

# **Recommended Protocol for Evaluating the Location of Sensitive Land Uses Adjacent to Major Roadways**

## **Technical Appendix**

**January 2009**

**Version 2.1**



# Technical Appendix to the Recommended Protocol for Evaluating the Location of Sensitive Land Uses Adjacent to Major Roadways

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## Document Revisions

### 2008

On October 23, 2008, the Board of Directors for the Sacramento Metropolitan Air Quality Management District approved major revisions to the Protocol and its Technical Appendix.

The approved 2008 revisions to the Protocol included:

- Revised health risk assessment procedure, for consistency with state guidance
- Shading removed from the screening tables (evaluation criterion remains)
- Expanded section on potential mitigation measures
- Guidance on how to address:
  - Background risk levels
  - Multiple sources
  - Non-cancer health effects
  - Controversy in developing and reporting health risk values

The Technical Appendix was also expanded to reflect the revised health risk assessment procedures and shading removal. In addition, the Technical Appendix now includes step by step guidance on air dispersion modeling and health risk assessment.

The 2008 approved revisions were in addition to updated cancer risk and traffic values to reflect 2008 EMFAC information.

### 2009

The 2009 revisions are minor, reflecting updated cancer risk and traffic values to reflect 2009 EMFAC information.

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### Health Risk Assessment Overview

In its basic form, a health risk assessment (HRA) is a methodology to quantify the potential health risk posed by a source of a pollutant to the individuals affected by exposure to this pollutant.

The HRA translates an emission rate [mass per time, i.e. grams per second (g/s)] through its dispersion in the various environmental pathways (such as the inhalation pathway) it can follow to present a dose to an exposed individual through each pathway. This dose, in turn, can cause an adverse health effect in the exposed individual. In its most detailed and complicated form, many exposure pathways are evaluated and corresponding health risks through each pathway quantified. These pathways could include air pollutant dispersion in the atmosphere leading to an inhalation dose as well as air pollutant deposition leading, again through various pathways, to an ingestion dose. For toxic air contaminants, the pathway having the greatest significance with respect to the general population is atmospheric dispersion, leading to exposure and inhalation dose. Inhalation is the only pathway considered in the present analysis and Protocol.

For the inhalation pathway, the source's mass emission rate (g/s) is dispersed in the atmosphere to give concentration distributions [microgram per cubic meter ( $\mu\text{g}/\text{m}^3$ )] in the area affected by the source. These concentration distributions are in turn translated into measures of health risk to persons exposed to the concentration using risk factors that take into consideration how exposures become doses leading to an end point adverse health effect. For non-cancer adverse health end points, the quantitative measure is termed the hazard index. The hazard index is the ratio of the predicted concentration to a threshold concentration. The threshold concentration is that which has been associated with some adverse health effect.

For cancer end points, no threshold concentration can be defined because carcinogens are considered non-threshold pollutants. That is, there is some increased risk of cancer at any non-zero concentration of the carcinogen. Thus, for carcinogens, the measure of the significance of exposure is the predicted increased risk of cancer. This increased risk is determined by first calculating the dose. The dose is then multiplied by the cancer potency factor and then by one million to express risk per million people. The most common cancer risk measure used in HRAs is the increased cancer risk for continuous lifetime exposure to a pollutant concentration. Lifetime is usually considered to be 70 years. The cancer risk measure is the predicted number of additional cancer cases from lifetime exposure to the pollutant concentration.

The dose equation and potency factor established by California's Office of Environmental Health Hazard Assessment (OEHHA) and ARB are universally accepted for use in preparing HRAs.<sup>1</sup>

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<sup>1</sup> Consolidated Table of OEHHA/ARB Approved Risk Assessment Health Values, can be obtained from [www.arb.ca.gov/toxics/healthval/healthval.htm](http://www.arb.ca.gov/toxics/healthval/healthval.htm), April 2005

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See the section entitled *Site Specific Health Risk Assessment Methodology Using CAL3QHCR: Potential Cancer Risk Due to Diesel Particulate Matter* for more information on calculating potential cancer risk.

### Other Toxic Air Pollutants of Concern

Table 1 lists the cancer potency factors for the more prevalent mobile source air toxics (MSATs) from vehicle sources. For diesel particulate matter, the cancer potency factor is  $1.1E + 00$ . The cancer potency factor assumes standard exposure and breathing rates as documented by OEHHA/ARB.

Table 1: Cancer Potency Factors for Prevalent MSATs

Air Toxic Species	Cancer Potency Factor (increased risk per mg/kg-day)
Diesel PM	1.1E + 00
Benzene	1.0E-01
1,3-Butadiene	6.0E-01

Significant health risks are associated with carcinogenic toxic air contaminant emissions in vehicle exhaust. The most significant carcinogenic toxic air contaminants in vehicle emissions identified are 1,3-butadiene and benzene from gasoline-fueled vehicles, and diesel PM from diesel-fueled vehicles.<sup>2</sup> The cancer risk due to diesel PM exposure is more significant than the other carcinogenic MSATs.

Because the cancer risk posed by vehicle MSAT emissions is dominated by diesel PM exposure, the screening tables are based on diesel PM cancer risk. Nevertheless, the same screening methodology and a site specific HRA can be applied to other MSATs if so desired.

### Diesel Particulate Matter Overview

Diesel particulate matter is an air pollutant consisting of small particles with an aerodynamic diameter less than or equal to 10 microns (about 1/7 the diameter of a single human hair).

Diesel exhaust causes health effects from both short term or acute exposures and also long term chronic exposure. Their small size allows them to make their way to the air sacs deep within the lungs where they can become lodged and result in adverse health effects such as the aggravation of existing respiratory and cardiovascular disease, alteration in the body's defense systems against foreign materials, damage to lung

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<sup>2</sup> Reducing Toxic Air Pollutants in California's Communities, brochure from [www.arb.ca.gov/toxics/toxics.htm](http://www.arb.ca.gov/toxics/toxics.htm), viewed May 2006

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tissue and reduced lung function, carcinogenesis, premature birth rates and premature death.

Children, the elderly, the ill, pregnant women and postmenopausal women are most susceptible to the adverse health effects of diesel particulate matter exposure.

For more information on the health effects of diesel particulate matter, see *Addressing Non-Cancer Health Effects* in the main Protocol document.

### **CAL3QHCR Line Source Dispersion Model Overview**

Several Gaussian dispersion models have been developed that estimate the concentration distributions due to pollutant source emissions. Parameters needed by all Gaussian dispersion models include meteorological data (wind speed and direction and atmospheric stability, for example), emissions data and additional source characteristics.

For modeling pollutant dispersion from a roadway source, the line source models of the CALINE family are preferred. Of these, CAL3QHCR is the more recently developed and most flexible in terms of being able to model a variety of roadway characteristics situations.

CAL3QHCR is a relatively user-friendly model that has the ability to process up to a year of hourly meteorological, emissions, traffic (including the queuing/idling at intersections), and signal (at intersections) data for non-complex terrain. CAL3QHCR accepts SMAQMD's recommended meteorological data set of hourly data over a year. The inputs for each scenario modeled are easily documented and results can easily be reproduced by others.

CAL3QHCR is one of EPA's preferred/recommended dispersion modes referenced in Appendix W of 40 CFR Part 51 (November 9, 2005). It is available for free at [http://www.epa.gov/scram001/dispersion\\_prefrec.htm#cal3qhc](http://www.epa.gov/scram001/dispersion_prefrec.htm#cal3qhc).

