Report No. SR2013-07-01

Conceptual Research Studies to Assess the Feasibility of Near-Roadway Pollution Mitigation Technologies: Vegetative Barriers

prepared for:

South Coast Air Quality Management District

July 31, 2013

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CONCEPTUAL RESEARCH STUDIES TO ASSESS THE FEASIBILITY OF NEAR-ROADWAY POLLUTION MITIGATION TECHNOLOGIES: VEGETATIVE BARRIERS

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EXECUTIVE SUMMARY

The purpose of this research was to investigate the conceptual feasibility, design, benefits, and effectiveness of roadside barriers, especially vegetative barriers, in reducing roadway air quality impacts on nearby receptors. The study was carried out by Sierra Research, with field sampling and related support by subcontractor T&B Systems of Valencia, California.

The study was based primarily on computer modeling using results from AERMOD, a dispersion model approved by the U.S. Environmental Protection Agency. The selection and application of the model was guided by an analysis of data from a brief (five day) field study that was conducted in the Lake Balboa District of Los Angeles County in June of 2012 (see the Google Earth photo in Figure ES-1, below, annotated with sampling site names).

Figure ES-1
Field Study Site in the Lake Balboa District of Los Angeles County

This field study site was selected primarily because it afforded a location within the South Coast Air Quality Management District (SCAQMD, or District) where measurements could be made downwind from a busy freeway, in this case north of US Highway 101, at sites having a vegetative barrier and also at nearby control sites with similar traffic, meteorology, etc., but without the vegetative barrier.

Conclusions of the study are summarized below. These are based on the results of the sampling study and the conceptual modeling study of the dispersion of on-road vehicle pollutants downwind of a heavily trafficked freeway, both with and without near-roadway vegetative barriers.

1. Roadside barriers, whether vegetative or other, have the potential to either increase or decrease near-roadway concentrations (compared to the case of no barrier), depending on a number of factors, including roadway height, barrier height, wind speed, and others. The effects of these and other factors upon dispersion are reasonably estimated based on modeling for the case of meteorology observed and configuration of the subject study site.

2. Substantial effort was made to identify the optimum vegetative barrier study site for model calibration, but no ideal site was found in the SCAQMD. The study site ultimately selected and sampled for five days in June 2012 was an elevated freeway segment with adjacent vegetative barrier in Lake Balboa, California. Measured data were used successfully to validate application of the AERMOD air quality model at the study site.

3. Downwind measurements of NOx concentrations during the brief field study showed isopleth concentrations that were generally parallel to the freeway as expected. However, under the sea breeze conditions that were targeted in the monitoring program, the downwind study area tended to be in the wake downwash of the freeway and of one or more barriers, resulting in a complex pattern of downwind concentrations, both measured and modeled. In all cases, the highest monitored location was located immediately behind the vegetated barriers, which was also the closest sampling location to the freeway.

4. In analyzing measured data, treating barriers as roughness elements was unproductive. Instead, treating them as buildings with potential for downwash yielded more predictable results.

5. For the study site, measurement data suggested, and modeling estimates tended to confirm, that a taller barrier resulted in lower ground-level concentrations in the downwind cavity, which is presumed to be due to greater dilution.

6. From the current study data, the point-source approach to modeling barriers in AERMOD was best at wind speeds above 3.2 m/s, and the volume-source approach was best at wind speeds of 1.6 – 3.2 m/s; neither approach was very good at lower wind speeds (although the volume-source approach was probably

best). The point-source approach works better at higher wind speeds because building-wake downwash, which occurs at higher wind speeds and is associated with vegetative and other roadside barriers, can be simulated.

7. Modeling results, which examined hypothetical barrier heights ranging from 33–100 feet, further suggested that as barriers were reduced in height, the modeled source concentrations increased and shifted closer to the freeway. Conversely, the taller a barrier was,[1] the farther from the freeway the modeled contribution shifted, to the point where the maximum was no longer always right at the edge of the freeway, but further away. The distribution of impacts also broadened, forming zones where concentrations were heightened.

8. The sensitivity of modeling results to relatively small changes in wind speed in the field study pointed to the need for great care in air quality modeling practice, particularly under lower wind conditions.

9. For a hypothetical at-grade roadway that otherwise meets the specific conditions of the current study site, modeling results suggested that a barrier has a near-field air quality benefit, a (smaller) disbenefit at intermediate distances, and no significant effect at further distances.

10. Results from an exploratory modeling study of the dispersion of unit freeway emissions in the vicinity of a hypothetical adjacent multi-building block of structures downwind of a vegetative barrier (as referenced in Section 4-3 and depicted in Figure 4-4) were consistent with a pattern of downwash and elevated concentrations partially downwind of the barrier. Other possible effects on measured concentrations from the subject vegetative barriers, such as pollutant removal by deposition, were considered, but no significant effects could be documented.

11. While direct individual comparisons are problematic due to differences in sites, conditions, etc., the current modeling results tended to be consistent with previously reported study results to the extent that previous modeling conditions (including roadway height) were sufficiently detailed to compare. Where roadway heights were not reported, consistency could not be evaluated.

Consideration of the downwash effects from roadside barriers provides a new perspective on dispersion from roadways and on the potential for providing benefits from barriers in the near-roadway environment. Key elements that are new from this work are documentation of the importance of roadway elevation in understanding downwind effects and the identification of at-grade roadways as possible sites where the benefits of roadside barriers can be maximized. Importantly, however, the analysis indicates that it is not possible to generalize the benefits of freeway barriers. For this reason, it is

[1] The height where this occurred was not determined precisely—it could vary depending on the height of the freeway or other factors.

recommended that when a project includes such barriers, data be collected on the key parameters determined to influence the calculation of those benefits, including freeway height, barrier height relative to the freeway, appropriate wind directions and other meteorological data, etc. These factors need to be accounted for in any assessment of potential benefits of near-roadway barriers, vegetated or otherwise.

###

1. INTRODUCTION AND BACKGROUND

1.1 Study Purpose

This purpose of this research was to investigate the conceptual feasibility, design, benefits, and effectiveness of selected mitigation measures in reducing roadway air quality impacts on nearby receptors, with a focus on vegetative barriers. The study was carried out by Sierra Research with field sampling and related support by subcontractor T&B Systems of Valencia, California.

The remainder of this section provides background and major findings from a literature review on roadside barrier effects, including vegetative barriers. Section 2 provides information on a brief roadside monitoring study conducted as part of this investigation, Section 3 discusses modeling of roadside concentrations, and Section 4 discusses effects of alternative designs. Section 5 presents Study Conclusions and Recommendations. Supporting documents are provided in a series of appendices.

1.2 Background and Literature Review

A literature search was conducted on near-roadway barriers and air pollution, considering both porous barriers (e.g., vegetative) and impervious barriers (e.g., sound walls, berms, etc.) The search was conducted via a comprehensive library search at Caltrans headquarters and a search of the Transportation Research Board's (TRB's) TRID database.[2] We also conducted a broader internet search. From these and other sources, including personal contacts, a list of the most pertinent references was compiled. Results are summarized below with additional details in Appendix A, which also provides the full listing of documents reviewed.

The cited literature shows that when the wind is approximately perpendicular to the roadway, near-roadway barriers, including certain types of vegetative barriers, offer the potential to reduce the concentration of primary roadway pollutants in the area immediately downwind of the roadway. This finding is supported by measurement, modeling, and wind-tunnel type studies. The research further shows that near-roadway reductions on the order of 50% or more are possible. However, important caveats apply.

[2] As described by TRB, "TRID is an integrated database that combines the records from TRB's Transportation Research Information Services (**TRIS**) Database and the OECD's Joint Transport Research Centre's International Transport Research Documentation (**ITRD**) Database."

Relatively few studies have measured the full range of actual wind speeds and directions (i.e., long-term monitoring), including winds that aren't perpendicular to the roadway, and on-road impacts. However, even with the most commonly studied case of fixed and relatively simple geometry of perpendicular winds, the amount by which concentrations are reduced can vary significantly, depending upon dispersion conditions, traffic, type of pollutant, and other factors.

There is evidence that barriers can, under certain conditions, increase concentrations upwind of the wall and on-road. In addition, modeling studies indicated that the mechanism of lofting emissions—which produces an immediate reduced concentration—may also result in a higher concentration at some point downwind when the plume "reattaches" to the surface. Depending upon conditions, reattachment distances have been estimated from about 3 to 30 barrier heights downwind.

Porous vegetative barriers are generally ineffective as noise barriers but can offer concentration reduction benefits both by lofting pollutants (similar to impervious noise barriers) and, potentially, by removal of pollutants. The former effect is much more important for near-roadway concentrations.

Gaining a better understanding of the role of vegetation in mitigating air quality impacts from traffic has been the subject of a number of workshops sponsored by the U.S. Environmental Protection Agency (EPA)[3] and others[4] and continues to be an active area of research.

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[3] See, for example, "The Role of Vegetation in Mitigating Air Quality Impacts from Traffic Emissions," at *http://www.epa.gov/nrmrl/appcd/nearroadway/workshop.html* (accessed 9/17/2011)
[4] See 2012 Vegetation Conference, at *sacbreathe.org.*

2. MEASURING CONCENTRATIONS NEAR A ROADSIDE VEGETATIVE BARRIER

The current study was designed with an integral roadside sampling element that was intended to help guide the selection of a dispersion model and its application. This section describes the site selection; equipment and methods used; and results from the brief sampling study, which was conducted over five days in June of 2012.

2.1 Site Selection

The field study sought a sampling site with a vegetative barrier and similar nearby control site with no barrier. The sites would need to have substantially the same traffic and meteorological conditions—ideally nothing would be changed except for the presence of the vegetative barrier. Both sites should afford access to the downwind study area where measurements could be made at any desired distance downwind of the roadway, from near roadside to as much as 500 meters downwind. For practicality of downwind sampling, a site with repeatable, predictable winds was required.

Seven candidate study sites located in the District were considered in detail and reviewed in consultation with District staff. Three of the candidate sites[5] (actually site pairs) had been used in prior studies that included assessment of roadside barrier effects, but those studies focused on sound walls rather than vegetative barriers, and review of the study sites did not show the presence of a suitable vegetative barrier site and control site. A fourth candidate site has been used by the District for long-term freeway monitoring (Polidori 2010), but no vegetative barrier and matched control site could be identified. One candidate site in the eastern part of the LA Basin was identified with assistance from District staff, but that too was found to be unsuitable, primarily due to topography.

Ultimately, two sites were deemed potentially suitable: the Harbor Freeway (I-110) north of the I-405 junction in Long Beach, and the Ventura Freeway (US 101) west of the I-405 junction in the Lake Balboa District of Los Angeles County. These were visited by a member of the Sierra team in order to perform a first-hand site assessment, and were photographed for documentation. A summary of the most critical features of each site is provided in Table 2-1, which also includes a list of the desired features for the ideal site. As noted earlier, and in the table, the Lake Balboa site was characterized by an above-grade freeway segment.

[5]Sioutas (2011) used monitoring sites adjacent to I-5 and I-710, and Zhu et al. (2002) used the I-405 freeway and adjacent National Cemetery.

Table 2-1
Prospective Sites in the SCAQMD for Measuring Vegetative Barrier Effects Downwind of Freeways

Parameter	Ideal Site	Long Beach Site, Harbor Freeway, (I-110) n. of I-405	Lake Balboa Site, Ventura Freeway (US101) w. of I-405
Area wind	Regular, predictable cross wind, e.g., afternoon sea breeze	Yes	Yes
Local wind	Free of local influences, e.g., hills, large buildings, trees	Yes	OK
Topography	Flat. Upwind, downwind and freeway all at-grade	Yes	No Freeway segment is above grade
Freeway	Predictable, heavily trafficked	Yes	Yes
Barrier site	Prefer vegetation barrier only, but may be veg. barrier with sound wall	W. 157th Sound wall and low trees	Tall trees and bushes
Control site	Everything same as barrier site except the barrier	Trees only, thick but not tall; 0.2 miles N of veg. barrier site	Sound wall upwind of freeway, no barrier downwind; 0.1 miles E of veg. barrier site
Access	No access issues. Free travel perpendicular to freeway to ~300m	Private property; limited control site access at <50m	Private property; (farm land)
Security	No security issues. Overnight equipment safe	OK	OK
Distance	Close to sampling team home base to minimize travel and maximize data collection	moderate – would limit on-site sampling time	Excellent
Emission sources	Free of interfering stationary or mobile sources, similar sources upwind and downwind of barrier and control	Complex mix at barrier site; reasonably uniform at control site	Uniform farm land
Other	-	Suitable loop adjacent to freeway	Suitable loop adjacent to freeway

While each of the candidate sites appeared to offer a potentially usable site pair and both land owners expressed a willingness to cooperate in the study by affording access for sampling, neither candidate was ideal. In particular, the Harbor Freeway site had only a relatively low vegetative barrier (and sound wall) on the downwind side and quite poor access in the vicinity of the barrier due to conflicting land uses. The Lake Balboa site had a taller barrier and good access due to farmland, but more complex terrain and geometry, and it had a sound wall on the upwind side. Ultimately, the better sampling access at Lake Balboa led the Sierra team to select that as the preferred study site. District staff reviewed the details of each site and the selection process and concurred on the chosen site.

Figure 2-1a shows a Google Earth image of the selected study site, which is located in Los Angeles County. The site encompassed a section of the Ventura Freeway (US Highway 101) having mixed use development to the south and farmland/seasonal floodplain to the north, bounded by trees and Burbank Boulevard. Van Nuys Airport is located about 2 miles to the north, and Interstate 405 (San Diego Freeway) is located about 1 mile to the east. The annotated Google Earth photo corresponds roughly to the measurement and modeling domain.

As described in the next section, measurements were concentrated in specific locations (labeled as 'Roadside x') north of the freeway (typically downwind), but were sometimes made at other points as well, including one background site south of the freeway and a few brief traverses along the freeway and roads to the east and west. As noted above, this segment of Highway 101 runs approximately east-west and is elevated about 25 feet above the grade level to the south and to the north. Less noticeable, but also important to interpreting the study results, is the presence of a low sound barrier on the upwind (south) side of the freeway. The shadow of this barrier is evident in the photo, extending about 2/3 of the way across the photo from the right (eastern) side.

Additional important features of the site to note in the figure are the tall roadside trees on both the north and south sides of the freeway (i.e., upwind and downwind of the freeway) on the west side of the study domain (left half of Figure 2-1a), and the absence of such vegetative barriers on the east side. The monitoring site labeled "Roadside 4" can be seen in the shadow of the downwind tree barrier.

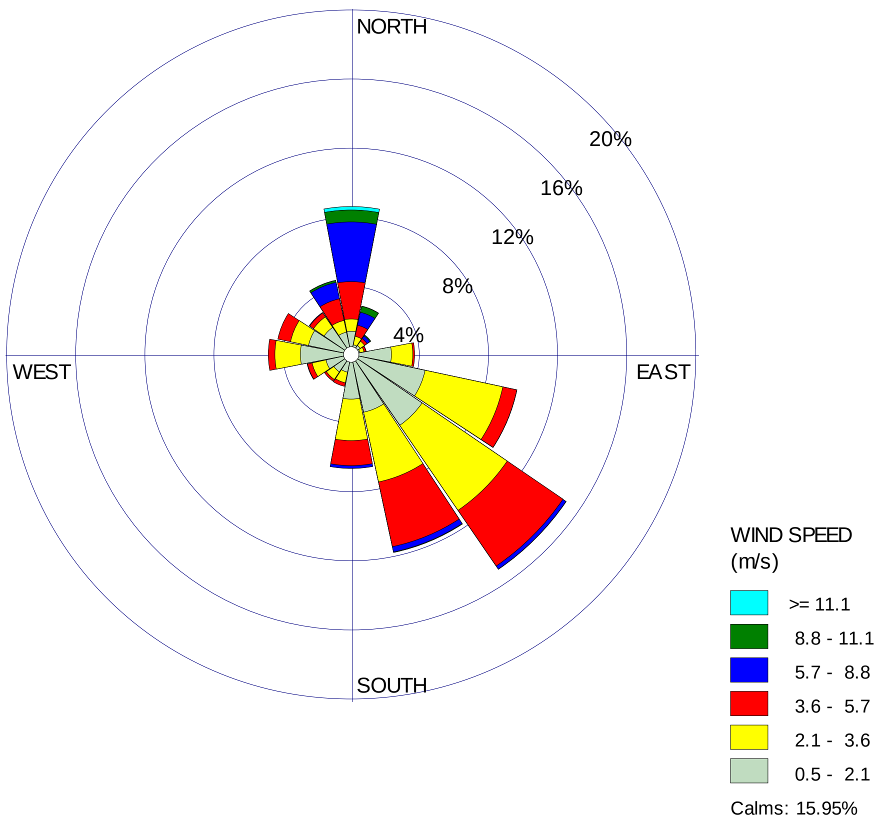
Figure 2-1b shows the view of the SW corner of the study site from approximately the "Roadside 5" sampling location, looking toward the SE (photo by B. Baxter of T&B Systems). In the foreground is the two-height anemometer meteorological tower (along with the sampling vehicle), positioned here at the site labeled "Met West." Most of the study area was planted in strawberries at the time (unlike the fallow ground shown in the much earlier Google Earth photo). In the background is the elevated Highway 101 section, lined on the north side (as shown) by moderately thick deciduous trees and shrubs that extended up to about 25 feet above the height of the freeway segment.

