning) that includes high efficiency filters for particulates (MERV-13 or higher). If required, based on exposure measures, the system could also include a carbon filter to remove other chemical matter. The system should operate to maintain positive pressure within the building interior to prevent entrainment of outdoor air indoors.

Alternatively, if the development limits infiltration though non-operable windows and other techniques, it may reduce the need (and energy requirements) for maintaining building at positive pressure. Minimum design standards for a ventilation conditioned on low-infiltration would include the following: (1) ASHRAE MERV-13 supply air filters; (2) >= 1 air exchanges per hour of fresh outside filtered air ; (3) >= 4 air exchanges / hour recirculation; and (4) <= 0.25 air exchanges per hour in unfiltered infiltration. Systems with the above parameters should remove 80% of fine particulate matter mitigating all expected additional roadway effects of particulates and having added health benefits in terms of reducing allergen loads (Fisk 2001).

In either case, air intake systems for HVAC should be placed based on exposure modeling to minimize roadway air pollution sources. A licensed mechanical engineer should certify that the designed HVAC system offers the best available technology to minimize outdoor to indoor transmission of air pollution.

The developer should also ensure an ongoing maintenance plan for the HVAC and filtration systems. Residential project developers should disclose to buyers the findings of air quality evaluations. Developer should inform occupant's regarding the proper use of any installed air filtration.

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APPENDIX I-- EXPOSURE MODELING AND HEALTH RISK ASSESSMENT EXAMPLES FROM SAN FRANCISCO

Several examples below illustrate the use of CAL3QHCR by the San Francisco Health Department to model $PM_{2.5}$ concentration from high volume roadways at potential sensitive receptors for several locations in San Francisco. For some sites in the examples, the examples include estimates of human health hazards attributed to roadway pollutants. The reader should note that modeled pollutant concentrations do not take into account background concentrations or non-roadway sources and health risk assessments do not address all roadway pollutants. Model Parameters, sources, and assumptions for this case study are listed in the table below.

Model Parameter	**Data Sources and Assumptions**
Traffic data	California Department of Transportation Traffic Data (Peak hour traffic volume. Annual average traffic volume. Percentage of Truck Traffic)
Vehicle Emissions rates	California Air Resources Board EMFAC 2007
Traffic speed	25mph local, 30 mph arterial, 55mph freeway
Temperature and Humidity	Area Annual Average (e.g., 50% relative humidity, and 50 degrees F)
Surface meteorology	San Francisco International Airport (Available at the Meteorological Resource Center, http://www.webmet.com/State_pages/met_ca.htm)
Number of Receptors	Minimum six receptors per acre
PM 2.5 Concentration Response Function	Jerrett et al. 2005 (1.4% Increase in Rate of Non-Injury Mortality per unit ug /m^3 increase in PM 2.5)
Cancer Unit Risk Factors for	Office of Environmental Health Hazard Assessment 2002
Crude Non-Injury Mortality Rate	California DPH County Health Status Profiles 2006 (733 /100,000)

Example 1: Executive Park

Example 1 is an air quality analysis of Executive Park, a proposed mixed use residential community adjacent to and to the east of US 101 at the southern border of San Francisco. Figure 1 illustrates modeled annual average PM 2.5 concentrations and modeled DPM concentrations attributable to roadway emissions. The subsequent table provides findings including estimates of exposure from vehicle sources along with associated health effects. The modeled roadway attributable concentrations of PM 2.5 range from <0.10 to 0.5 at the project site. This concentration translates into a 0.7% excess annual risk of mortality for those exposed or 51 excess premature deaths per million people exposed at the location of highest exposure. The maximum modeled level of diesel particulate matter in the Executive Park Project was 0.2. The excess lifetime Cancer Risk attributable to traffic diesel particulate matter (DPM) would be 0.2 ug/m^3 times the unit risk factor for DPM of 3.0 x 10^{-4} times 10^6 population for an addition lifetime risk of 60 cancers in one million exposed people.