### **Development of the Screening Tables**

SMAQMD developed screening tables to help the user determine if a site specific health risk assessment is needed. Each horizontal row in the screening tables (Table 3 and Table 4) of this document represents the results of an air dispersion modeling run and corresponding health risk assessment calculations.

In creating the screening tables, SMAQMD used the following information:

- 1987 meteorological data file
- VMT normalization factors extracted from EMFAC2007
- Grams/vehicle mile PM10 emissions factors extracted from EMFAC2007

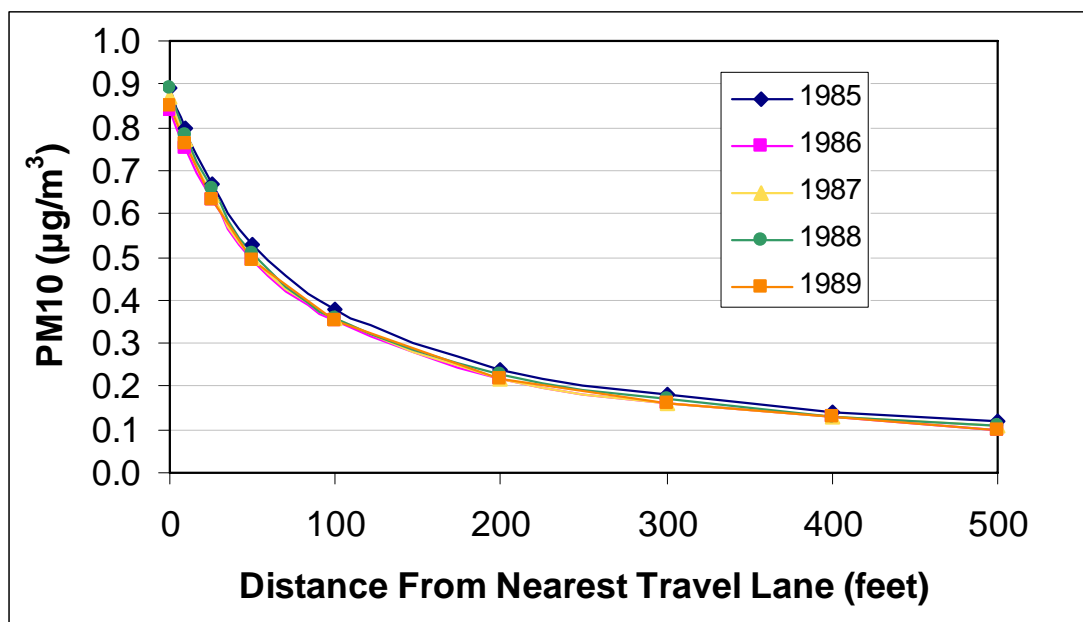
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- Generic roadway and receptor locations
- Additional inputs required by the model such as roadway length, surface roughness, etc

### ***Meteorological Data***

SMAQMD recommends the use of 1987 meteorological data. The 1987 data is part of the full set of hourly meteorological conditions (joint frequency distribution of wind speed and direction and atmospheric stability class) over an entire year that SMAQMD staff have used in air toxics hot spots analyses (as required by AB 2588) consisting of five individual year's data, for 1985 through 1989. This set is referred to as the "standard SMAQMD" meteorological data set.

Test cases were run using all five meteorological years. The risk from the 1987 data came closest to the average of all 5 years. All of the meteorological years were within 10 percent of the average and most were within 5 percent of the average. Figure 1 shows that dispersion model calculated ground level concentration distributions are not significantly altered by using one year's data set or another.



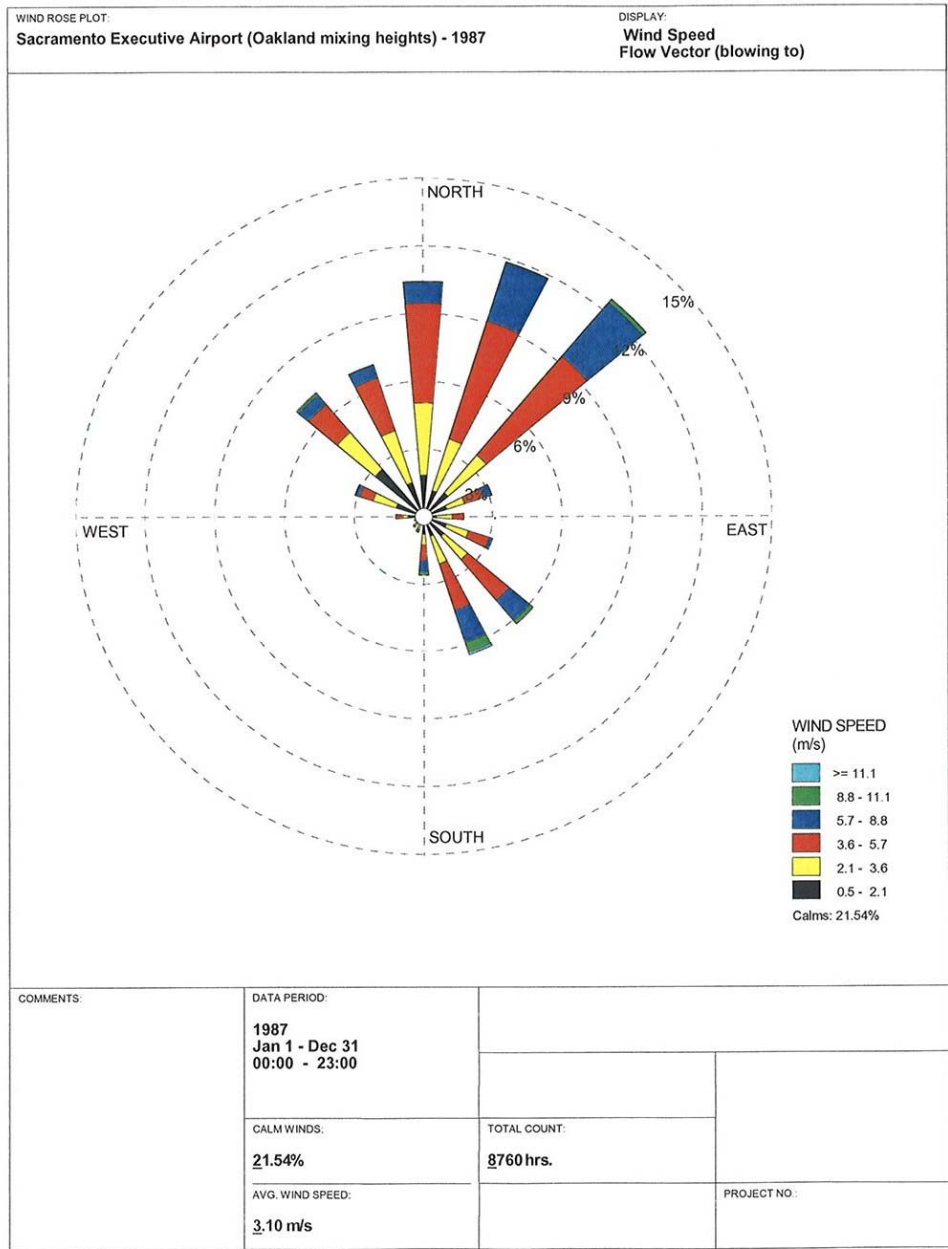
**Figure 1: Meteorological Year Comparisons, I-80 Example Project**

With the meteorological data established, the only meteorological parameter of importance that can be varied within the CAL3QHCR model is the compass orientation of the roadway. For generic screening distance calculations a roadway oriented east-west with receptors located north and south of the roadway, and a roadway oriented north-south with receptors located east and west of the roadway were used. These two roadway orientations are sufficient to cover most site locations within the SMAQMD boundaries.