Figure 2-1a
Study Site – Ventura Freeway in the Vicinity of Lake Balboa, CA

Figure 2-1b
View to the SE from "Roadside 5" Showing Samplers and Vegetation

The ten-year wind rose from nearby Van Nuys Airport[6] (Figure 2-2) shows that winds from the southeast quadrant are dominant in the study area. The field study was conducted in early June, at which time a (southeast) sea breeze typically develops by noon and persists into early evening. That pattern was, in fact, observed on most days in the chosen sampling window from June 4–11, 2012, as well as on all five selected study days.

Figure 2-2
Van Nuys Airport Windrose Plot



2.2 Field Study Plan – Equipment and Methods Used

The express purpose of the brief (five-day) field study was to provide data for comparing with the study's air quality model, but the field study data also assisted in selecting the model to use and in providing key insights on how to configure the model.

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[6] Source: Iowa Environmental Mesonet, Iowa State University Department of Agronomy, accessed 10/7/2011.

A specific goal of the sampling was to collect data in enough locations downwind of the freeway—i.e., to the north of it—to characterize the anticipated spatial gradients in freeway vehicle concentrations in the study area both behind the vegetative barrier (west side of the study domain) and where no downwind barrier was present (east side of the study domain). The period of interest for sampling and modeling was when the winds were from the southern quadrant, near perpendicular to the freeway. Under this condition, the sampling locations would be downwind (to the north) of the freeway.

The field sampling was scheduled at a time of year and times of day when persistent sea breeze winds were most likely and were expected to persist for the weeklong sampling study, which was mid to late June from mid-afternoon to early evening. Accordingly, the sampling window was set for mid- to late June in 2011, and nominally from about 12-5 pm PDT each day. Weather reports were monitored until a multiday period with afternoon sea breezes was forecast, at which time a sampling van was deployed to set up two meteorological towers and to conduct brief periods of pollutant monitoring along a circuitous route having successive air monitoring stops. Five days of sampling were conducted, although these were punctuated by several "stand-down" days when weather was forecast (correctly) to be unsuitable (limited or no sea breeze).

Two meteorological towers were deployed in order to capture conditions in the modeling domain downwind of both the vegetative barrier and the non-vegetative barrier portions of the freeway. One tower (shown earlier in Figure 2-1b) provided wind measurements (speed and direction) at two elevations (7.6 and 2.7 meters), while the other monitored a single elevation (2.7 meters). Wind speeds and directions were determined using R.M. Young AQ anemometers at one-second intervals, which were recorded on CSI CR1000 data loggers and subsequently used for 1-minute, 15-minute, and hourly average calculations.

During sample days, concentration measurements along the freeway and profiles downwind of the freeway were obtained by T&B Systems by means of an instrumented sampling vehicle (Figure 2-3). The vehicle continuously monitored and recorded PM_1, $PM_{2.5}$, PM_7, and PM_{10} (TSI model DustTrak DRX[7]); CO (API model 300E); and NO/NO2/NOx (API model 200E, chemiluminescent analyzers). The NOx analyzer used was a Federal Equivalent Method. Operations were consistent with what is needed to maintain the FEM designation, so the instrument precision is best characterized by the manufacturer's specification, which is 0.5% of reading.[8] The precision is a measure of repeatability, which for this application was very good when comparing location-to-location concentrations because the same instrument was used for all measurements.

[7] The DustTrak used in the sampling van was kindly loaned to the study project by the SCAQMD.
[8] *http://www.teledyne-api.com/products/200e.asp*

Figure 2-3
Instrumented Sampling Vehicle Operated by T&B Systems

The absolute accuracy of the NOx measurements is determined from the calibrations, as no audits were conducted. The instrument had a full multipoint calibration performed at the start of the program and zero/span checks prior to sampling each day. The results of the daily zero/span checks provided small offsets (but no slope change) and these were applied to the final data. Considering the quoted uncertainty in the EPA protocol gases used for calibration, T&B Systems judged the final data accuracy to be better than 5% and likely within 2%. This is the absolute accuracy of the data, not the precision or repeatability described above.

The monitoring van followed a fixed loop pattern within the test area, stopping to collect approximately 5-10 minutes of concentration measurements at each of six designated downwind sites from the freeway (three positions each for the open vs. vegetated downwind roadside areas). Generally, the route of the sampling vehicle proceeded in a circular loop around the perimeter of the field. In this way, each “circuit” or “sampling loop” could be completed in about one hour, essentially providing a snapshot of the gradients downwind of the barrier and non-barrier segments of the study area. An on-board geographical positioning system (GPS) recorded vehicle speed and Carchip data were used to document the periods where the vehicle was stationary. Following two complete sample loops, the van sampled upwind (south) of the freeway and then made a stop at the location of the stationary DRX for comparison purposes. The cycle would then be repeated for a total of about four hours each day. Direction of the driving loop was varied to help minimize possible bias (from sampling at sites going toward or away from the freeway).

All data loggers (van, meteorological tower, and DustTrak DRX) were synchronized to Pacific Daylight Time from a common computer at the start of each sample day. Time drift of all loggers was less than 5 seconds during the day. The gaseous analyzers had a multipoint calibration at the start of the study and had a zero and span performed prior to sampling each day. The DustTrak DRX in the van had a flow calibration and size shape calibration performed at the start of the sampling. Prior to and at the conclusion of each sample day the unit had a zero check performed. The $PM_{2.5}$ data recorded on the data logger are limited to 250 ug/m^3; however, the digital data from the DRX provide the full dynamic range. The DustTrak 8832 had a flow calibration performed prior to the sampling period and, like the DRX, had a zero check performed at the start and end of each sample day.

The engine was normally turned off when the van was parked briefly at each of the sampling locations.[9] It is important to recognize that the first minute or so after arrival at a sampling site may reflect the dust and/or exhaust that was generated by the sampling van. Additionally, because of the response time of the gaseous analyzers, it is important to use only the last three to four minutes of data while parked at a given location (as determined from the indicated speed).[10] The DRX response was much faster as it was set to a one-second time constant.

Profiles were not precisely perpendicular to the freeway—particularly towards the vegetative barrier to the west, profiles were canted from perpendicular. There were three regions where measurements were concentrated:

- An eastern area, intended to be barrier-free, but actually often subject to the effects of a 6-8’ sound wall on the south (upwind) side of the freeway;

- A western area, adjacent to a vegetative barrier, and on the near-side of vegetative barrier with respect to the freeway; and

- For the last two days of measurements, a second further west area, adjacent to the same vegetative barrier, but on the far (northwest) side of vegetative barrier with respect to the freeway.

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[9] Use of a Davis Instruments Carchip recorded dates and times of engine starts and durations, documenting engine shutdowns and sampling times. The resulting trip log summary is included with Field Notes in Appendix C.

[10] Note that in a few cases, stops were very brief but gaseous instruments appeared stable—in these cases, the values were retained so as not to exclude the measurement points.

Initially, the two-height anemometer tower was located at the "Met East" location and the one-height anemometer was located at Met West, but locations were swapped during the measurement period in order to provide the best characterization of both sites (with the taller, two-instrument tower). Regardless of location, however, data for the modeling were chosen from the higher of the two-mast data (height = 7.6 m), since that height is closest to EPA recommendations for met data gathered for use in regulatory dispersion modeling.

Additional details about the sampling program may be found in the Field Study Plan in Appendix B. Sampling study results are discussed in the following section.

2.3 Field Study Results

Sampling was conducted on June 4, 5, 7, 8, and 11, 2012, typically from about 12:00 pm to 5:00 pm. Daily field study notes that describe both the routine daily measurements and any unusual events are provided in Appendix C.

For the purposes of the current study, NOx measurements tended to be the most useful marker for roadway emissions, allowing the unit roadway impacts to be distinguished from background concentrations.[11] Measured CO concentrations (not shown here, but included in the data files compiled from the study) generally mimicked and supported the behavior of measured NOx concentrations.

Highest concentrations initially were near Roadside 4, which was also the nearest site to the roadway (see Figure 2-4, which has been rotated slightly and scaled to correspond approximately to the contour plots which follow). Subsequent sampling was done at sites 7, 8, and 9 to try to locate the peak. Also, on the last field study day, sites A, B, C, and AA (seen in Figure 2-1) were sampled briefly to look for a possible PM attenuation effect behind the 100-foot thick barrier, but there was no discernible effect on the generally low concentration, noisy PM data.

NOx concentration measurements are presented in a series of isopleth plots (Figures 2-5 through 2-9), each of which corresponds to one selected traverse by the sampling vehicle of the main sampling loop (corresponding to sampling points 1, 2, 3, 6, 5, 4, if traveling in the counterclockwise direction.) Thus, each plot attempts to show, for a snapshot in time, the gradient in roadside concentrations as one moves northward (downwind) from the freeway both on the west side (generally downwind of the vegetative barriers) and on the eastside (with no vegetative barriers). The ordinate and abscissa represent the UTM[12] Northing and Easting, respectively (units are meters).

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[11] The field measurements collected upwind of the freeway were too few and scattered to characterize background concentration precisely; thus, no such estimate is presented. Nor was it necessary to assume a background concentration to reasonably reconcile the modeling results with measurements.

[12] The Universal Transverse Mercator (UTM) system is a two-dimensional Cartesian system that assigns coordinates based on metric distance (meters) expressed in a "northing" and "easting" pair; these axes align approximately north-south and east-west within each particular UTM zone.

Figure 2-4
Modeling Domain Image, Rotated and Scaled to Match Contour Plots

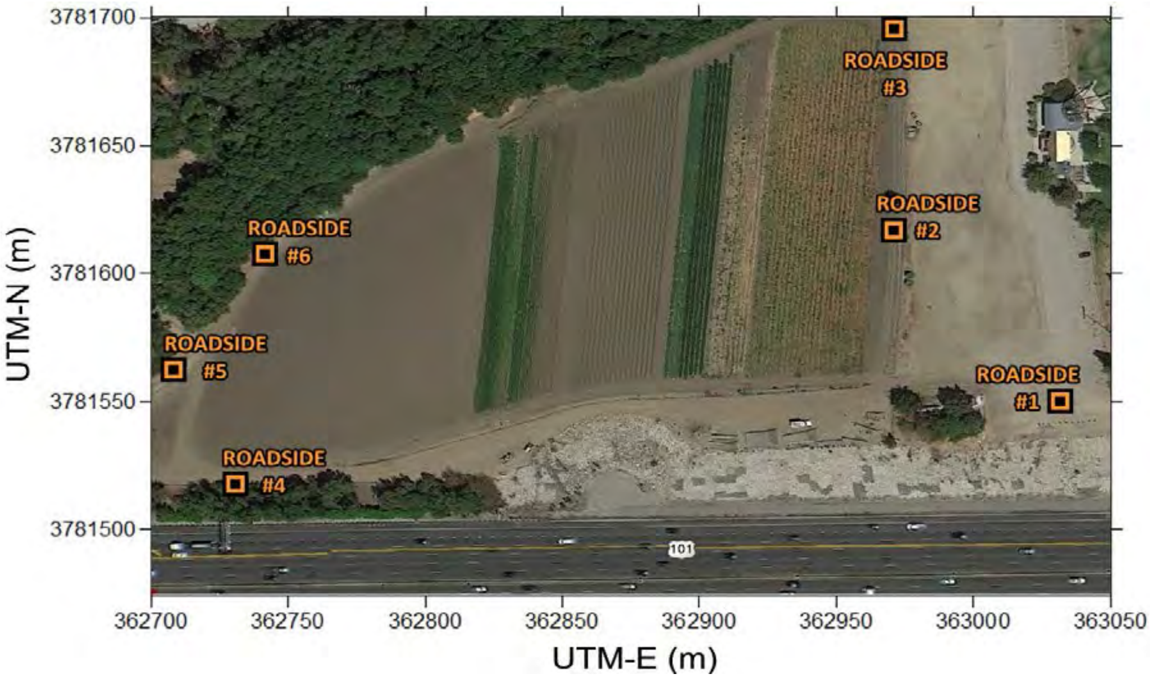
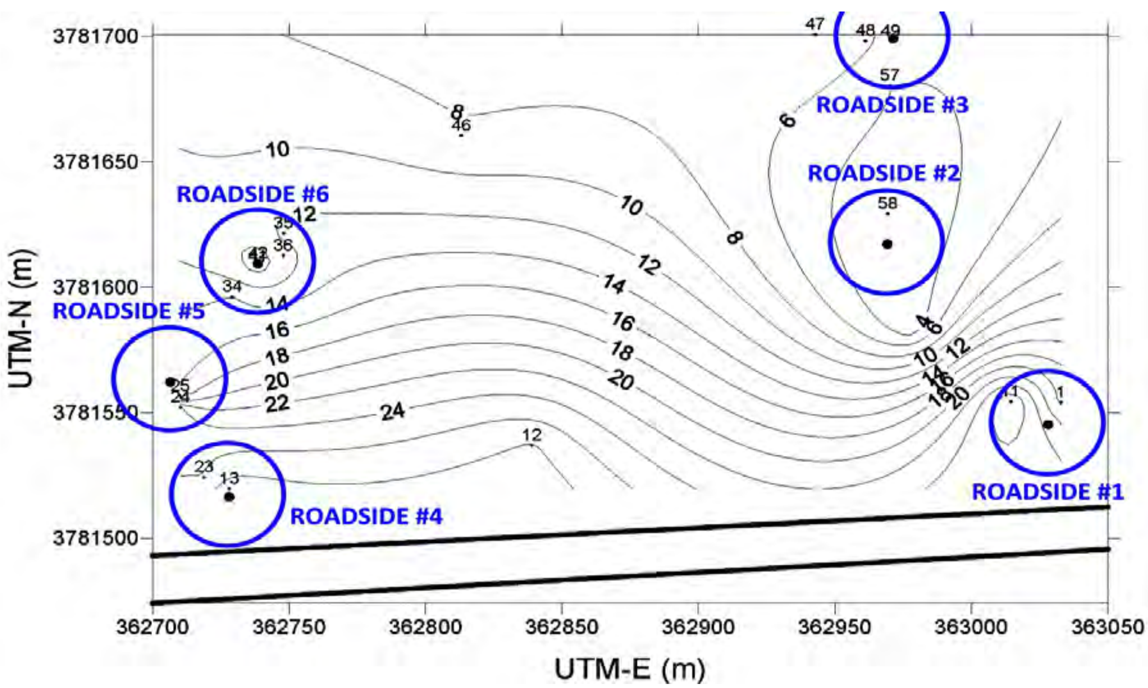


Figure 2-5
NOx Isopleths for First Mobile "Circuit" on June 4, 2012; Wind 179º at 1.98 m/s
(Concentration labels in bold are ppb by volume)



Bold numerical values in the figures represent "best fit" values for the isopleth lines showing contours of constant concentration.[13] Measurement locations are marked with a dot and labeled with a lightly shaded numerical value,[14] such as "11" and "1" at the lower right in Figure 2-5, with the number representing the number of minutes after the start of the sampling circuit when the sample at each measurement point was collected. Roadside sampling sites1-6 are circled and labeled in each plot.