Figure 1 Spatial Extent of Roadway Emissions of PM 2.5 at the Executive Park Project Site from US 101 at Alana Street (Annual Average ugs/ m^3**).**

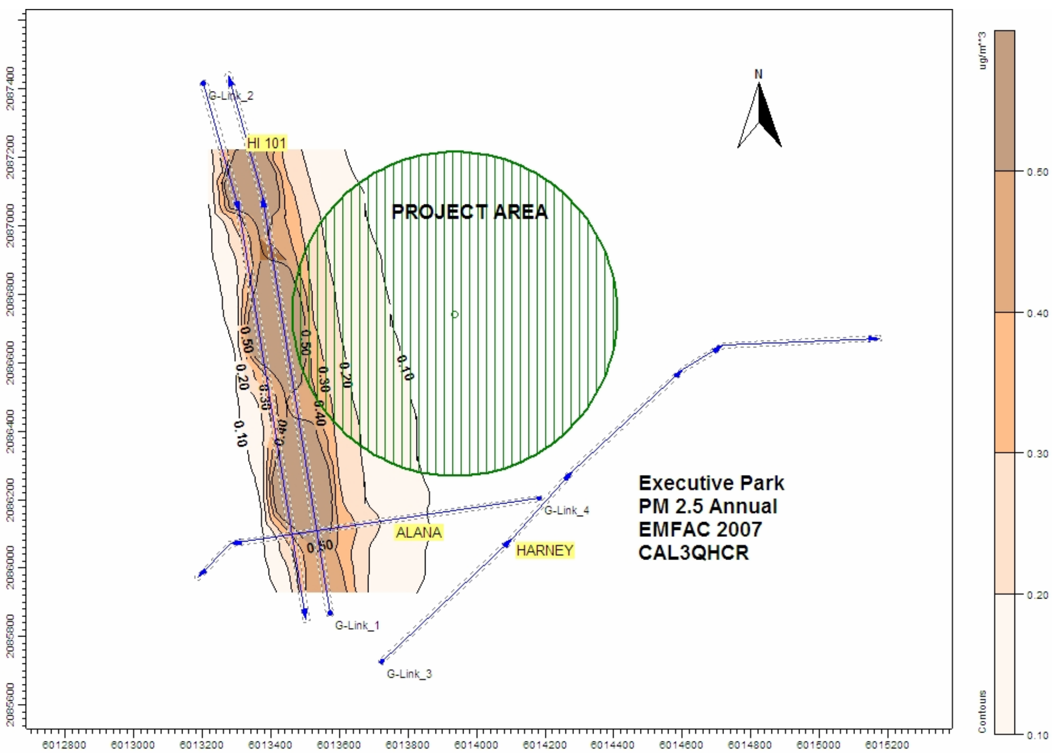
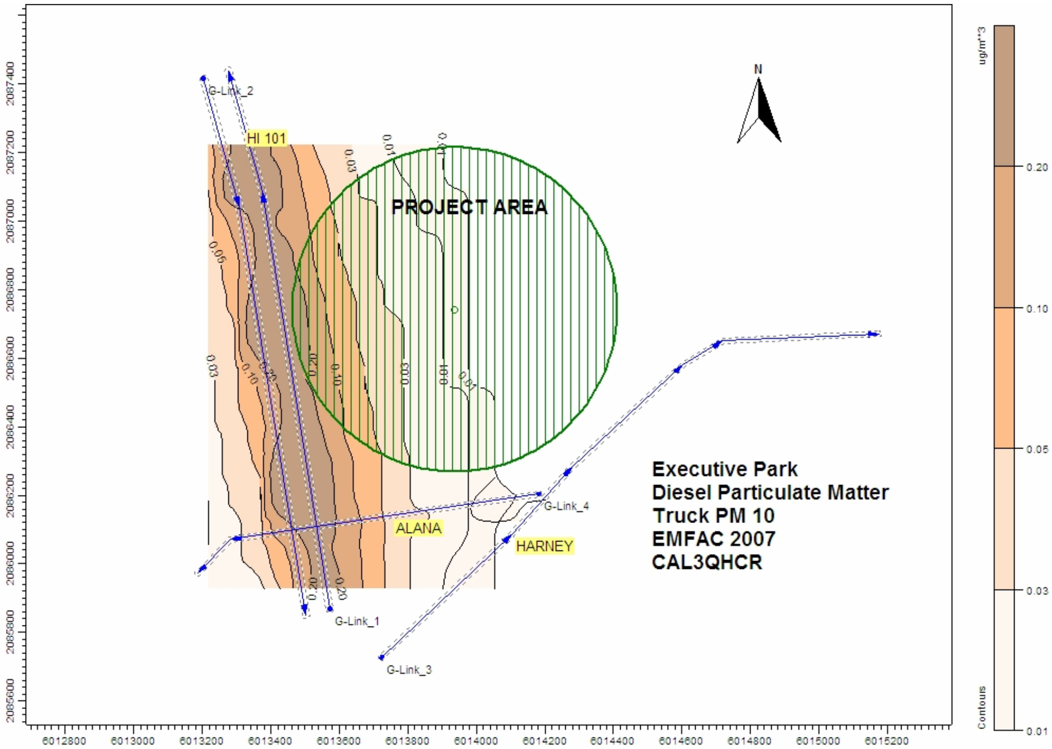