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Figure 2 is the 1987 annual wind rose for SMAQMD. Figure 2 shows that north of an east-west roadway, and east of a north-south roadway would generally be considered downwind locations. South of an east-west roadway, and west of a north-south roadway would generally be considered upwind locations.



**Figure 2: Wind Rose Chart of the SMAQMD 1987 Meteorological Data**

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### ***Emissions and VMT data***

EMFAC2007 was used to supply total PM10 exhaust emission factors and VMT data within the SMAQMD boundaries. The PM10 emission rates (ton/hr) are for SMAQMD mix of vehicles for the user-designated year. The EMFAC report takes into consideration the vehicle category and model year distribution in the state's vehicle population for the specified calculation year.

PM10 emissions were used as the measure of diesel PM since all diesel PM is considered to be less than or equal to 10  $\mu$ m in diameter. PM10 represents an upper bound for diesel PM emissions.

Table 2 provides the hourly distributions of VMT and PM10 emissions from EMFAC2007 data within the SMAQMD boundaries for 2009.

**Table 2: EMFAC2007 Traffic Volume and Vehicle PM10 Emission Rates for SMAQMD (2009)**

Time	VMT (vehic miles traveled/hr)	PM10 emissions	
		tons/hr as reported in EMFAC	g/veh-mi conversion, obtained by converting ton/hr to grams/hour and then dividing by the VMT for that hour
Hr 00	391,000.00	0.03	0.070
Hr 01	159,000.00	0.01	0.057
Hr 02	185,000.00	0.02	0.098
Hr 03	102,000.00	0.03	0.267
Hr 04	177,000.00	0.02	0.103
Hr 05	316,000.00	0.03	0.086
Hr 06	1,218,000.00	0.07	0.052
Hr 07	2,456,000.00	0.08	0.030
Hr 08	2,322,000.00	0.08	0.031
Hr 09	1,464,000.00	0.08	0.050
Hr 10	1,536,000.00	0.07	0.041
Hr 11	1,923,000.00	0.08	0.038
Hr 12	1,982,000.00	0.08	0.037
Hr 13	1,957,000.00	0.08	0.037
Hr 14	2,246,000.00	0.07	0.028
Hr 15	2,286,000.00	0.07	0.028
Hr 16	2,407,000.00	0.08	0.030
Hr 17 (pk hour VMT)	2,618,000.00	0.06	0.021
Hr 18	1,812,000.00	0.04	0.020
Hr 19	1,354,000.00	0.03	0.020
Hr 20	1,042,000.00	0.04	0.035
Hr 21	1,060,000.00	0.04	0.034
Hr 22	793,000.00	0.02	0.023
Hr 23	597,000.00	0.02	0.030

The data and distributions shown in Table 2 reflect total traffic flow and emission rates for the entire SMAQMD region. The total emissions listed and the traffic VMT noted in the table are averages for the SMAQMD region as a whole.

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### ***For input into the air dispersion model, each peak traffic situation considered was normalized according to the factors shown in Preparing the Hourly Traffic Count Data***

To develop hourly traffic count values needed by CAL3QHCR, first find the highest hourly VMT count reported by EMFAC. In this scenario, the highest hourly VMT count is 2,618,000 miles, which falls on Hour 17. Then, divide each hourly VMT value from EMFAC by the highest hourly VMT count. See Figure 4: Example Scenario Development of Normalization Factors below. Each result is known as a normalization factor. Each normalization factor is then multiplied by the project's peak hour traffic count from Caltrans (11,900). The results are normalized hourly traffic volumes for input into CAL3QHCR. See Table 5 for this scenario's hourly traffic data.

### ***Roadway, Receptor and Other Parameters***

As shown in Table 3 and Table 4, SMAQMD chose generic peak hour traffic volumes of 4,000; 8,000; 12,000; 16,000; 20,000 and 24,000. The upper bound peak traffic volume corresponds to worst case Sacramento County situation.

Generic sensitive receptor distances of 10, 25, 50, 100, 200, 300, 400 and 500 feet from the edge of the nearest travel lane were chosen.

A generic roadway width of 140 feet was chosen (which includes 10 feet on each side to account for the mixing zone), and total roadway length of 10,000 feet was chosen.

Other parameters of lesser impact on the modeling run were used as required by CAL3QHCR. See Table 6.

Table 3 and Table 4 are the screening tables developed under the preceding assumptions for 2009.

### ***The Evaluation Criterion***

For 2009, the evaluation criterion (point at which a site specific health risk assessment is recommended) falls at a cancer risk of 296/million. The evaluation criterion of 296/million was selected as that level of risk corresponding to a 70 percent reduction from the highest risk calculated

**Table 5:  
Example  
Scenario  
Normalized  
Traffic Counts**

Time of day	Traffic veh/hr
Hr 00	1777
Hr 01	723
Hr 02	841
Hr 03	464
Hr 04	805
Hr 05	1436
Hr 06	5536
Hr 07	11164
Hr 08	10555
Hr 09	6655
Hr 10	6982
Hr 11	8741
Hr 12	9009
Hr 13	8895
Hr 14	10209
Hr 15	10391
Hr 16	10941
Hr 17	11900
Hr 18	8236
Hr 19	6155
Hr 20	4736
Hr 21	4818
Hr 22	3605
Hr 23	2714

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at 50 feet<sup>3</sup> from the edge of the nearest travel lane to the nearest receptor for the highest peak traffic volume reported by Caltrans for Sacramento County (24,000 vehicle per hour) east (downwind) of a north-south roadway. The highest risk represents the worst case siting situation within the boundaries of the SMAQMD.

Note that the evaluation criterion does *not* represent a “safe” risk level or a regulatory threshold; it is simply the point at which a site specific health risk assessment is recommended.

**Table 3: Diesel PM Cancer Risk (Potential Incremental Cancer Cases per Million People North and South of an East-West Roadway (2009))**

<b>PROJECTS NORTH AND SOUTH OF AN EAST-WEST ROADWAY Version 2.1 EMFAC2007 (Analysis Year 2009)</b>								
Peak Hour Traffic (vehicle/hr)	Receptor Distance from Edge of Nearest Travel Lane (feet)							
	10	25	50	100	200	300	400	500
Incremental Cancer Risk Per Million: North (downwind)								
<b>4000</b>	204	181	149	111	73	54	45	38
<b>8000</b>	407	363	299	219	143	108	89	73
<b>12000</b>	614	541	448	331	216	162	134	111
<b>16000</b>	935	830	690	512	337	254	207	172
<b>20000</b>	1021	903	750	553	363	273	219	184
<b>24000</b>	1224	1084	900	661	432	328	264	223
Incremental Cancer Risk Per Million: South (upwind)								
<b>4000</b>	114	95	76	54	35	25	19	16
<b>8000</b>	229	191	149	108	70	51	41	35
<b>12000</b>	343	286	226	162	105	76	60	51
<b>16000</b>	493	407	321	229	149	111	89	73
<b>20000</b>	572	477	375	267	172	127	102	86
<b>24000</b>	687	572	452	321	207	156	124	102

**Table 4: Diesel PM Cancer Risk (Potential Incremental Cancer Cases per Million People East and West of a North-South Roadway (2009))**

<b>PROJECTS NORTH AND SOUTH OF AN EAST-WEST ROADWAY Version 2.1 EMFAC2007 (Analysis Year 2009)</b>								
Peak Hour Traffic (vehicle/hr)	Receptor Distance from Edge of Nearest Travel Lane (feet)							
	10	25	50	100	200	300	400	500

<sup>3</sup> Previous versions calculated the evaluation criterion from 10 feet. In order to more closely align with ARB modeling methodology set forth in the Land Use Handbook, SMAQMD now uses the 50 foot distance to determine the evaluation criterion.