In the fairly typical period of sampling represented in the figures, the start and end of the clockwise sampling loop were separated by about 60 minutes—although not a true snapshot, this was felt, due to the relatively short traverse time, to reasonably represent the ambient concentration gradients.[15] For each case shown, isopleths of concentration tended to be roughly parallel to the freeway, and readily discernible gradients usually existed moving away from the freeway, as expected (the approximate centerlines of eastbound and westbound lanes are denoted by the two parallel lines toward the bottom of each figure). As discussed later, the sampling vehicle was stopped and (except for rare, very brief stops) the engine was turned off when measurements were taken. Therefore, idling exhaust from the sampling vehicle was not expected to affect the concentration measurements significantly (this is especially true for NOx, which typically has extremely low emissions at idle for late-model vehicles).

Figure 2-5 shows NOx concentration isopleths for the first sampling circuit on the afternoon of June 4, 2012 (time 14:59 – 16:07). Winds during this sampling period were from the south (average wind speed 1.98 m/s and direction 179 degrees), nearly perpendicular to the freeway. A zone of higher concentration is visible on the right, as well as a low-concentration zone a short distance north. The high concentration zone may be associated with the sound wall on the upwind side of the freeway (as discussed later); however, it is important to note that there is a declining intensity of the hot spot on the eastern end. Winds that are more parallel to the freeway likely shift the hot spot along the freeway, and away from locations where measurements were collected.

Two days later, on June 6, the first sampling loop of the day (time 12:52 – 14:01) saw winds from the southeast (average wind speed 2.92 m/s, direction average 133 degrees) and a diminution of the eastern hot spot (see Figure 2-6), although concentrations overall in the area are higher than on June 4. Continuing the same pattern, the first circuit on June 7 (time 12:24 – 13:35) showed winds from the southeast (average wind speed 2.21 mph, average wind direction 134 degrees), and further reduction in the peak concentrations on the east side of the study domain (Figure 2-7). However, as the wind shift continued later in June 7 (time 14:27 – 14:39), the eastern high concentration vanished (Figure 2-8, average wind speed 3.45 m/s, direction 127 degrees and Figure 2-9, average wind speed 3.52 m/s, direction 157 degrees).

[13] Isopleths maps were prepared using Surfer, Scientific Software Corp, Sandy, Utah.
[14] Sampling locations in the contour maps are based on contemporaneously measured GPS coordinates; on different dates and times they may differ from the typical locations shown in Figures 2-1 and 2-4.
[15] For this clockwise vehicle traverse, sampling points defining the gradient along the western (left side) perpendicular were closer in time than on the right; later drives were performed in the counterclockwise direction to help minimize any resulting bias.

Figure 2-6
NOx Isopleths for First Mobile "Circuit" of June 6, 2012; Wind 134º at 2.92 m/s

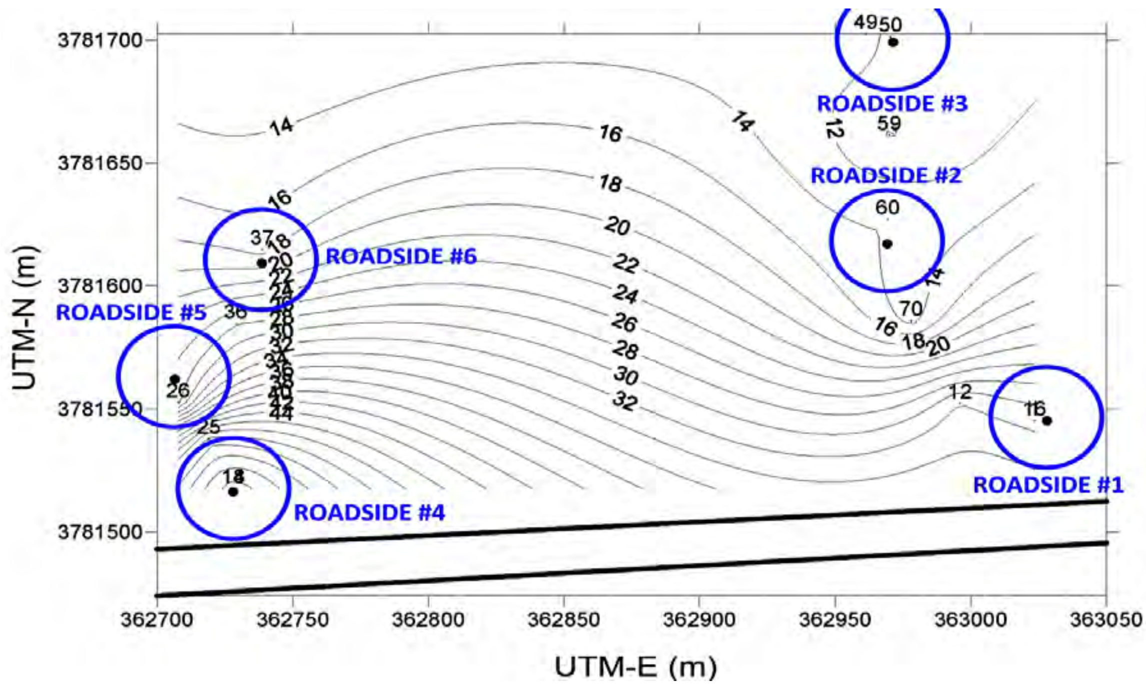


Figure 2-7
NOx Isopleths for First Mobile "Circuit" of June 7, 2012; Wind 134º at 2.21 m/s

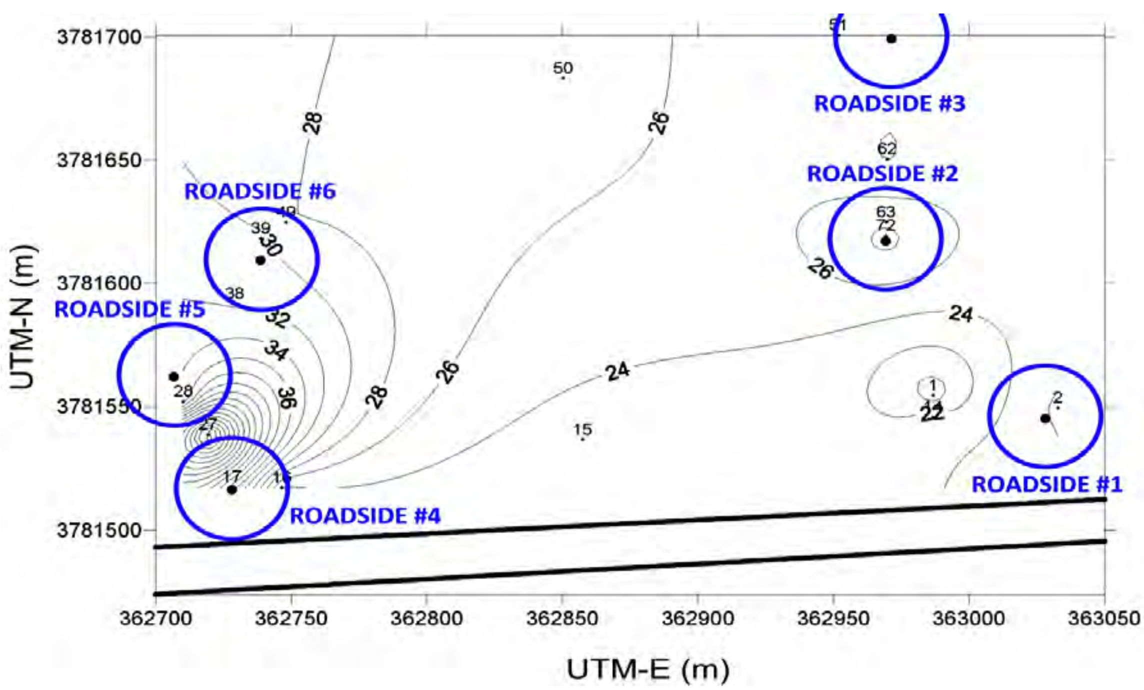


Figure 2-8
NOx Isopleths for Third Mobile "Circuit" on June 7, 2012; Wind 127º at 3.45 m/s

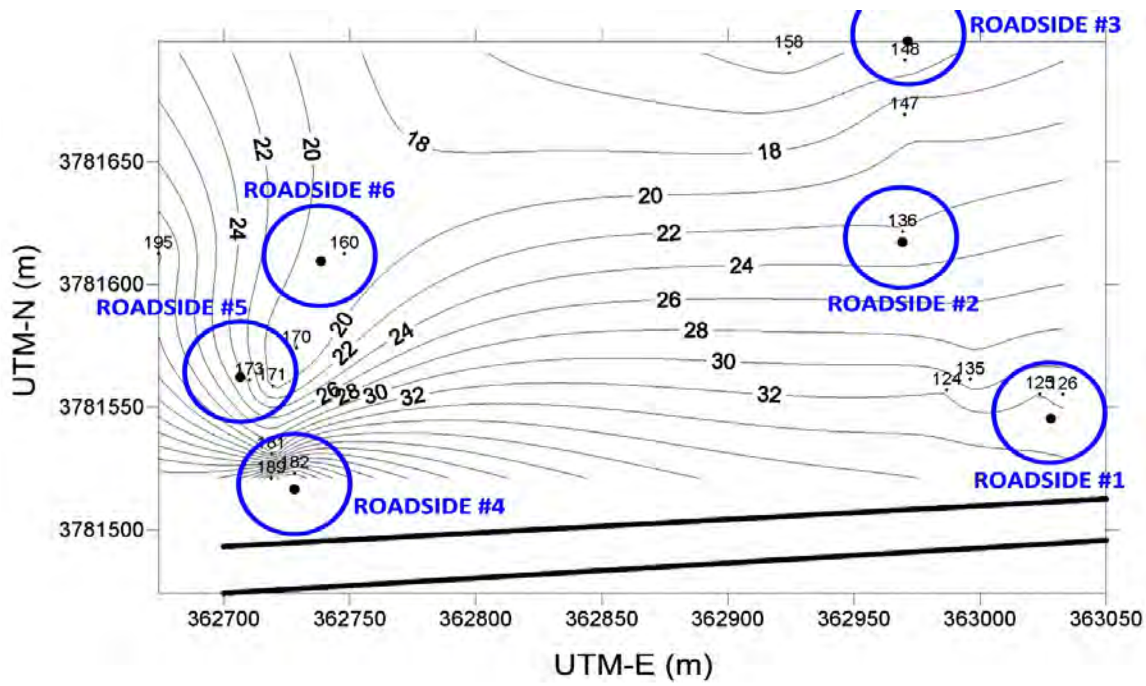
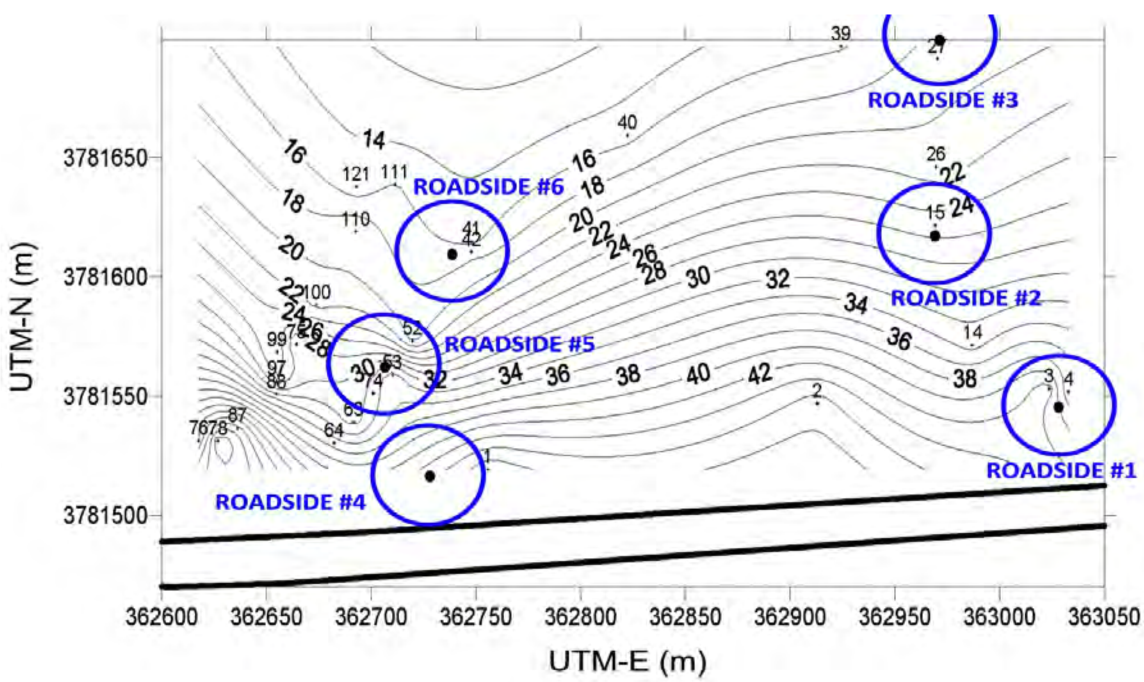


Figure 2-9
NOx Isopleths for First Mobile "Circuit" on June 8, 2012; Hour 12:00-14:00; Wind 157° at 3.52 m/s



Notably, measurement locations in the eastern part of the modeling domain are excluded from the "GEP [Good Engineering Practice] 5L region of influence"[16] of the sound wall at wind directions less than 125 degrees—nearly identical to the wind direction of about 130 degrees at which enhanced concentrations are observed to disappear. This observation suggests that downwash from the sound wall may be responsible for the enhanced concentrations at the higher wind angles.

PM data in several size ranges were also collected, but no clear gradients were seen for the fine PM concentrations in the size ranges that were sampled, which is likely due to the fact that roadway contributions at this site are relatively small compared to ambient fine PM concentrations. Results may differ for other sites and especially for gases and particles that have a shorter atmospheric lifetime, such as 1,3-butadiene[17] and ultrafine particles (Sioutas, 2011).

Additional measurement data and discussion of wake downwash effects are presented in Section 3, which also compares measurements and modeling results, and in Appendix D, which illustrates the building downwash-affected regions for winds from several different directions.

Lastly, while field study measurements have been discussed here in the context of barrier effects, it is important to bear in mind that the outdoor concentrations of primary pollutants from motor vehicles tend to be correlated with distance from the roadways, more so than for secondary pollutants generated in the atmosphere and from regional sources (Polidori and Fine, 2012). This roadway distance-effect is evident in Figure 2-10, which shows the average NOx concentrations at the six measurement sites (Roadside 1 – 6) on the sampling loop plotted as a function of perpendicular distance of each site from the centerline of the westbound freeway lane. For this analysis, only the stops of approximately 10 minutes at the six fixed locations were considered. Concentrations averaged over 10 minutes at these six points fall nearly on a smooth curve, suggesting that distance from the freeway is the primary variable and the effects of the barriers (vegetation, sound wall, etc.) are secondary. Note too that Site No. 4, which had the highest average concentrations, is not only the closest of the west-side sites downwind of the vegetative barrier, but also the closest of all sites to the freeway. For comparison of concentrations of sites at the same distance, site no. 1 (no vegetation) should probably be compared with vegetated site no. 5, and in that comparison, the nonbarrier site no. 1 had the higher average concentration. This fact adds to the uncertainty about attributing the higher average concentrations on the west side to vegetation alone and drawing any conclusion about higher maxima in the western portion of the measurement domain.