Figure 2. Spatial Extent of Diesel Particulate Matter (DPM) at the Executive Park Project Site from US 101 at Alana Street (Annual Average ugs/ m^3).



Modeled $PM_{2.5}$ and Diesel PM Concentrations from Roadway Sources and their Associated Mortality Hazards for the Project Site for the Executive Park Sub Area Plan in San Francisco

Roadway Location & AADT	Roadway PM 2.5 Concentration at Project Site (ugs/ m3)	Mortality Hazard Attributable to Roadway PM 2.5 based on highest site concentration	Roadway DPM Concentration at Project Site	Cancer Hazard Attributable to Roadway Diesel PM based on highest site concentration
US 101 @ Alana 216,000 vehicles/day	0.10 – 0.5 ugs/ m^3	10-51 excess deaths per million population per year	0.01 – 0.2 ugs/ m^3	60 excess cancers per million population

__Example 2: 129 Girard Street Project, San Francisco__

This example looks at a single family residential development on the upwind side of the Highway 101, Highway 280, Silver Avenue, and Bayshore Boulevard interchange. The impact of prevailing wind from the West disperses much of the particulate matter away from the development site and toward the downwind side of the freeway. Exposures above the action threshold can be seen to impact much of the Silver Terrace neighborhood including a significant portion of the Silver Terrace Playground shown below in green. The development site, however, is exposed below the action threshold. A similar analysis of the diesel particulate matter threshold is seen in Figure 4. Again the downwind dispersion of prevailing westerly wind results in low exposures at the development site.

Figure 3 Spatial Extent of Particulate Matter 2.5 at US 101 I-280 Interchange at Silver Avenue.