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Incremental Cancer Risk Per Million: East (downwind)								
<b>4000</b>	242	207	165	114	73	54	45	35
<b>8000</b>	483	413	328	232	146	108	86	73
<b>12000</b>	725	623	493	347	223	162	130	108
<b>16000</b>	1094	932	735	518	331	245	194	159
<b>20000</b>	1212	1037	820	579	369	273	216	178
<b>24000</b>	1453	1243	986	693	442	328	261	216
Incremental Cancer Risk Per Million: West (upwind)								
<b>4000</b>	153	121	89	60	38	29	22	19
<b>8000</b>	308	242	178	121	76	54	45	35
<b>12000</b>	461	366	267	181	114	83	67	54
<b>16000</b>	728	576	423	289	181	134	105	86
<b>20000</b>	770	611	448	305	191	140	111	89
<b>24000</b>	922	731	623	366	229	169	130	108

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### *Notes on Screening Tables*

As expected, the data provided in the tables predicted PM10 concentrations, and associated cancer risk downwind (north) of the roadway uniformly higher than predicted concentrations and risks upwind (south) of the roadway.

The screening tables for roads at grade can be referenced for roads below grade due to similar exposure for both roadway elevations. Because the estimated cancer risks are insensitive to roadway elevation at distances of 50 to 100 feet or greater, and the highest estimated risks are for roadways at grade, only at grade calculations were used to assemble the screening tables shown above and in the main document.

The four variable parameters that significantly affect predicted ground level concentration distributions are roadway compass orientation, peak hour traffic volume, roadway elevation, and roadway width. Varying roadway width within a reasonable range of 44 feet, (two lane road, no median) to 140 feet. (8-lane freeway with 24-foot median, or 10-lane with no median) had much less of an effect on predicted ground level concentration distributions than reasonable variations in peak hour traffic volume and roadway elevation.

Please note that the risk values in the screening tables are incremental risks and do not include the existing background cancer risk from air contaminants. For comparison, the ARB estimated that in 2000 the overall cancer risk due to all toxic air contaminants monitored in the Sacramento Valley Air Basin was 520/million. The cancer risk from diesel PM alone is 360/million.<sup>4</sup>

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<sup>4</sup> <http://www.arb.ca.gov/aqd/almanac/almanac05/chap505.htm>, viewed June 2006

## Site Specific Health Risk Assessment Methodology Using CAL3QHCR: Potential Cancer Risk Due to Diesel Particulate Matter

### *Introduction*

This step by step guidance explains how to use the CAL3QHCR line source model to carry out diesel particulate matter air dispersion modeling, and how to calculate potential cancer risk. Nine potential receptors are assumed to lie directly south of an east-west free-flow freeway with a peak hour traffic count of 11,900 vehicles. The freeway is assumed to be 120 feet wide, with an additional 10 feet on each side to account for the wake of moving vehicles<sup>5</sup>, making for a total link width of 140 feet.

This example is based on an EMFAC run for the year 2009.

This example represents one specific scenario. For guidance on other CAL3QHCR modeling scenarios not contained herein, contact your local air district or consult the User's Guide to CAL3QHC, Version 2.0<sup>6</sup>.

### *Data Sources*

This example scenario relies on basic information needed to complete the site specific HRA. Such information includes:

- meteorological data
- traffic data (from Caltrans), later developed into hourly data
- vehicle emissions (derived from EMFAC)
- location of the nearest sensitive receptor (proposed by the project) to the edge of the travel lane, in addition to the generic receptor locations, if required (for example, at 10, 25, 50, 100, 200, 300, 400 and 500 feet) in X-Y coordinates
- roadway orientation in terms of its X-Y coordinates (arbitrary origin / 0,0), including length and width

The above information, including additional information required by the model, is further discussed in the ensuing sections of this document.

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<sup>5</sup> The mixing zone is an area where dispersion results are considered to be inaccurate.

<sup>6</sup> User's Guide to CAL3QHC Version 2.0, EPA-454/R-92-006 (Revised, with CAL3QHCR addendum), September 1995.

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### ***Finding the Peak Hour Traffic Count***

The peak hour traffic count nearest to the proposed receptors is used to develop the hourly traffic count information for input into CAL3QHCR. The peak hour traffic count should be found on Caltran's website at <http://www.dot.ca.gov/hq/traffops/saferesr/trafdata/index.htm>. Select back peak hour for projects south or west of the nearest milepost location. For projects north or east of the nearest milepost location, select ahead peak hour.

For the scenario considered herein, the Caltran's data indicates a peak hour traffic count of 11,900 vehicles.

### ***Running EMFAC to Produce Hourly PM10 Emissions and Data on Vehicle Miles Traveled***

The most current version of EMFAC should be run to determine preliminary vehicle miles traveled (VMT) and emissions data. The VMT data will be used to develop the hourly traffic count information required by CAL3QHCR, and the PM10 exhaust emissions data will be used to determine the hourly PM10 emissions rates for input into CAL3QHCR.

The EMFAC run should be based on the following parameters:

- Year: first year of project build out
- Season: annual
- Burden: standard
- Output Frequency: hourly

The following data from the EMFAC output file will be used:

- VMT/1000 for each hour
- PM10 emissions for each hour

Figure 3 is a screen shot of the first page of the EMFAC output file. The circled hourly data is the data that will be used.

For a conservative approach, this methodology recommends use of total exhaust emissions for *all* vehicles. Studies continue to point to the toxicity of not only diesel exhaust, but also vehicle exhaust, for which there is no assigned toxicity value.