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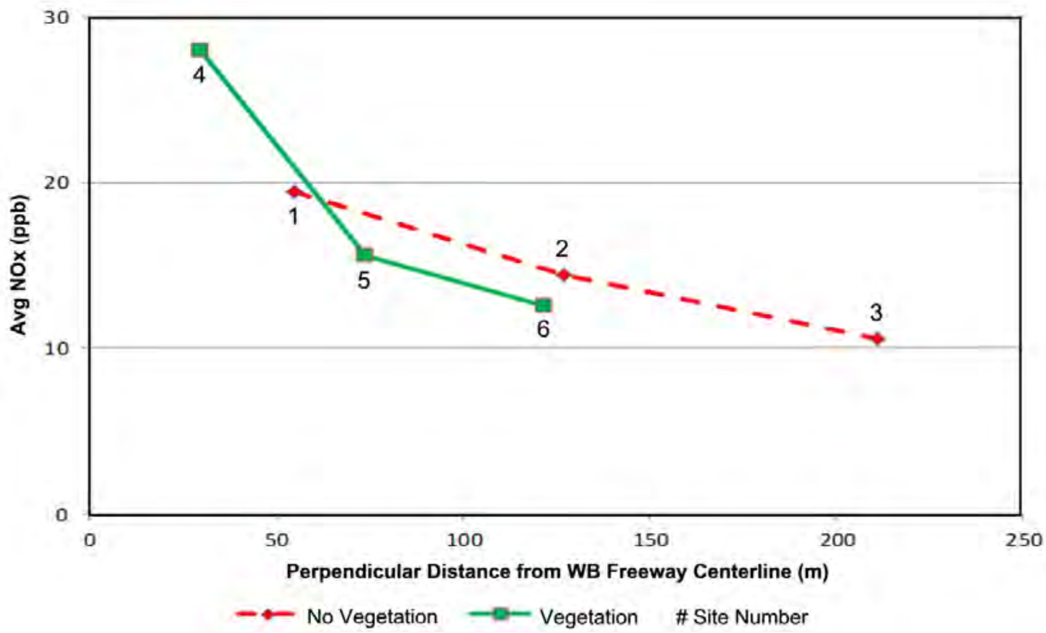
[16] According to EPA, "Sources situated within 5 times the lesser of the height or the width dimension of a structure but not greater than 0.8 km (0.5 mi.) downwind from the trailing edge of the structure are presumed nearby enough to the building to be of concern in determining downwash potential" (Source: "Guideline for Determination of Good Engineering Practice Stack Height" (Technical Support Document for the Stack Height Regulation), revised, U.S. Environmental Protection Agency, EPA-450/4-80-023R, June 1985).
[17] See, for example, *http://www.epa.gov/ttn/atw/hlthef/butadien.html*.

Figure 2-10
Avg. NOx Concentration vs. Downwind Distance at Sampling Sites with (site nos. 4-6) and without (site nos. 1-3) Roadside Vegetative Barriers (includes data from all sample periods of about 10 minutes; labels are site nos.)



In summary, concentrations dropped as one departed the freeway, going north, whether behind a roadside vegetative barrier or not. Behind the barriers in the western end of the measurement domain, concentrations tended to be consistently higher than in the middle part, where barriers were fewer, although sampling tended to be closer to the freeway (as constrained by site limitations). In the eastern end, concentrations could also be high, but in a much more fleeting manner that appeared to be associated with wind direction. As a result, average concentrations tended to be higher on the west side than the east (e.g., Figure 2-9). However, it's difficult to state with assurance whether the eastern or western hot spots had a higher magnitude, because monitoring coverage of the eastern area was sparser. Occasional high readings and the presence of sharp gradients on the eastern side suggest that it may be subject to greater variation and higher concentrations than were observed in this limited sampling program. Wind directions less than 130 degrees from the southeast were not associated with any hot spot activity—only winds more from the south, at wind direction angles greater than 130 degrees. The likely explanation is that the eastern hot spot is caused by the sound wall on the south side of the freeway. Further modeling was required to help distinguish these effects.

###

3. MODELING CONCENTRATIONS NEAR A ROADSIDE VEGETATIVE BARRIER

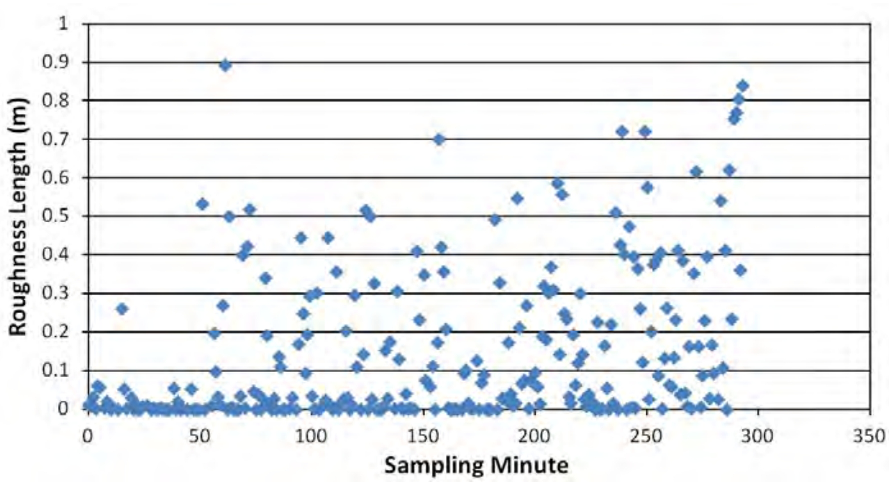
Two possible approaches to modeling the effect of vegetative and sound barriers on dispersion in the vicinity of a freeway were investigated:

- Treat the barriers as roughness elements[18] when processing the meteorological data; or
- Treat the barriers as buildings.

The first approach quickly ran into difficulties. Assuming a log-wind profile, and knowing wind speeds at two anemometer heights, roughness lengths were calculated. Roughness lengths were neither stable nor consistent, but instead showed substantial scatter when plotted against time of data collection (see Figure 3-1, below).

The approach of treating barriers as buildings yielded more predictable results.

Figure 3-1
Calculated Roughness Length (z0) vs. Minute of Day 1 Afternoon Sampling, Eastern Meteorological Sampling Site



[18] As used here, "roughness elements" means anything that will disrupt the smooth flow of air.

3.1 Roughness Length

Calculations of roughness length at the first two-mast anemometer site (Met East, eastern area, away from vegetative barriers, minute-by-minute, June 4 meteorological data only) showed mostly low turbulence levels, and resulting low, calculated roughness lengths, punctuated by bursts of turbulence, and much higher, calculated roughness lengths. The observations suggest that this area is just downwind of the upwind soundwall's "GEP 5L region of influence."

The "Met East" site (which can be seen in the earlier Figure 2-1) is often likely in what is called the "wake region," just downwind of the reattachment point of the air flow after being disrupted by some obstacle. Wind directions (not shown here) from generally 140 to 170 degrees appear particularly prone to higher turbulence levels. Winds that are either more parallel to the freeway (90 to 140 degrees in this case), or more perpendicular (170 to 240 degrees), are less likely to generate higher turbulence levels.

3.2 Modeling Setup

A number of air quality models are available for estimating dispersion from highway emission sources, including CAL3QHCR, Caline-4, and AERMOD. Although the absence of initial dispersion sometimes renders AERMOD somewhat unsuitable for representing highways, it was chosen in this case in order to represent the complex system to be modeled. AERMOD (Version 12060) was run with hourly, on-site meteorological data (both two-anemometer tower data using the upper anemometer, and Van Nuys ASOS surface meteorology). The remainder of this section describes the rationale for the source representation used in the model, and other aspects of the site-specific-configuration of the model.

3.2.1 Point- vs. Volume-Source Modeling

Sources and receptors were entered in the Lakes Environmental[19] modeling setup. Flat terrain was assumed, with receptor height of zero meters. Generally, highway sources are configured in models as volume sources; however, the current effort needed to account for various "buildings" and other bluff structures that can alter the wind flow, and this required configuring the sources as points, because the AERMOD building-wake algorithms work only for point sources. Accordingly, volume sources were set up in Lakes and then exported and reimported into AERMOD as point sources. The resulting point and volume sources were tracked as separate source groups, and the modeled results from the two source groups were validated against each other. There were 55 westbound sources and 54 eastbound sources, each representing a short, straight segment of the freeway in one direction within the modeling domain. The roadbed for the elevated freeway was represented as a "building."

[19] Lakes Environmental, 60 Bathurst Drive, Unit 6, Waterloo, Ontario, N2C 2A9, Canada.

Parameters for representing the on-road emissions as volume sources included the following:

- Source height = 7.62 meters, or 25 feet;
- Initial plume width = 17 meters, or 3 freeway lane widths of 12 feet, plus 20 feet on either side, according to usual CAL3QHC[20] convention; and
- Initial sigma y = 7.91 meters, and initial sigma[21] z = 3.54 meters.

Alternatively, the following parameters were used to represent the on-road emissions as point sources:

- Source height = 7.62 meters, or 25 feet;
- Plume temperature = -2 K (which tells the model that it is an ambient temperature release); and
- "Stack" exit velocity = 0.001 m/s and "stack" diameter = 1 meter (these virtual stack parameters essentially zero out the momentum term of the internal plume rise algorithm).

Interestingly, modeling results appeared to be very insensitive to meteorological data assumptions regarding roughness length. Apparently the building wake downwash assumptions in AERMOD largely override roughness length assumptions and the modeling results appear to correlate better with measurements when meteorological data are processed with the assumption of greater roughness, so Z_0 = 1 meter was assumed throughout. Nevertheless, urban dispersion was not used, since parameters like anthropogenic heat flux seem mostly to affect dispersion at night, and these field operations were conducted in daytime. Furthermore, specification of urban dispersion would have imposed roughness lengths on the modeling, and it was desired to retain control over those parameters.

Hourly averaged wind speeds, directions, and temperatures were processed as on-site met data in AERMET, the meteorological data preprocessor for AERMOD. Stability information is based on San Diego National Weather Service sounding data and cloud cover, per usual AERMET practice. Measured minute-by-minute turbulence data were not used for this purpose.

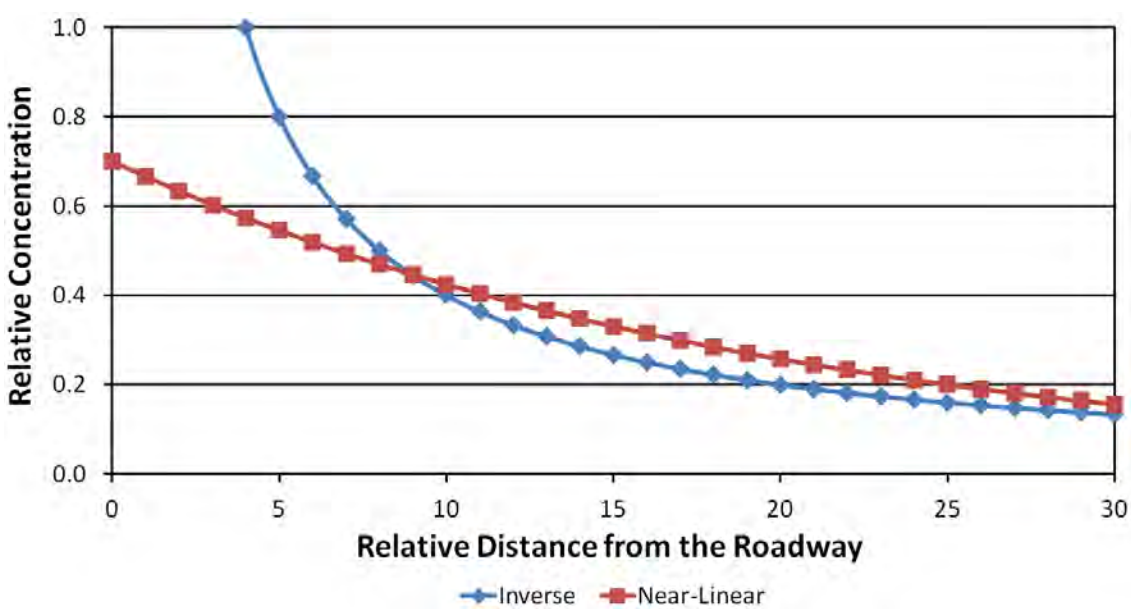
It is not possible for AERMOD to make calculations for time periods shorter than an hour. AERMOD uses hourly met data, and not the minute-by-minute meteorological data the project made available. Nevertheless, meteorological conditions are not changing dramatically over the hour because the distances between source and receptors are so

[20] See, for example: "User's Guide to CAL3QHC, Version 2; A Modeling Methodology for Predicting Pollutant Concentrations Near Roadway Intersections," EPA-454/R-92-006 (revised), U.S. EPA, September 1995.
[21] Sigma y and sigma z represent the initial standard deviation of the plume dispersion in the horizontal and vertical, respectively.

short (limiting plume meander) and the sources are distributed upwind quite evenly; therefore, minute-by-minute concentrations will not vary much over an hour and will thus be similar to an hourly averaged concentration calculated from those minute-by-minute data. The narrowness of minute-averaged plumes will be offset by the even distribution of sources across a broad front upwind of the receptors. Offsetting effects should make AERMOD results broadly applicable. In addition, AERMOD is a steady-state model, not a puff model, and thus assumes plumes will reach infinite distances downwind, even if puffs cannot reach those distances within an hour.

In general, modeling for freeway sources—using either the CALINE family of models[22] or AERMOD for volume sources—shows that concentrations drop roughly inversely with distance from the edge of the freeway. Measurements in the current field study indicate something different: a nearly linear drop with distance from the edge of the freeway, tailing off eventually to a roughly inverse drop with distance from the edge of the freeway (see Figure 3-2).

Figure 3-2
Comparison of Inverse and Near-Linear Decrease of Concentrations with Increasing Distance from Freeway



Both the point- and volume-source modeling approaches matched this behavior, provided the sources were elevated. The monitoring data suggest that the more elevated the sources, the more linear the concentration drop with distance from the edge of the freeway.

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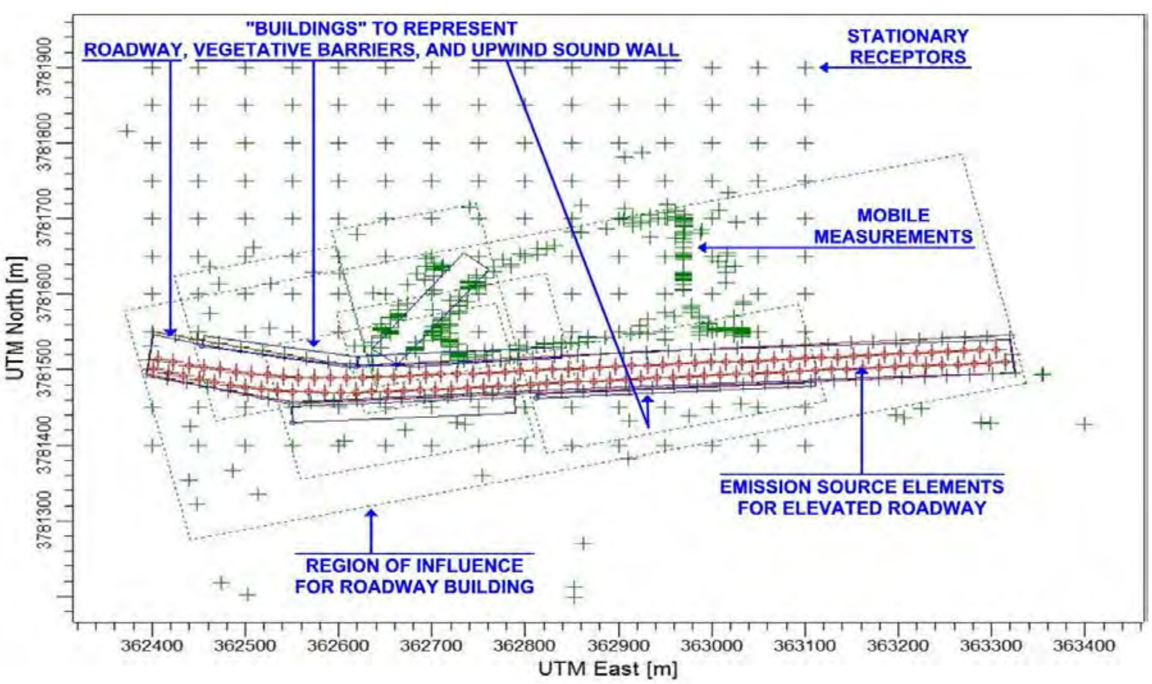
[22] See CALINE-4 Manual, at *http://www.dot.ca.gov/hq/env/air/pages/calinemn.htm.*

3.2.2 Geometric Representation

Figure 3-3 shows the geometric configuration that was used to represent the modeled system. Specifically, the figure shows point- and volume-source locations (in red), "building" locations (blue), and receptor points (green). The irregularly spaced receptors generally show the path of the sampling vehicle as it travelled the roughly circular sampling loop. Dotted lines display the rectangular AERMOD "GEP 5L region of influence" for each of the buildings for an example wind flow vector of 347 degrees (wind from 163 degrees, i.e., the SSE). For any given wind direction, this rectangle extends 2*L upwind of the leading edge of the building, 5*L downwind of the trailing edge of the building, and 0.5*L to the sides. For example, for the roadway, L is defined as the minimum of building height or projected width (L = 25 feet, so 5*L = 125 feet). The full GEP 5L 360 degrees region of influence for all wind directions is often considerably larger than a region of influence for a particular wind direction.