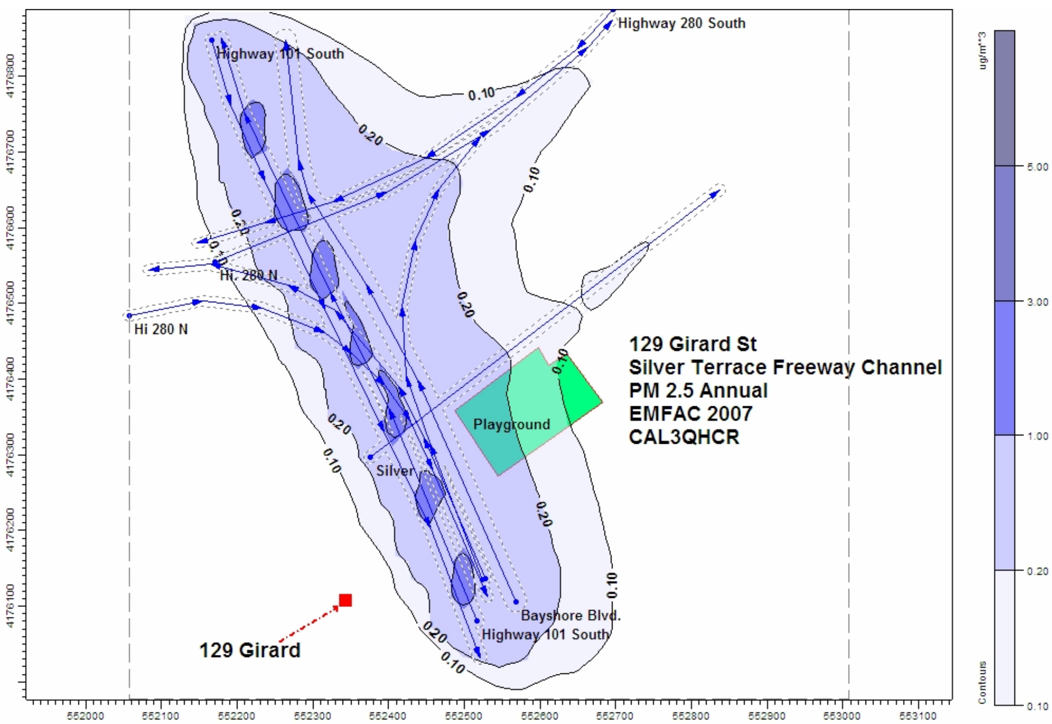
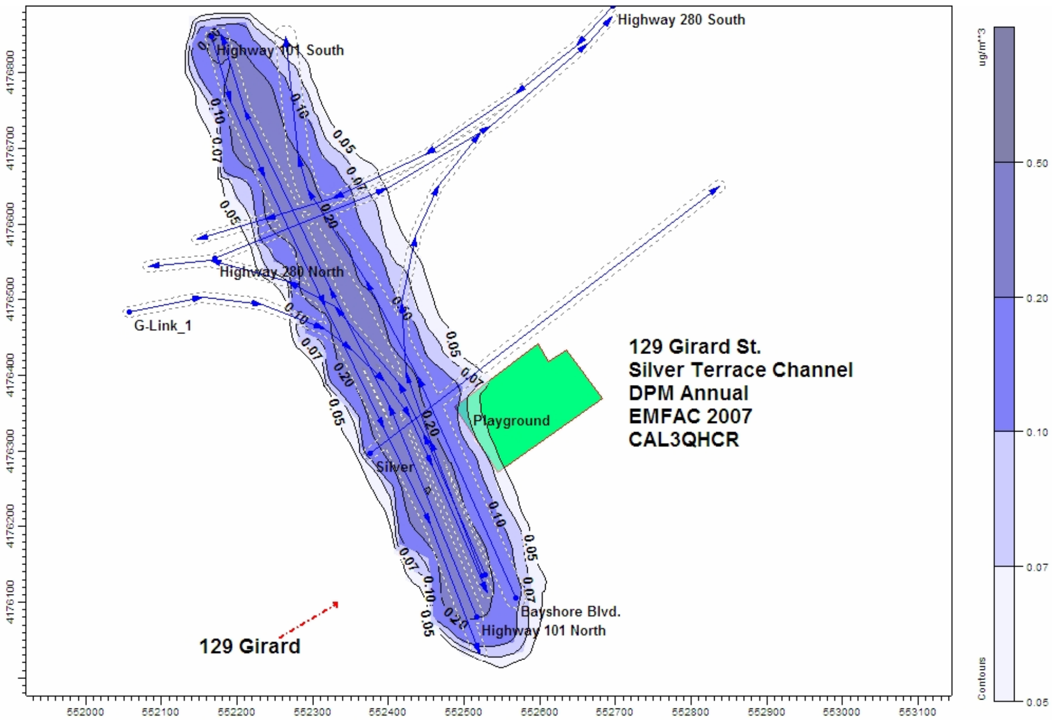