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## Figure 3: Example Scenario EMFAC Output, Page 1

Version : Emfac2007 V2.3 Nov 1 2006  
 Run Date : 2008/02/06 15:08:23  
 Scen Year: 2009 -- All model years in the range 1965 to 2009 selected  
 Season : Annual  
 Area : Sacramento Metropolitan AQMD Averag  
 I/M Stat : Enhanced Interim (2005) -- Using I/M schedule for area 31 Sacramento (SV)  
 Emissions: Tons Per Hr00

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	Light Duty Passenger Cars				Light Duty Trucks			Medium Duty Trucks			Heavy Duty Trucks			Urban Buses	Motor-cycles	All Vehicles				
	Non-cat	Cat	Diesel	Total	Non-cat	Cat	Diesel	Total	Non-cat	Cat	Diesel	Total	Gasoline Trucks				Diesel Trucks	Total MD Trucks		
Vehicles	7632.	483025.	1673.	492331.	5806.	307893.	8213.	321912.	1391.	117094.	9051.	127537.	1330.	11346.	12677.	18201.	30878.	371.	34494.	100750.
VM/1000	1.	160.	0.	162.	1.	109.	2.	112.	0.	41.	21.	63.	0.	1.	1.	50.	51.	0.	3.	391.
Trucks	256.	25555.	78.	25889.	198.	16328.	423.	16950.	76.	8729.	3082.	11887.	326.	1629.	1954.	965.	2920.	16.	580.	3824.
Total Organic Gas Emissions																				
Run Exh	0.01	0.01	0.00	0.02	0.01	0.01	0.00	0.02	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.03	0.04	0.00	0.01	0.10
Idle Exh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Start Ex	0.00	0.02	0.00	0.02	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.02	0.00	0.02	0.00	0.00	0.07
Total Ex	0.01	0.03	0.00	0.04	0.01	0.02	0.00	0.03	0.00	0.02	0.00	0.03	0.01	0.01	0.02	0.04	0.06	0.00	0.01	0.17
Diurnal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hot Soak	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Running	0.01	0.02	0.00	0.02	0.00	0.02	0.00	0.02	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Resting	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Total	0.02	0.06	0.00	0.08	0.01	0.05	0.00	0.06	0.00	0.03	0.00	0.04	0.01	0.01	0.02	0.04	0.06	0.00	0.02	0.26
Carbon Monoxide Emissions																				
Run Exh	0.10	0.36	0.00	0.45	0.08	0.31	0.00	0.39	0.05	0.14	0.02	0.20	0.01	0.01	0.03	0.15	0.18	0.00	0.14	1.37
Idle Exh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01
Start Ex	0.01	0.21	0.00	0.22	0.01	0.16	0.00	0.17	0.00	0.18	0.00	0.18	0.06	0.19	0.25	0.00	0.25	0.00	0.01	0.82
Total Ex	0.10	0.57	0.00	0.67	0.09	0.47	0.00	0.56	0.05	0.31	0.02	0.38	0.07	0.20	0.28	0.16	0.44	0.00	0.15	2.21
Oxides of Nitrogen Emissions																				
Run Exh	0.01	0.04	0.00	0.05	0.00	0.05	0.00	0.06	0.00	0.03	0.11	0.14	0.00	0.01	0.01	0.73	0.74	0.01	0.00	1.00
Idle Exh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.02
Start Ex	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.02	0.00	0.02	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.06
Total Ex	0.01	0.05	0.00	0.06	0.01	0.06	0.00	0.07	0.00	0.05	0.11	0.16	0.00	0.02	0.02	0.76	0.77	0.01	0.00	1.08
Carbon Dioxide Emissions (000)																				
Run Exh	0.00	0.06	0.00	0.06	0.00	0.05	0.00	0.05	0.00	0.03	0.01	0.04	0.00	0.00	0.00	0.09	0.09	0.00	0.00	0.25
Idle Exh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Start Ex	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Total Ex	0.00	0.06	0.00	0.06	0.00	0.05	0.00	0.05	0.00	0.03	0.01	0.04	0.00	0.00	0.00	0.09	0.09	0.00	0.00	0.25
PM10 Emissions																				
Run Exh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.03
Idle Exh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Start Ex	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Ex	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.03
TireWear	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BrakeW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Total	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.04
Lead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SOx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fuel Consumption (000 gallons)																				
Gasoline	0.08	6.49	0.00	6.57	0.07	5.48	0.00	5.55	0.03	2.91	0.00	2.94	0.03	0.13	0.16	0.00	0.16	0.02	0.07	15.32
Diesel	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	1.11	1.11	0.00	0.00	0.00	8.26	8.26	0.07	0.00	9.53

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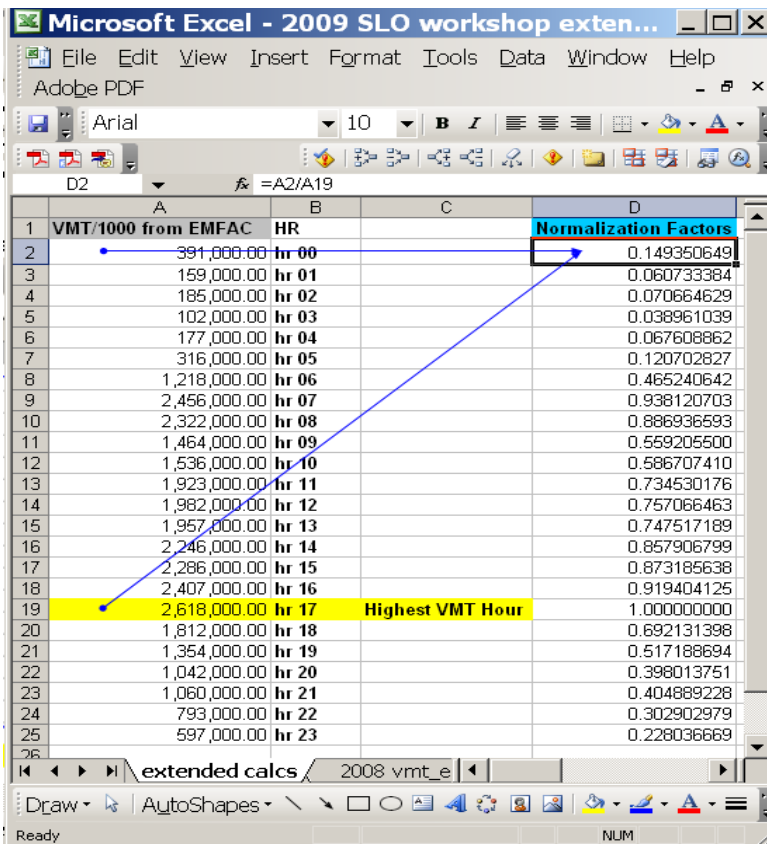
Title : 2009 info  
 Version : Emfac2007 V2.3 Nov 1 2006  
 Run Date : 2008/02/06 15:08:23  
 Scen Year: 2009 -- All model years in the range 1965 to 2009 selected  
 Season : Annual  
 Area : Sacramento Metropolitan AQMD Averag  
 I/M Stat : Enhanced Interim (2005) -- Using I/M schedule for area 31 Sacramento (SV)  
 Emissions: Tons Per Hr01

# Technical Appendix to the Recommended Protocol for Evaluating the Location of Sensitive Land Uses Adjacent to Major Roadways

## Preparing the Hourly Traffic Count Data

To develop hourly traffic count values needed by CAL3QHCR, first find the highest hourly VMT count reported by EMFAC. In this scenario, the highest hourly VMT count is 2,618,000 miles, which falls on Hour 17. Then, divide each hourly VMT value from EMFAC by the highest hourly VMT count. See Figure 4: Example Scenario Development of Normalization Factors below. Each result is known as a normalization factor. Each normalization factor is then multiplied by the project's peak hour traffic count from Caltrans (11,900). The results are normalized hourly traffic volumes for input into CAL3QHCR. See Table 5 for this scenario's hourly traffic data.