It is important to note that the region of influence varies depending upon the wind direction. This can be seen in the series of site layout drawings shown in Appendix D depicting the same barriers and showing how the regions of influence change with wind direction. One important observation to note from the layout drawings is that no wind direction shown results in the upwind sound wall having a region of influence that affects downwind measurements on the west (vegetated) side of the study domain north of the freeway—rather, that side reflects the effects of the vegetative barriers only.

Figure 3-3
Geometric Representation of the Modeled System



What are described here as individual “buildings” are, as noted earlier, not buildings at all, but bluff structures (including the elevated roadway itself). The individual barriers are described further in the next section and identified explicitly in Figure 3-3 as B1 (building 1), B2, etc.

Note that Figure 3-3 shows, for illustrative purposes, the GEP 5L wake-effect area for each building for the given wind direction. The GEP 5L wake-effect area is defined in original modeling guidance.[23] The GEP-5L region determines which point sources are considered candidates for calculating downwash. Candidate point sources need to be within that area to be considered.

According to the original modeling guidance, each structure produces an area of wake effect influence that extends out to a distance of five times L directly downwind from the trailing edge of the structure, where L is the lesser of the building height or projected building width. For older dispersion models like ISCST3, the GEP-5L wake-effect area also illustrates the area of building-wake downwash influence. The AERMOD-model calculation uses a related, but different, and substantially-more-complicated calculation method, called PRIME,[24] to calculate the area of building-wake downwash influence. Similarly to ISCST3, AERMOD’s BPIP-PRIME preprocessor uses the GEP-5L wake-effect area to determine which candidate point sources need to be considered, but unlike ISCST3, AERMOD’s PRIME calculation method does not also use the GEP-5L wake-effect area to determine the area of wake effect. Thus, wake-effect areas that might be calculated using PRIME (and not a model output in any event) need not map precisely onto the GEP 5L wake effect areas. Odd features in Figure 3-3, like the GEP 5L region for the roadway extending far downwind past the northeast corner of the roadway, need not have any influence on AERMOD modeling calculations at all[25].

3.3 Modeling Results

3.3.1 Point- vs. Volume-Source Modeling Representations

AERMOD results are shown here for two modeling formulations, each of which represents unitized NOx impacts (since arbitrary values are used for the input strengths, the absolute concentrations have no meaning). The first formulation, or model configuration, uses the point-source approach to modeling, and the second uses a volume-source approach. For both cases shown here, measured meteorology for one typical hour on June 4 was selected (this choice was useful both because it was introduced in the previous section on measurement results and because it was typical for the study period).

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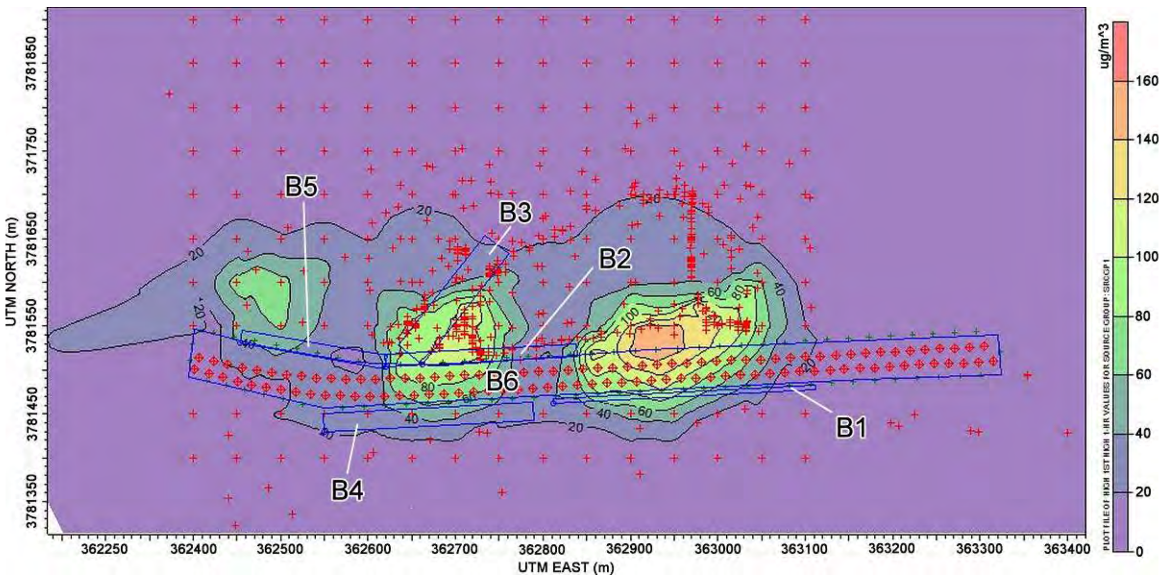
[23] Guideline for Determination of Good Engineering Practice Stack Height. Technical Support Document for the Stack Height Regulations (Revised), U.S. EPA Office and Air and Radiation, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 27711, EPA-450/4-80-023R, NTIS PB85-225241, June 1985. *http://www.epa.gov/ttn/scram/guidance/guide/gep.pdf*

[24] Development and Evaluation of the PRIME Plume Rise and Building Downwake Model. Schulman, L., D.G. Strimaitis, and J.S. Scire, Earth Tech, Concord, MA. *http://www.epa.gov/ttn/scram/7thconf/iscprime/tekpapr1.pdf*

[25] Similar considerations apply to the building downwash figures in Appendix D.

Figure 3-4
Typical Point-Source Unit Impact Modeling Results
(Hour 16 on June 4 - Wind 162º at 1.99 m/s)



Note: These modeling results are consistent with using hourly meteorological data but, as discussed in Section 3.2.1, should be reasonably consistent with average minute-by-minute data for this case.

Figure 3-4 shows the predicted isopleths resulting from the point-source approach with unit impacts, using a short-hand description of building heights. Specifically, for the case shown, the short-hand description of (35, 40, 40, 55, 55, and 25) refers to the following, in order:

- Building 1 – Sound wall height (on the upwind S side of the freeway) = 35 feet;
- Building 2 – Vegetative barrier adjacent to freeway, NE side, height = 40 feet;
- Building 3 – Vegetative barrier canted NE-SW from freeway, height = 40 feet;
- Building 4 – Vegetative barrier adjacent to freeway, SW side, height = 55 feet;
- Building 5 – Vegetative barrier adjacent to freeway, NW side, height = 55 feet; and
- Building 6 – Elevated freeway itself, height = 25 feet.

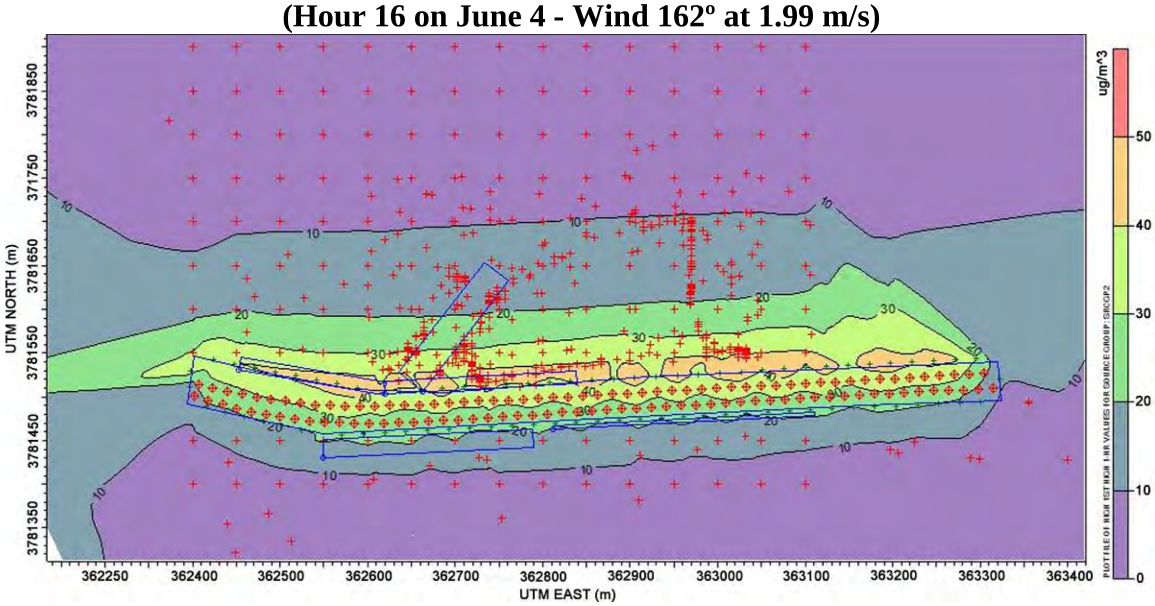
Each application includes representation of the sound wall on the south (upwind) side of the freeway on the east side of the modeling domain, and results show the potential for downwash from the sound wall in this case (June 4, 2012), with the sound wall assumed to be 35' feet high (i.e., 10' above the level of the 25' tall freeway) generating higher impacts than downwash from the taller vegetative barriers to the west. That may occur because the cavity region of the sound wall is smaller than for the taller vegetative barriers. Since vehicle exhaust from the freeway is trapped in a smaller volume, concentrations are higher.

Presumably, because the elevated roadway is shorter than the sound wall, concentrations could be yet higher there. Nevertheless, because the emission height is the same height as the roadway height, and because the location of emissions is upwind of the start of the cavity, the roadway emissions cannot be fully captured within the cavity—i.e., a portion of the plume escapes capture. Thus, if these emissions could be measured (which they were not in this study, because monitoring locations were too distant from the roadway), it is unlikely that the concentrations immediately adjacent to the elevated roadway alone would be as high as with an elevated roadway plus sound wall: the obstacle providing downwash needs to be taller than the roadway to fully capture the plumes.

Also notable is how limited the effects of all of the barriers are upon concentrations. Farther than about 200 meters from the roadway, the presence or absence of barriers makes no real difference.

Figure 3-5 shows the results of the volume-source modeling approach. Some isopleth "beading" [26] close to the sources is evident, which shows the effect on modeling results of having discrete sources. It was assumed for this model run that the east- and west-bound freeway segments were three lanes wide (rather than the actual value of five lanes).

Figure 3-5
Typical Volume-Source Unit Impact Modeling Results
(Hour 16 on June 4 - Wind 162º at 1.99 m/s)



[26] "Beading" refers here to the somewhat regular artifact in the separation or spacing of isopleth lines for receptors positioned very close to the source. In general, such artifacts may be caused by either source or receptor grid approximations.

Using five lanes, the isopleth beading would have been even more severe. It is also noteworthy, but unsurprising, how the concentration isopleths are uniformly parallel to the freeway.

3.3.2 Concentrations as a Function of Distance Downwind

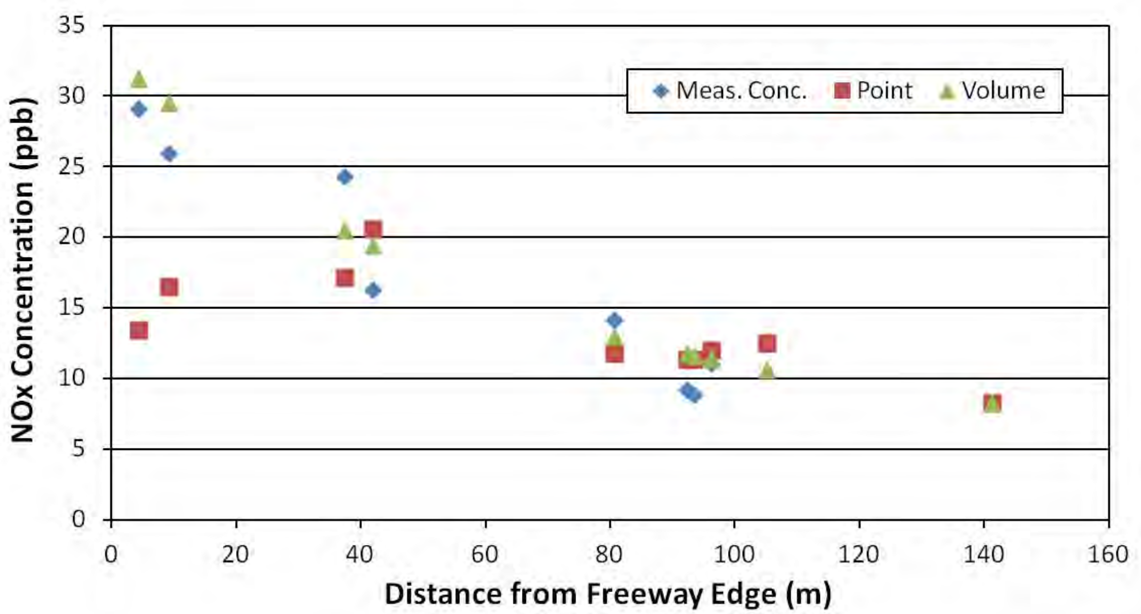
This section reviews the modeling results by examining NOx concentrations presented as a function of distance downwind from the downwind edge of the freeway. As before, modeled emissions are represented as unit impacts (eastbound and westbound lanes each emitting[27] at a hypothetical 1 g/s.) In order to compare model results with measured concentrations, there is a choice that needs to be made: against which measurements should modeled concentrations be scaled?

Initially, the unit impact concentrations were scaled to the measured concentration at the closest location to the freeway on the western end. But extrapolating away from the freeway to smaller and smaller values, that choice tends to obscure mismatches at lower concentrations. More revealing is to scale to the measured concentration at the farthest location from the freeway. This choice takes advantage of the fact that both volume and point-source approaches should yield identical results very far from the freeway. By extrapolating to larger and larger values towards the freeway, this choice tends to heighten mismatches at higher concentrations near the freeway, allowing the mismatches to be seen more easily. More than the absolute values, it is the shape of the modeled distribution that is of most interest here, since that shape best reveals the underlying physics.

The first concentration vs. distance plot is shown in Figures 3-6a, with additional clarifying data shown in Figure 3-6b. Both figures represent the case for the June 4, 2012, Hour 15, first circuit, western-end NOx concentration profile (i.e., adjacent to the vegetative barrier: points labeled 13 – 47 in Figure 2-5), with the previously described building heights: (35, 40, 40, 55, 55, 25). In Figure 3-6a, modeled point-source contributions appear to dip at the two locations closest to the freeway, but that is deceiving—it reflects receptor locations too far east to experience the zone of higher concentration noted at the nexus of vegetative barriers in the western end of the modeling domain. This can be seen in Figure 3-6b, which is a contour plot of the modeled (unit) concentrations; the "+" symbols showing the location of measurement points. Contours of modeled concentrations are scaled, like the values in Figure 3-6a, to the concentration at the furthest measurement point (designated "46" in the figure). The important observation to note from both figures is that for this particular approach and case, the modeled point source (unit) concentrations are not at a maximum closest to the freeway.

[27] More realistically, westbound traffic at this site was generally heavier from the mid-afternoon through early evening period of the daily field measurements and tended to increase over the course of each day's sampling.

Figure 3-6a
Measured & Modeled NOx Concentration vs. Roadway Downwind Distance
Western End (Vegetative Barrier)



Note: Modeled case is for June 4, 2012, Hour 15, first circuit; NOx concentration profile, and building heights assumed are (35, 40, 40, 55, 55, 25). Modeled concentrations are scaled to measurements at the farthest distance.

Figure 3-7 shows the corresponding profile for the eastern end (no vegetative barrier: point 11, and points 47-58) NOx concentration profile.