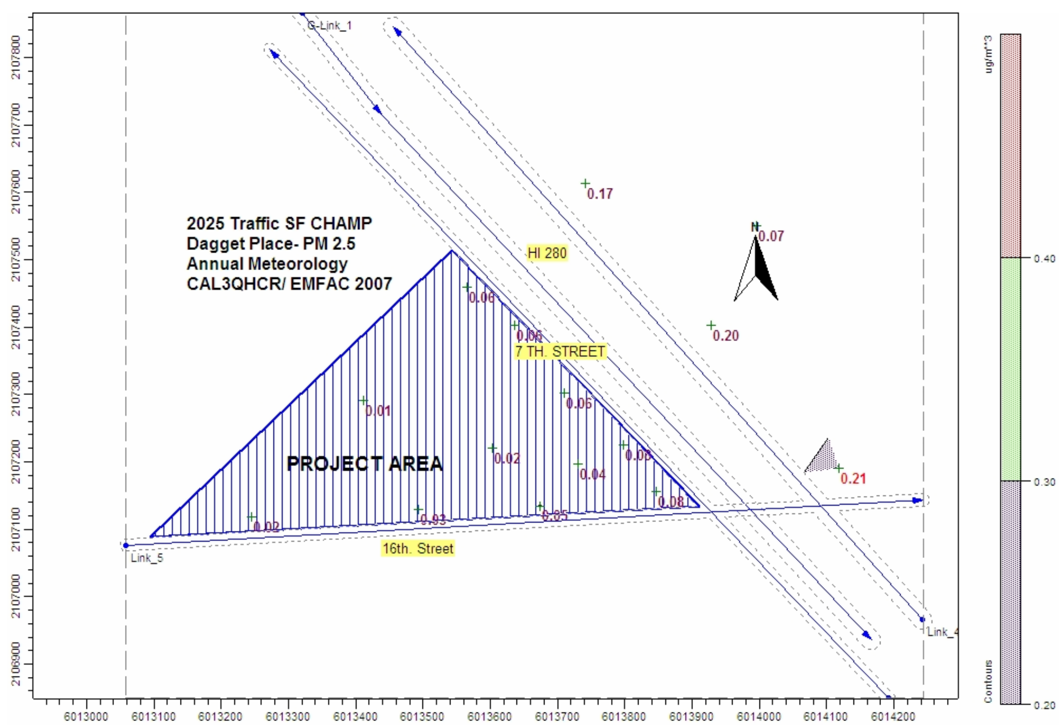
Figure 4 Spatial Extent of Diesel Particulate Matter at US 101 I-280 Interchange at Silver Avenue.



Example 3: Dagget Place Project, San Francisco

Example 3 demonstrates the use of the San Francisco County Transportation Authority traffic model, SF CHAMP, and the model's ability to predict future traffic volumes to the year 2025. In addition, EMFAC 2007, the California Air Resources Board's emission model produces traffic emissions for 2025 by including anticipated improvements in vehicle traffic emissions over time. In this development the effect of prevailing westerly wind, future emissions, and future traffic volumes results in exposure levels at the site beneath the action level of 0.2 ug/m^3. On the other hand, exposures at a similar development on the downwind side of Highway 280 would exceed the action level of 0.2 ugs/m^3.