**Figure 4: Example Scenario Development of Normalization Factors**



**Table 5: Example Scenario Normalized Traffic Counts**

Time of day	Traffic veh/hr
Hr 00	1777
Hr 01	723
Hr 02	841
Hr 03	464
Hr 04	805
Hr 05	1436
Hr 06	5536
Hr 07	11164
Hr 08	10555
Hr 09	6655
Hr 10	6982
Hr 11	8741
Hr 12	9009
Hr 13	8895
Hr 14	10209
Hr 15	10391
Hr 16	10941
Hr 17	11900
Hr 18	8236
Hr 19	6155
Hr 20	4736
Hr 21	4818
Hr 22	3605
Hr 23	2714

## **Technical Appendix to the Recommended Protocol for Evaluating the Location of Sensitive Land Uses Adjacent to Major Roadways**

### ***Preparing Hourly Emissions Data***

PM10 emissions data is reported by EMFAC in tons/hour and needs to be converted to grams/hour. The grams/hour then need to be divided by the overall VMT per hour for each hour (as reported by EMFAC) to obtain grams per vehicle mile needed for input into CAL3QHCR.

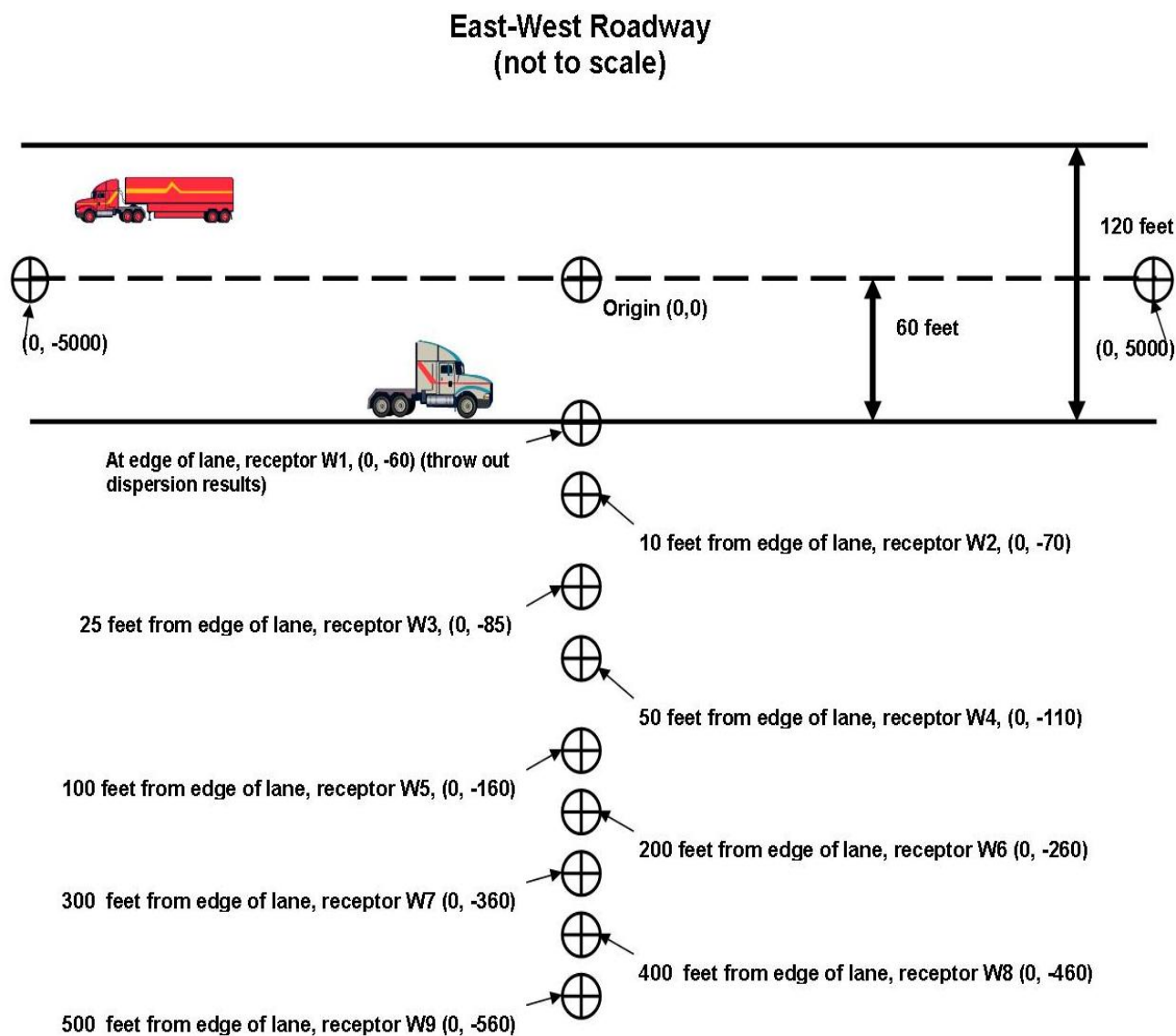
### ***Defining the Calculational Domain for the Input File***

The CAL3QHCR input file requires data that defines the calculational domain. The X-Y coordinates (arbitrary origin, y axis aligned with north) of the beginning and end of the roadway section being modeled as well as and the link width (mixing zone) of the roadway need to be defined. Always allow for an additional 10 feet added to the edge of nearest travel lane to the receptors to account for the wake of moving vehicles. The minimum roadway length is 10,000 feet. The elevation of the roadway compared to the surrounding area needs to be specified. For roadways at grade the height is 0; for elevated roadways the relative height is positive; and for depressed roadways the relative height is negative. The z-coordinate (receptor breathing height) needs to be defined. The default recommendation is 6 feet.

In this scenario, the freeway is 120 feet wide, and after accounting for the wake, the total link width becomes 140 feet. The length of the roadway modeled is 10,000 feet, or 5,000 feet on each side from the center point. The roadway is at grade. A modeling receptor has been placed at the edge of the roadway to define the roadway dimensions; however the dispersion results for this receptor should be discarded as a 70 year exposure at the roadway edge is unlikely. See Figure 5 below.

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Figure 5: Example Scenario East-West Roadway and Receptors Illustration



Other parameters required by the model need to be defined. Table 6 below discusses recommended and/or default parameters. Any changes to the default recommended values should be thoroughly explained.

## Technical Appendix to the Recommended Protocol for Evaluating the Location of Sensitive Land Uses Adjacent to Major Roadways

**Table 6: Other Recommended Parameters for Input into CAL3QHCR**

Parameter	Default	
Calculation averaging time (min)	60	
Surface roughness (cm, from 3 to 400). For mixed uses and others not listed here, the modeler should make a reasonable assumption.	single family	108
	offices	170
	apartments	370
Settling velocity (cm/s)	0	
Deposition velocity (cm/s)	0	
Site setting (U=urban, R=rural)	U	
Form of traffic volume, emission rate data (1=one hour's data, 2=one week of hourly data)	2	
Pollutant (P for PM10 to give output in $\mu\text{g}/\text{m}^3$ )	P	
Hourly ambient background concentration ( $\mu\text{g}/\text{m}^3$ )	0	
Roadway height indicator (AG=at grade, FL=elevated and filled, BR=bridge, DP=depressed)	AG	
Roadway height (ft, 0 if AG, relative height if FL, BR, or DP)	0	

### ***Preparing the CAL3QHCR Files***

#### **Downloading CAL3QHCR**

Download the CAL3QHCR model from EPA's Preferred/Recommended Dispersion Models website at [www.epa.gov/scram001/dispersion\\_prefrec.htm](http://www.epa.gov/scram001/dispersion_prefrec.htm). There are five files needed to run the program: the input file (.inp), the batch file (.bat), the control file (.ctl), the meteorological data file (.asc), and the executable file (.exe).