Concentrations at the western side of the modeling domain (with vegetation barrier) are reasonably well predicted by the volume-source approach (i.e., in Figure 3-6a, the volume-source modeling prediction reasonably agrees with the field measurements), while the point-source agreement is poorer. Concentrations are not as well predicted by either approach in the eastern end, where no vegetation barrier is present, as can be seen in Figure 3-8. Here, both the point and volume modeled concentrations appear to be more variable than in the western area.

Figure 3-6b
Unit Contours of Modeled Concentrations and Measurement Locations (+)
Western End (Vegetative Barrier)

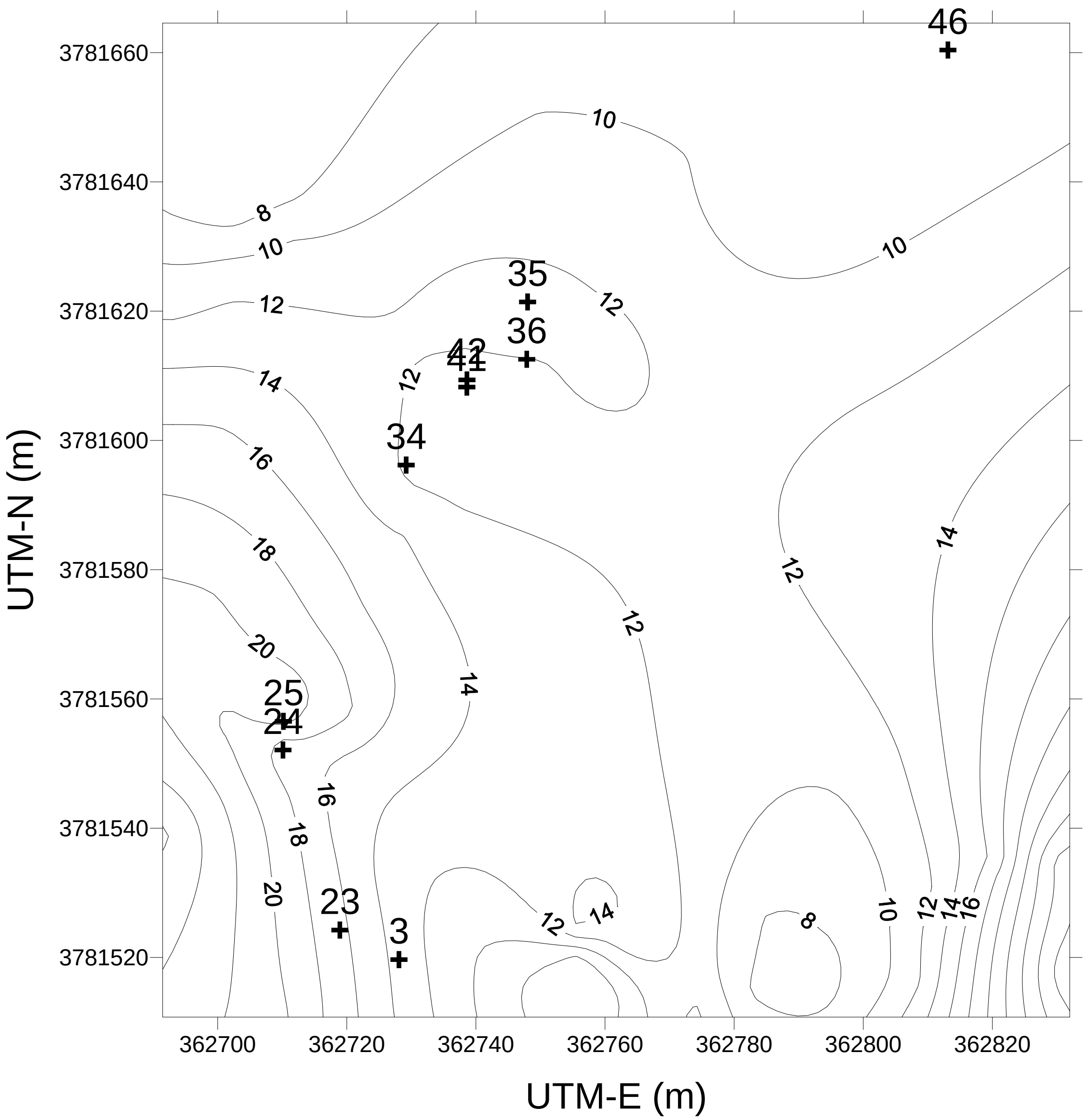
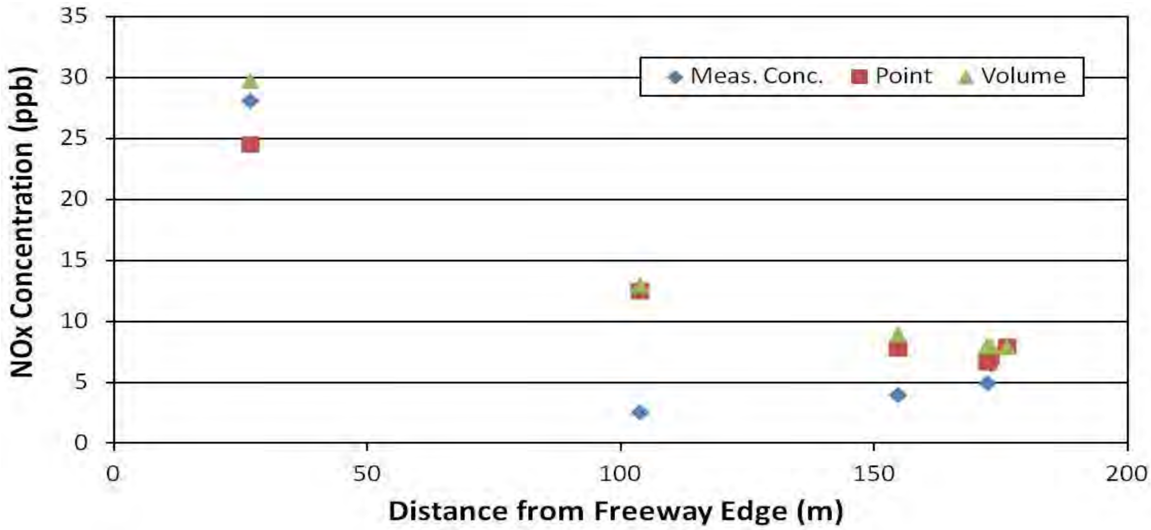


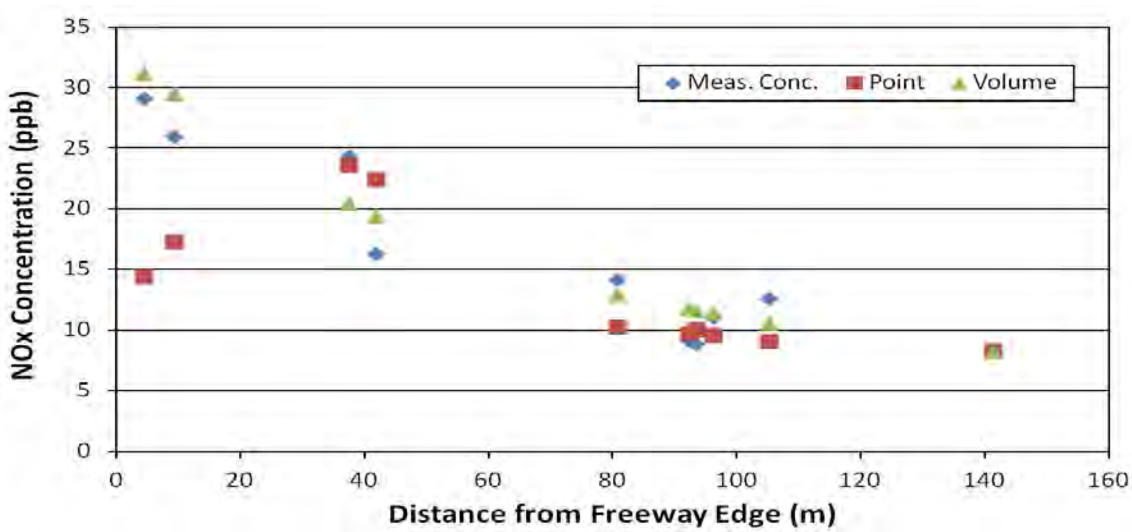
Figure 3-6b: Close-up of the point source approach modeled values in the western profile illustrated in Figure 3-6a. Modeled case is for June 4, 2012, Hour 15, first circuit; NOx concentration profile, and building heights assumed are (35, 40, 40, 55, 55, 25). Modeled concentrations are scaled to measurements at the farthest distance (point 46).

Figure 3-7
Measured & Modeled NOx Concentration vs. Roadway Downwind Distance, Eastern End (No Vegetative Barrier)



Note: Modeled case is for June 4, 2012, Hour 15, first circuit; NOx concentration profile, and building heights assumed are (35, 40, 40, 55, 55, 25). Modeled concentrations are scaled to measurements at the farthest distance.

Figure 3-8
Measured NOx Concentrations and Modeled Point- and Volume-sources vs. Downwind Distance from Roadway, with Hypothetical Building Heights on the West Side (Representing Vegetative Barrier Heights) Reduced



Note: Modeled case is for June 4, 2012, Hour 15, first circuit; NOx concentration profile, and building heights assumed are (35, 40, 40, 55, 55, 25). Modeled concentrations are scaled to measurements at the farthest distance.

In order to explore why the point source modeling approach did not correlate well with either the volume-source modeling approach or the measurements, modeled roadside vegetative barrier heights were shortened towards the western end, yielding somewhat increased point-source model predictions near the freeway for the western end (and for this case, improved), and somewhat decreased predictions farther away from the freeway. The result is shown in Figure 3-8 (June 4, 2012, first circuit, western end NOx concentration profile, building heights assumed: 35, 30, 30, 35, 35, 25). Compared to the two previous diagrams above, note how the location of the maximum shifts towards the freeway when the (hypothetical) building heights are reduced.

3.3.3 Theoretical and Model Treatment of Building Cavities

For upwind barriers that are tall enough for their cavities to stretch completely across the freeway, and those nearby downwind barriers that can fully capture freeway emissions (which may not happen if emission height is sufficiently high), modeled concentrations will be inversely dependent on building height,[28] as shown by the equation below.

$$Xc = Q/(1.5 * A_p * u) = q/(1.5 * H_b * u)$$

where:

> Xc = modeled concentration (microgram/m^3);
>
> u = wind speed (m/s);
>
> $A_p = H_b * W$ = cross-sectional area of the building normal to the wind (m^2), with building height Hb and width W; and
>
> Q = Emission rate (g/s) = $q * W$, where q is the emission density on the freeway, or "emission factor" (g/s-m).

(This particular equation is used in EPA's SCREEN3 model. AERMOD's building-wake downwash algorithms are more sophisticated, but behave similarly.) Thus, concentrations near the freeway will be inversely dependent on barrier height. In addition, as barriers are reduced in height, the modeled point-source distribution shifts closer to the freeway. Conversely, the taller a vegetative barrier is, the farther from the freeway the modeled distribution shifts,[29] to the point where the maximum may no longer be right at the edge of the freeway, but farther away. The distribution also broadens, forming zones where concentrations are heightened.

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[28] Hosker, 1984, via SCREEN3 manual.

[29] This is analogous to the manner in which the peak ground-level concentration from an individual point source tends to occur further downwind as the source is elevated (see, for example Turner, D.B, "Workbook of Atmospheric Dispersion Estimates," U.S. Department of Health, Education and Welfare, revised 1970.)

At the study location, the freeway is elevated, which might cause the appearance of a "hot stripe" immediately adjacent to the freeway, provided the emissions are captured in the cavity of the freeway.

At the eastern end of the modeling domain, the sound barrier wall is likely tall enough to affect a significant fraction of the emissions of the freeway (8 feet tall – cavity = 5 * 8 feet = 40 feet wide, enough to affect at least eastbound traffic). Adding the elevated freeway height to the sound wall (33 feet tall – cavity = 5 *33 feet = 165 feet wide, enough to affect emissions from both directions of traffic), it is likely that most of the emissions from the freeway are affected. Since the sound barrier is among the shortest barriers at this location, it will tend to produce the highest concentrations, particularly right on the freeway, or just beside the freeway, but those high concentrations do not extend very far from the freeway, leading to sharp concentration gradients a short distance from the freeway.

At the western end of the modeling domain, vegetative barriers are found that are considerably taller than the sound wall. These barriers create a larger zone of higher concentrations than found in the eastern end of the modeling domain, but the maximum concentrations in this zone are smaller than found in the eastern end of the modeling domain. The vegetative barriers help dilute concentrations but they also extend the zone of higher concentrations further from the freeway.[30] Therefore, the effects of vegetative barriers are two-fold:

- They can establish zones of higher concentrations near the freeway that might otherwise not occur; and
- Conversely, they can dilute zones of higher concentrations near the freeway, whether due to their own presence or the presence of other barriers, and extend them farther away from the freeway.

Thus, whether the resulting barrier effects are beneficial or detrimental to resulting air quality will depend on details of the receptor location, the particular source(s), barrier(s) and meteorology, and other factors (discussed below). In addition, there may be uncertainties regarding the effects of lateral wrap-around flow.

[30] Such an effect is not apparent in Figure 3-3. However, the modeling results shown in that figure also reflect the effects of the sound barrier (B1) that is on the upwind side of the freeway, which has a complex effect on the downwind concentrations on the east side of the measurement domain; this renders the modeled concentrations in the figure unsuitable for a simple comparison of the barrier-to-no barrier cases.

3.3.4 Modeled vs. Measured Concentrations and Effect of Wind Speed on Modeling Predictions

This section shows the comparison of modeled (point- and volume-source modeling) vs. measured concentrations, and the effect of wind speed on dispersion modeling predictions downwind from a roadside barrier.

Below are a series of comparisons of modeled-to-measured NOx concentrations. In all cases, the point- and volume-source unit impacts for the elevated freeway are scaled to measured concentrations, not at the edge of the freeway as is often done but at the farthest measured distance from the freeway. The rationale, as noted earlier, is that the two approaches should asymptotically reach the same value far from the freeway, and that the differences between the approaches will be highlighted near the freeway where concentrations are high. Thus, rather than obscuring differences when making measured-to-modeled comparisons, the differences will be revealed.

In all point-source modeled cases, the following building heights are assumed: (35, 40, 40, 55, 55, 25).

The documentation for AERMOD[31] identifies several possible approaches for making measured-to-modeled comparisons:

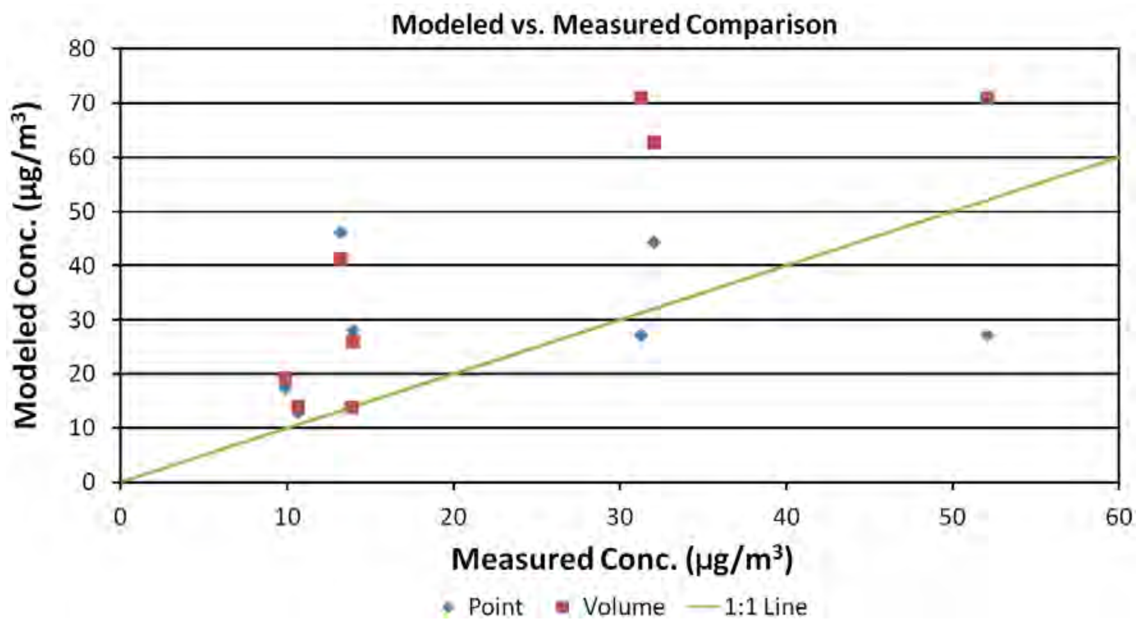
- Scatterplots (comparisons paired in time and space);
- Quantile-quantile (Q-Q) plots (comparisons not paired in time or space); and
- Robust high concentration (RHC) statistic (not paired in time or space).