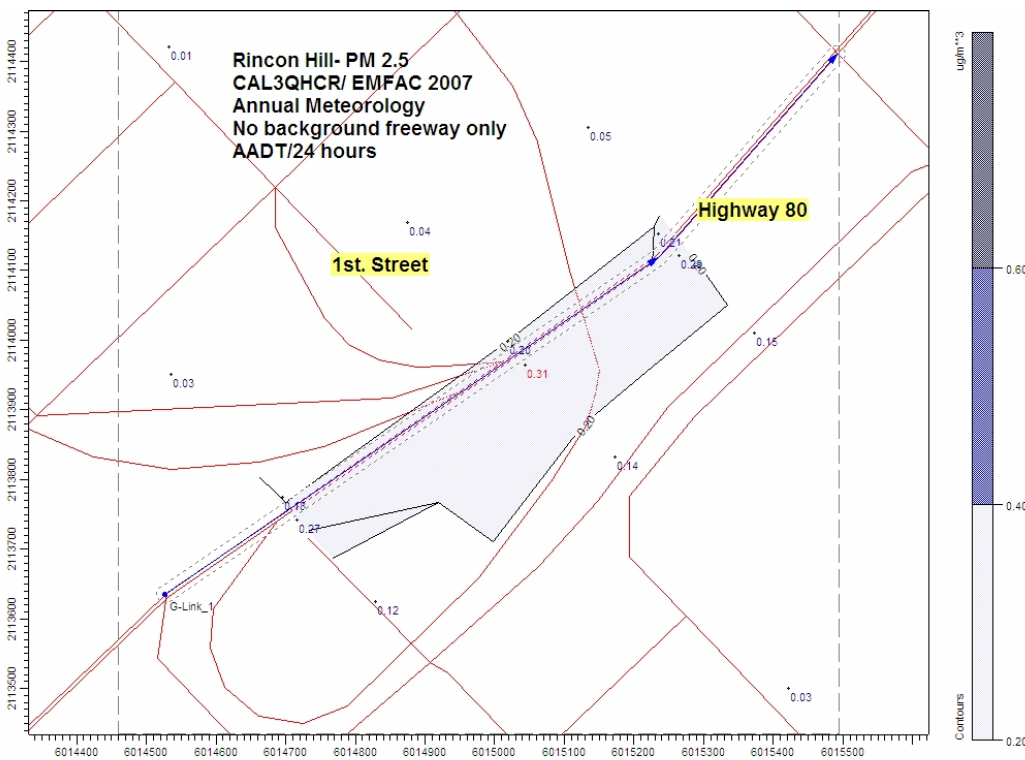
Figure 5 Spatial Extent of Particulate Matter 2.5 from Roadway Emissions at I-280 at 16th Street, San Francisco (Modeled as Annual Average).



Example 4: Rincon Hill, San Francisco

Example 4 represents the modeling of the Rincon Hill Tower on First St. near Highway 280. Again the effect of prevailing westerly wind can be seen with much of the particulate dispersion downwind of the development site. If this same development was located on the downwind side of the freeway it would have exceeded the action level and been subject to health risk assessment similar to Example 1, Executive Park, and would have required mitigations including strategic location of supply air inlets as well as possible filtration.

Figure 6 Spatial Extent of Particulate Matter 2.5 from Roadway Emissions at I-80 at 1st Street, San Francisco (Modeled as Annual Average).



APPENDIX II—AIR QUALITY MONITORING DATA FOR SAN FRANCISCO

In San Francisco, the Bay Air Quality Management District maintains one station for routine collection of monitoring data on criteria air pollutants on Arkansas Street. Criteria air pollutant monitoring data from that station is available at the URL: http://gate1.baaqmd.gov/aqmet/aq.aspx.

Some finer grained long term monitoring for Particulate Matter has recently been conducted in San Francisco for PM_{10} and $PM_{2.5}$ from several community stations contemporaneous with the BAAQMD measures. Sierra Research conducted the monitoring which started in early July 2005 and continued through late March 2006. Monitoring took place at two locations in Bayview/Hunters Point and two locations in Potrero at sites were chosen to be representative of community exposures. The study also monitored at the BAAQMD Arkansas Street monitoring station so that we could directly compare the BAAQMD measurements with those from our program.

Monitoring demonstrated that particulate matter measures (as an annual average) ranged from 16.9 to 20 ugs/ m^3 fro PM_{10} and from 7.6 to 9.3 ug/m3 for $PM_{2.5}$. The results of the study are described in the tables below.

PM10 (ug/m3) Monitoring Results from San Francisco Electric Reliability Project

	Monitor Location	BAAQMD Arkansas St	Arkansas St	Southeast Community Center	Muni Maintenance Yard	Potrero Recreation Center	Malcolm X Academy	California Ambient AQ Std
PM 10	Average	19.0	18.6	18.3	20.0	16.9	17.5	20
	Maximum	46.8	45.3	41.5	45.0	36.7	35.2	50
PM 2.5	Average	9.1	8.9	9.3	8.9	7.6	7.9	12
	Maximum	27.7	22.8	22.2	22.7	16.1	18.4	None