Decide on a name for the run. The name of the example scenario run is "2009south11900k".

Note that in setting up your run, you will be editing over data already present in the files.

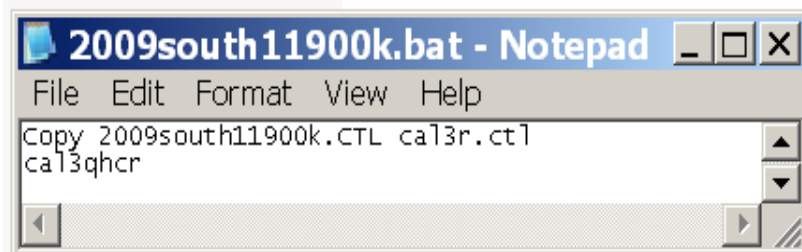
#### **Prepare the Batch File (.bat)**

The batch file is the DOS file batch command.

Right click on the file to open it for editing. Note that opening or double clicking on the file will cause the program to run. If this happens, simply delete the files the program creates and start again. Once the file is open, type in the name of your run after the word "Copy". Save the file with the name of the run. See Figure 6 below for the example scenario batch file.

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**Figure 6: Example Scenario Batch File**

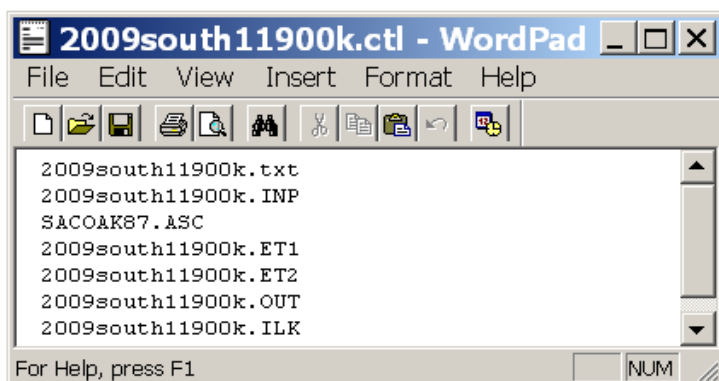


### Preparing the Control File (.ctl)

CAL3QHCR looks to the control file to find the file names that are read into the program and outputted by the program.

Type the name of your run in front of each file extension, except the .ASC file, where you will type in the meteorological data file name. Save the control file with the name of your run. See Figure 7 below for the example scenario control file.

**Figure 7: Example Scenario Control File**



### Meteorological File (.asc)

The meteorological file should be in the .asc format. Contact your local air district for the recommended meteorological file. This file will not be edited.

### Executable File (.exe)

The executable file runs the program. This file will not be edited.

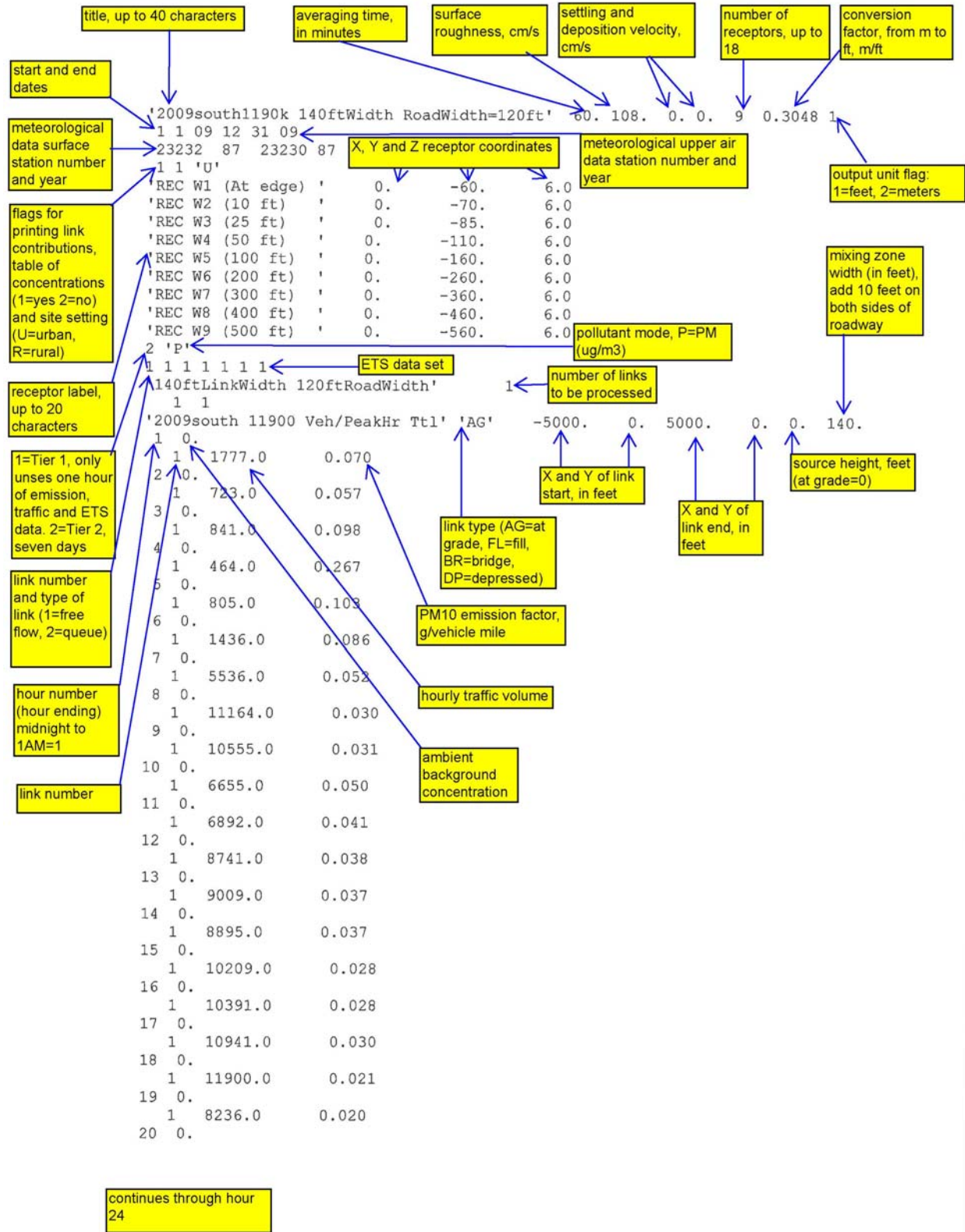
### Prepare the Input File (.inp)

The input file contains scenario parameters.

Prepare the input by editing over an example file provided with the model download, or by editing over a file provided by the local air district that more closely reflects the setup needed for this type of roadway modeling. Save the input file with the name of your run. See Figure 8 below for the example scenario input file and input explanations.