Using the scatterplot approach, which was chosen for its simplicity, Figure 3-9 compares the modeled and measured NOx concentrations for June 8, 2012, first circuit. Measured concentrations are on the abscissa and modeled concentrations for both point- and volume-source modeling are shown on the ordinate. Also shown is the 1:1 line representing theoretically perfect predictions (measured concentrations X = modeled concentrations Y). In most cases here, the model overpredicts modeled concentrations, but it is generally within a factor of two.

Following are several examples[32] of fits of measured and modeled concentrations (point- and volume-source models) for varying wind speeds. As shown in Figure 3-10 for the first example, higher wind speeds (mostly above 3 m/s), as on June 8, favor the point-source methodology (i.e., point-source modeling predictions better match measured concentrations). By contrast, lower wind speeds (2-3 m/s), as occurred on June 6 and shown in Figure 3-11, favor the volume-source methodology. Finally, as shown in Figure 3-12, very low wind speeds (<2 m/s) can sometimes confound both approaches.

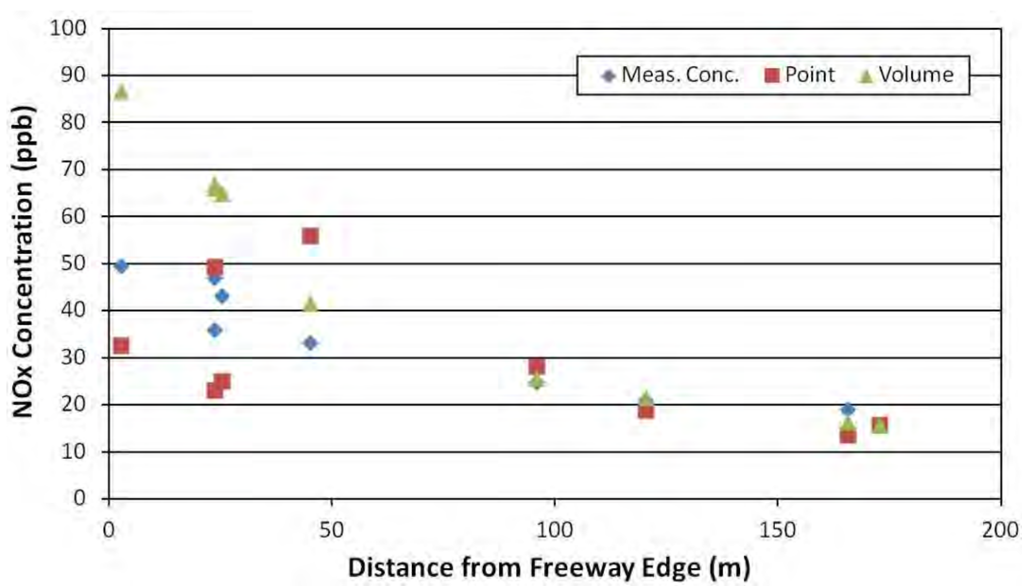
[31] AERMOD: Latest Features and Evaluation Results, U.S. EPA Office of Air Quality Planning and Standards, EPA-454/R-03-003. June 2003, *http://www.epa.gov/ttn/scram/7thconf/aermod/aermod_mep.pdf*.
[32] In all example cases, the following building heights are assumed: (35, 40, 40, 55, 55, 25).

Figure 3-9
Plot of Measured vs. Modeled Concentrations



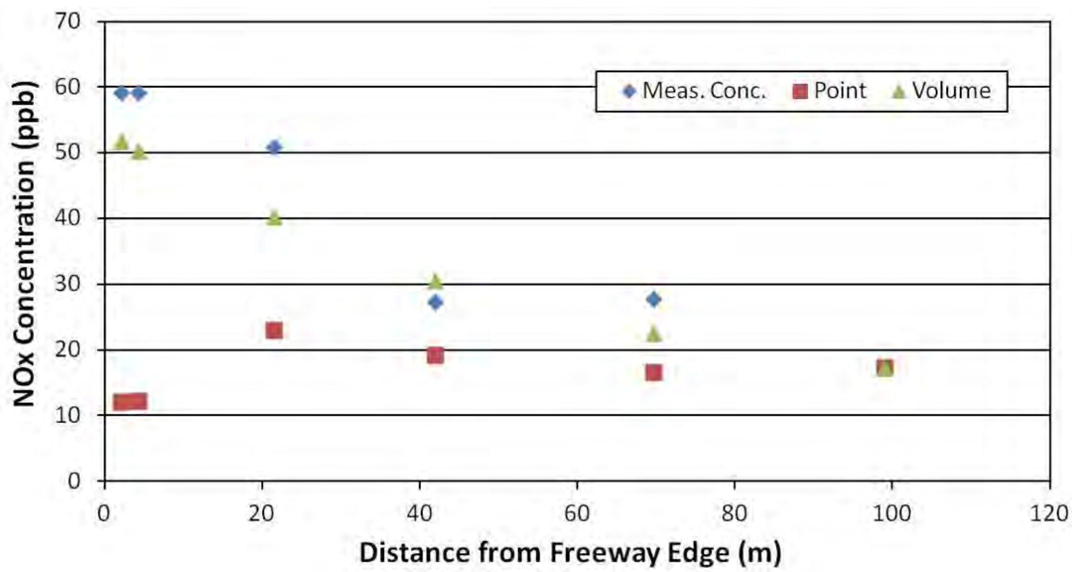
Note: Modeled concentrations are scaled to measurements at farthest distance.

Figure 3-10
Measured and Modeled Concentration vs. Distance Downwind
High Wind Speed Favors Point-Source Modeling Approach
(wind speed mostly > 3 m/s, June 8, 2012, first circuit, eastern end NOx)



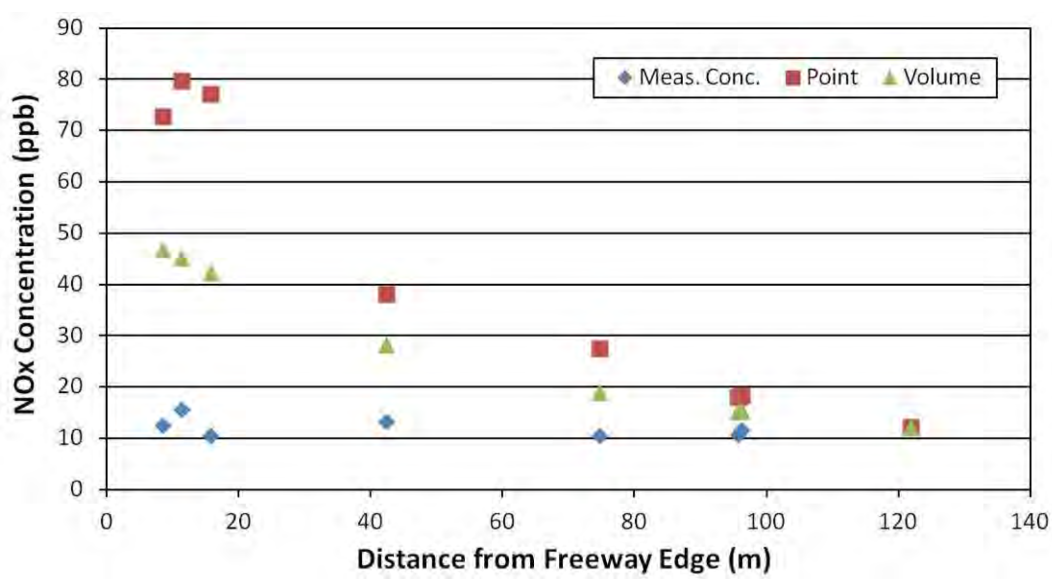
Note: Modeled concentrations are scaled to measurements at farthest distance.

Figure 3-11
Measured and Modeled Concentration vs. Distance Downwind
Low Wind Speed Favors Volume-Source Modeling Approach
(wind speed 2-3 m/s, June 6, 2012, first circuit, western end NOx)



Note: Modeled concentrations are scaled to measurements at farthest distance.

Figure 3-12
Measured and Modeled Concentration vs. Distance Downwind
Sometimes Low Wind Speed Confounds Both Point- and Volume-Source Modeling
(wind speed <2 m/s, June 11, 2012, first circuit, western end NOx)



Note: Modeled concentrations are scaled to measurements at farthest distance.

Results of the three simulations (and another that is not plotted) are summarized in Table 3-1. The relative quality of the two model fits is compared in the table by using the root-mean-square (rms) error of the paired measured-monitored difference.[33] This statistic measures the average deviation of the modeled concentrations from the corresponding measured values.

Table 3-1
Comparison of Results from Four Measured and Modeled Cases Using Point- and Volume-Source Modeling

Scenario	Average Wind Speed (m/s)	Sample rms error (ug/m^3)	
		Point-Source Model	Volume-Source Model
June 8, 2012, first circuit, eastern end	3.64	**13.00**	20.14
June 6, 2012, first circuit, eastern end	3.33	**17.44**	23.63
June 6, 2012, first circuit, western end	2.94	32.83	**7.54**
June 11, 2012, first circuit, western end	1.55	43.41	**22.00**

Note: The lower rms error, in bold, reflects the Preferred Approach for each case.

The mean square error is computed by squaring and summing the errors and then dividing by N-1 to account for the degrees of freedom in the data that remain after the normalization. The rms error is the square root of the mean square error. Computed this way, the rms error is conceptually the same as the standard error in Y that is often reported by linear regression packages as a measure of goodness of fit. The rms terminology is used here, rather than standard error, to avoid an implication that the X=Y reference line (i.e. the "measured concentration" line in Figure 3-8) is based on regression analysis.

For the comparisons shown in the table, the better fit of modeled to measured values (i.e., lower rms error) is highlighted in each case.

The comparison shows that the point-source approach was best at wind speeds above 3.2 m/s; the volume-source approach was best at intermediate wind speeds (1.6–3.2 m/s); and neither approach was judged to be very good at lower wind speeds (although the volume-source approach is probably better). In addition, the sensitivity of modeling results to relatively small changes in wind speed points to the need for great care in selecting representative meteorology for the site, proper choice of model, and appropriate model configuration in order to predict near-roadway concentrations, particularly for low wind speed conditions.

[33] Note that the rms statistic is used here only in a relative sense, to compare the relative errors of the two modeling approaches. Because the data are scaled, caution should be used in any attempt to interpret the resulting rms values in an absolute sense (which is not intended here).

3.3.5 Comparison of Modeling Results with Other Studies

The current modeling results are not inconsistent with previously reported studies. In the absence of vegetative or other roadside barriers, it is likely that the maximum in the vertical concentration profile will be above the ground for an elevated roadway segment (e.g., Heist, et al., 2009). In addition, the drop in surface concentration as one heads away from the immediate roadside of an elevated freeway segment will be broadly linear (Heist et al., 2009; Figure 7).

Regarding roadway configurations and barriers to the wind, the wind-tunnel study of Heist et al. (2009) concluded the following:

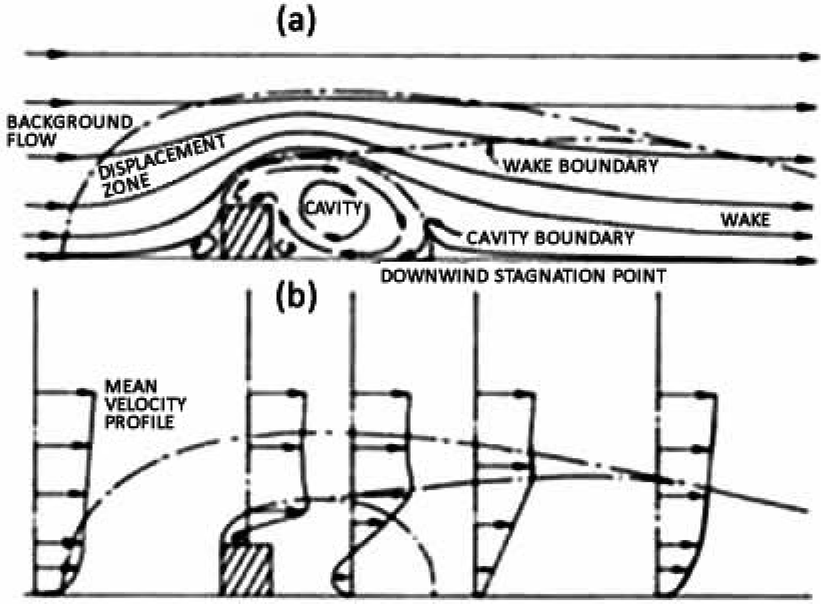
> *Of the configurations studied here, each one had the effect of reducing the ground level pollutant concentrations downwind of the roadway as compared to the flat-terrain case with no barriers.*

Our results, however, showed that vegetative and sound wall barriers can sometimes lead to higher concentrations near the freeway. The difference in conclusions between these studies can be explained by the fact that Heist et al. (2009) did not consider our specific case, where barriers overshadow an elevated freeway, but rather barriers with depressed or at-grade freeways; when they considered an elevated freeway, there were no overshadowing barriers considered. Thus, our results do not conflict with, or contradict, the results of Heist et al. (2009).

Figures 3-13 and 3-14, which are from different sources but which we have juxtaposed for illustrative purposes, provide a diagram and a photograph of building downwash effects showing some of the same features that are apparently present in the current study. The dominant feature in each case is the building downwash cavity which, in the photo, visibly captures smoke from the plume atop the building, entrains and mixes it within the cavity, and brings it down to ground level. Also apparent in the photo is the boundary of the cavity at the “stagnation point.”

The next two diagrams indicate effects associated with air flow over the top and around the sides of a bluff structure. In both cases, the streamlines shown in Figures 3-15 and 3-16 indicate “edge effects,” which may be characterized as “vortex rolls” and large spirals in the respective figures. Such effects can give rise to higher concentrations at downwind locations near the corners of barriers.