# Technical Appendix to the Recommended Protocol for Evaluating the Location of Sensitive Land Uses Adjacent to Major Roadways

**Figure 8: Example Scenario Input File and Input Explanations**



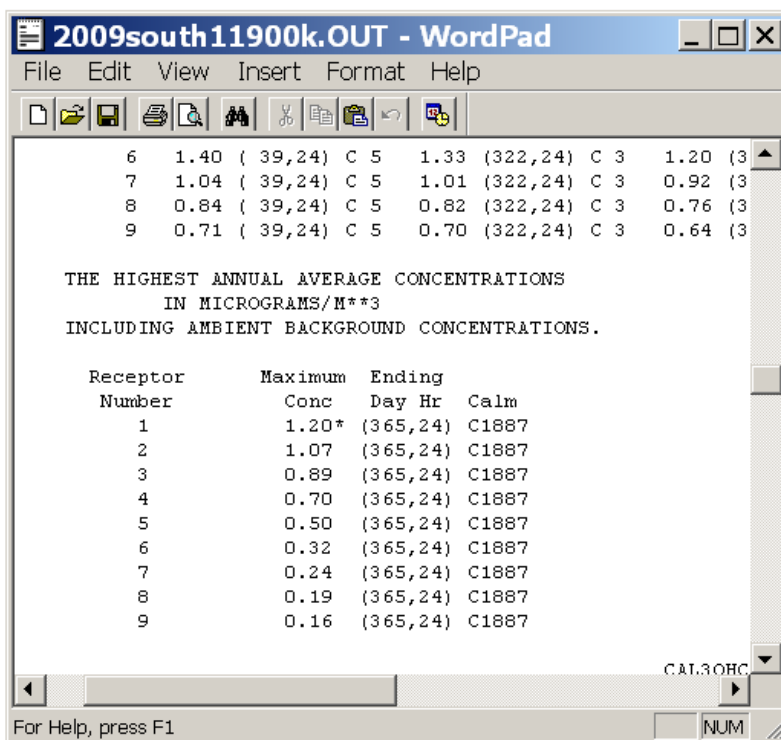
## Technical Appendix to the Recommended Protocol for Evaluating the Location of Sensitive Land Uses Adjacent to Major Roadways

### Running the Model and Calculating Potential Cancer Risk

Double click on the .bat file to run the model. The model will produce a series of files with extensions .ET1, .ET2, .ILK, .OUT, .txt, and .ctl. Open the .txt and check to be sure the run was error-free.

The output file (.OUT) will show, among other information, the highest annual average concentrations. See Figure 9 below for the relevant section of the example scenario output file.

**Figure 9: Example Scenario Output File, Highest Annual Average Concentrations**



The cancer risk assessment methodology should follow the recommendations contained within ARB's Recommended Interim Risk Management Policy for Inhalation Based Cancer Risk, which was established in consultation with the Office of Environmental Health and Hazard Assessment (OEHHA). Where a single cancer risk value for a sensitive receptor is needed for risk management decisions, the ARB recommends that the breathing pathway be based on the 80<sup>th</sup> percentile breathing rate. The 80<sup>th</sup> percentile breathing rate is the midpoint value of the percentile range between the mean and high-end points of value for the breathing pathway. The 80<sup>th</sup> percentile corresponds to a breathing rate of 302 Liters/kilogram-day.

To calculate potential cancer risk using the 80<sup>th</sup> percentile breathing rate, the inhalation dose must first be determined. The inhalation dose is calculated as follows:

$$Dose = \frac{(C_{air})(DBR)(A)(EF)(ED)(1 \times 10^{-6})}{AT}$$



## Technical Appendix to the Recommended Protocol for Evaluating the Location of Sensitive Land Uses Adjacent to Major Roadways

Where:

- Dose = Dose through inhalation (mg/kg/d)  
 $1 \times 10^{-6}$  = Micrograms to milligrams conversion ( $10^{-3}$  mg/ $\mu$ g),  
 liters to cubic meters conversion ( $10^{-3}$  m<sup>3</sup>/l)  
 Cair = Concentration in air ( $\mu$ g/m<sup>3</sup>), annual average from CAL3QHCR  
 DBR = Daily breathing rate (L/kg body weight-day or L/kg-day)  
 A = Inhalation absorption factor  
 EF = Exposure frequency  
 ED = Exposure duration  
 AT = Averaging time

SMAQMD recommends the default values shown in Table 7 for input into the inhalation dose equation.

**Table 7: Recommended Default Values for Dose Equation**

EF	350 days/year
ED	70 years
AT	70 years (25,550 days)
DBR	302 (80 <sup>th</sup> percentile) L/kg body weight-day
A	1

The following example dose calculation is based on an average annual concentration of 0.70 $\mu$ g/m<sup>3</sup> for Receptor 4 in Figure 9 above:

$$\text{Dose} = \frac{\left(\frac{0.70 \mu\text{g}}{\text{m}^3}\right) \left(\frac{302 \text{L}}{\text{kg} - \text{day}}\right) (1) \left(\frac{350 \text{days}}{\text{year}}\right) (70 \text{years}) \left(\frac{1 \times 10^{-3}}{1 \mu\text{g}}\right) \left(\frac{1 \times 10^{-3} \text{m}^3}{\text{liters}}\right)}{25,550 \text{days}}$$

$$\text{Dose} = 2.027 \times 10^{-4} \text{ mg/kg-day}$$

Once the dose is obtained, it is multiplied by the cancer potency factor of 1.1 mg/kg-day, and then by  $1 \times 10^6$  to express the risk per million people. The equation for calculating cancer risk is as follows:

$$\left(\text{Inhalation Dose} \frac{\text{mg}}{\text{kg} - \text{day}}\right) \left(\frac{\text{kg} - \text{day}}{\text{mg}}\right) (1 \times 10^6) = \text{Cancer Risk}$$

For the above calculated dose of  $2.027 \times 10^{-4}$  mg/kg-day, cancer risk is calculated as follows:

$$\left(2.027 \times 10^{-4} \frac{\text{mg}}{\text{kg} - \text{day}}\right) \left(1.1 \frac{\text{kg} - \text{day}}{\text{mg}}\right) (1 \times 10^6) = 223 \text{ chances per million people}$$

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The factor incorporates worst case, health-protective assumptions. Cancer potency factors (CPFs) are established using data from animal and epidemiological (human) exposure studies. The CPF represents the increased chance or probability of developing cancer assuming continuous lifetime exposure and other health-protective assumptions. In cancer risk assessments, it is assumed that the potential risk is directly proportional to the dose and there is no threshold for carcinogenesis. Cancer potency factors are expressed as the upper bound probability of developing cancer assuming a continuous lifetime exposure to a substance at a dose of one milligram per kilogram body weight, and are expressed in units of inverse dose as a potency slope [i.e., (mg/kg/day)<sup>-1</sup>].

Table 8 below displays the cancer health risk values for the sample project at various distances.

**Table 8: Example Scenario Potential Cancer Cases per Million**

	Distance from Edge of Nearest Travel Lane (feet)							
	10	25	50	100	200	300	400	500
PM10 cancer risk	340	273	223	159	102	76	60	51

### ***Modeling Diagonal Roadways***

SMAQMD has developed an Excel tool that defines the x-y coordinates of receptors located at 10, 25, 50, 100, 200, 300, 400 and 500 feet in diagonal modeling situations. The tool assumes a roadway link origin of 0, 0 and requires the x-y coordinates for the end of the roadway link being modeled (a mapping program can be used to find this coordinate). The tool can be found at <http://www.airquality.org/ceqa/index.shtml#SensitiveLU>.

CAL3QHCR offers many other features that allow modeling traffic intersections, traffic signaling, and traffic queuing. Employing these features is quite site-specific. If these features must be employed, the user's guide should be consulted.