Figure 3-13
Illustration of Building Wake Downwash

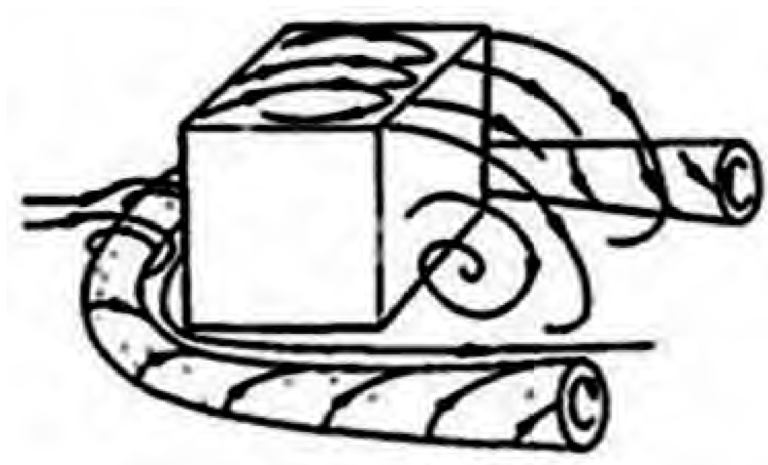


Adapted from *http://www.rag.org.au/tunnel/plumes.htm*

Figure 3-14
Downwash from a Short Stack – New Zealand Picture

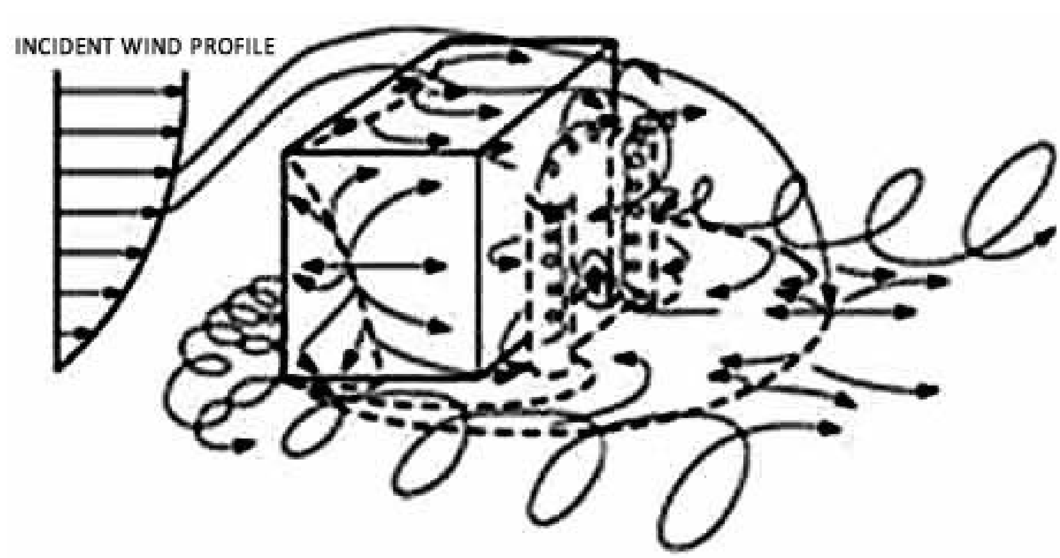
Source: *http//blog.nus.edu.sg/yiuyan/2009/10/08/Gaussian-plume-modeling/*

Figure 3-15
Building Wake Downwash Showing Vortex Rolls around Corners



Source: *http://mccabism.blogspot.com/2011/05/aerodynamics-of-buildings.html*

Figure 3-16
Building Wake Downwash
Showing Incident Wind Profile and Multiple Flow Detachment Areas



Adapted from *http://mccabism.blogspot.com/2011/05/aerodynamics-of-buildings.html*

In summary, as validated here by on-site measurements, at this location the point-source approach to modeling barriers in AERMOD was best at wind speeds above about 3.2 m/s; the volume-source approach was best at intermediate wind speeds (1.6 – 3.2 m/s); and neither approach was very good at lower wind speeds (although the volume-source approach is probably best). The point-source approach works better at higher wind speeds because building-wake downwash, which occurs at higher wind speeds and is associated with vegetative and other roadside barriers, can be simulated.

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4. ANALYSIS OF ALTERNATIVE DESIGNS

For the current study, AERMOD has been exercised and found to produce reasonable predictions of measured roadside concentration profiles for an elevated roadway segment under a narrow range of meteorological conditions, namely the southeast quadrant winds associated with the early summer afternoon sea breeze at the study location. These predictions are reasonable despite the fact that AERMOD does not simulate the effects of atmospheric chemistry, such as might affect NO and NO_2 concentrations, or aerosol physical mechanisms that might affect ultrafine particles.

Estimation of long-term pollutant exposure risks often requires annual average concentration estimates; however, real-world applications require consideration of a variety of roadway and barrier heights. This section presents, with caveats, the results from conceptual modeling of this broader range of conditions and alternative designs.

4.1 Annual Average Concentrations

This section shows the results from applying 2011 meteorological data collected at nearby Van Nuys Airport to the previously described AERMOD configuration. Except for the different meteorology assumed, the model setup is the same as described earlier. Only unit freeway impacts are shown (no other sources or background concentrations are considered), and only for the one elevated freeway source within the study domain (as described and shown earlier in Figure 2-1). For this application, like many other model-based forecasts, there are no annual or long-term measurements against which to compare the predicted concentrations. The analysis ignores the fact that freeway emissions typically vary diurnally, weekly, and seasonally at this and other locations. For these and other reasons, the profiles shown for the annual average cases represent hypothetical results that are neither intended nor expected to be realistic for the subject study site. Rather, they are intended primarily to demonstrate the conceptual approach, assumptions, and results for extending the earlier analytical approach to annual average meteorology.

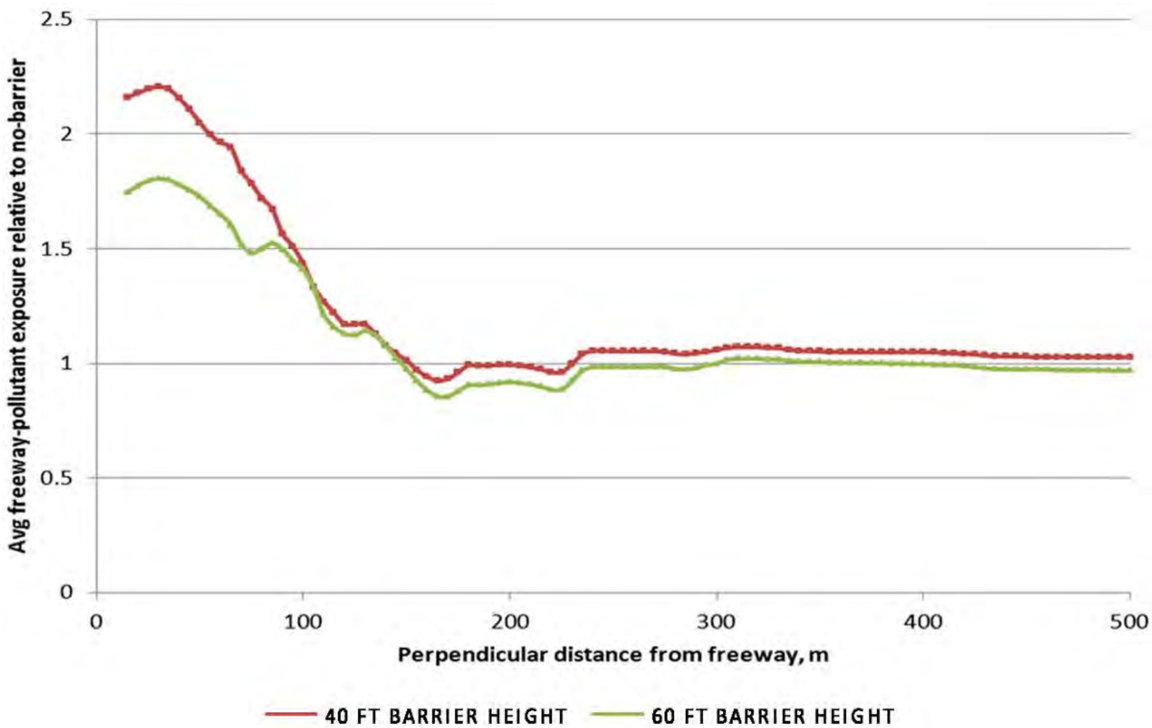
Modeling results for the annual average unit emission NOx concentration profiles are shown in Figure 4-1. Relative concentrations are shown out to a distance of 500 meters downwind (which is beyond the extent of the current study domain, but is intended to highlight aspects of the conceptual modeling results). Predicted concentrations are shown for hypothetical downwind barrier heights of 40’[34] and 60’ and are expressed relative to the predicted concentrations with no barrier. So, for example, a relative

[34] Note that the barrier height of 40’ means a 15’ barrier atop a 25’ elevated roadway segment.

concentration of "2" in the figure means that the expected concentration for that barrier height and downwind distance is twice as great as the case of having no barrier.

Figure 4-1 illustrates a complex pattern of behavior for the subject freeway segment with two alternative barrier heights. For these cases, a barrier of either height shows an air quality disbenefit (relative concentration greater than 1) in the near-field (less than 140 meters downwind of the freeway), a region of small benefit from 140 to about 225 meters, and a largely insignificant relative impact beyond that.

Figure 4-1
Modeled Relative Annual Average Exposure vs. Downwind Distance for 25-foot Elevated Freeway, Point-Source Approach, and Varying Barrier Heights

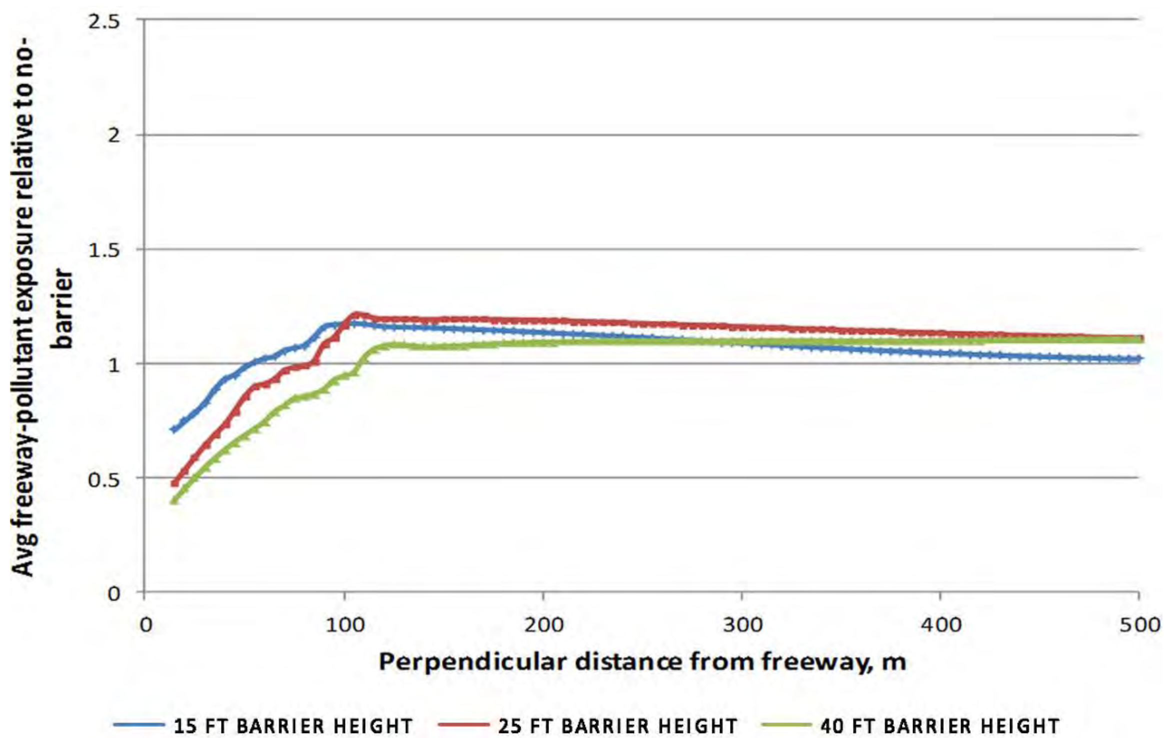


To help explain the model predictions in Figure 4-1 and relative concentration profiles in general, the following subsection presents the results from a series of model runs representing annual meteorology, but evaluating alternative hypothetical cases where the source freeway segment is either at-grade or at other heights and a hypothetical barrier is either at freeway height (i.e., no barrier) or other height. Van Nuys Airport 2011 meteorology is used throughout the examples.

4.2 Normalized Effect of Different Roadway and Barrier Heights

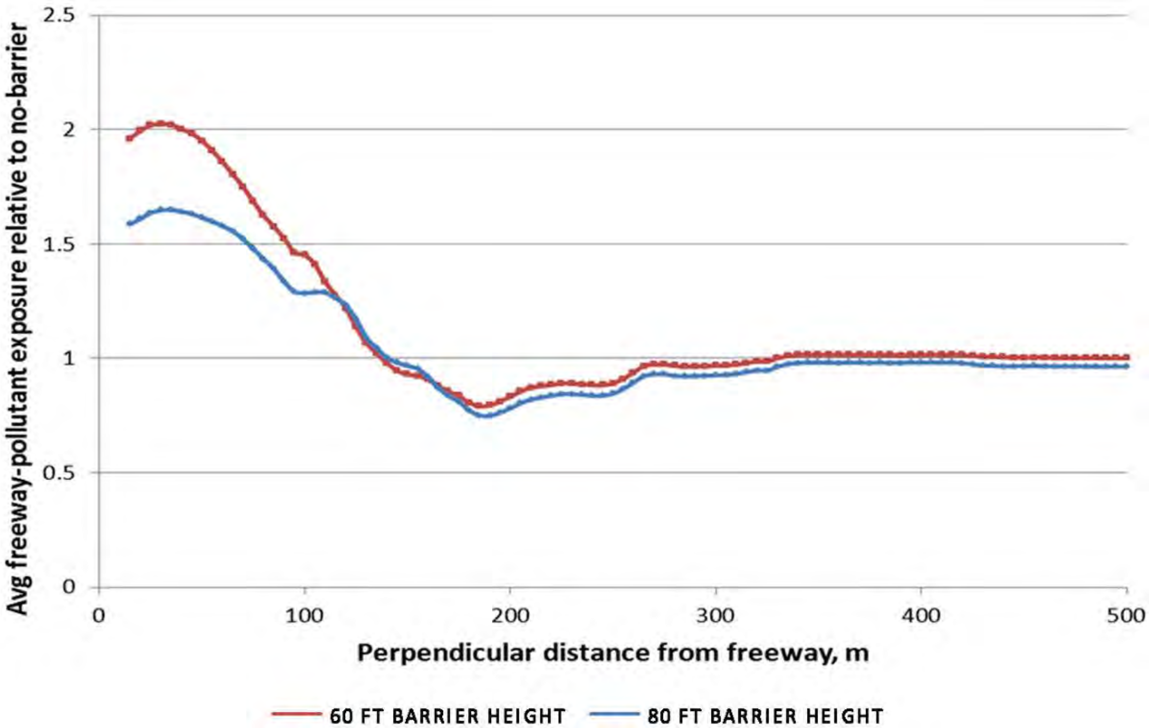
Figure 4-2 represents the case where, unlike the Lake Balboa study site, the modeled freeway segment is assumed to be at grade (i.e., not elevated relative to the rest of the study area). Three different barrier heights are shown. Relative to the case of no barrier, this figure shows a significant benefit (relative exposure less than 1) within the first 50-100 meters (where concentrations are greatest) and a disbenefit (relative exposure greater than 1) at further distances. For the shortest barrier shown (15'), the effect of the barrier diminishes rapidly with distance, and is essentially at background level 500 meters downwind.

Figure 4-2
Modeled Relative Annual Average Exposure vs. Downwind Distance for Hypothetical At-Grade Freeway and Varying Barrier Heights



The second alternative case (Figure 4-3, below) is that of a freeway elevated to 40 feet (i.e., 15 feet higher than the approximate 25-foot elevation of the freeway at the study site). Here, as in the case of the study site's freeway elevation (Figure 4-1), the barrier results in a substantial disbenefit near the freeway, then a relatively small benefit at an intermediate distance, and essentially no effect beyond that. This is similar qualitatively to the modeled result for the study site, but the magnitude of effects differs slightly for this hypothetical higher elevation freeway segment.

Figure 4-3
Modeled Relative Annual Average Exposure vs. Downwind Distance for 40-ft Elevated Freeway and Varying Barrier Heights



Many other freeway configurations are possible, including cut (below-grade) sections, but consideration of such geometric variations—as well as variations in meteorology, traffic, and other factors—was beyond the scope of the current study.

The results for all three roadway elevation cases, as well as several different barrier heights for each, are summarized in Table 4-1. The table shows the approximate ranges of downwind distance from the freeway where the barrier either reduced or increased the average (modeled) exposure to primary freeway pollutant emissions.

Although there are a number of caveats, the summary table suggests there is, for at-grade freeways, a near-roadway benefit predicted by the model for vegetative and other barriers, and a disbenefit further downwind. The picture is more complicated for elevated roadway segments, with benefits tending to occur only at intermediate distances and disbenefits occurring at shorter and longer downwind distances.

Table 4-1
Scenarios Illustrating Modeled Freeway Primary Emission Benefit & Disbenefit Distances for a Roadside Barrier (Compared to No-Barrier Case)

Scenarios (freeway and barrier elevations)	Downwind Distances (meters) with Modeled Freeway Exposure Benefit	Downwind Distances (meters) with Modeled Freeway Exposure Disbenefit
Hypothetical At-grade Freeway with barrier at:		
15 ft	<55	≥55
25 ft	<85	≥85
40 ft	<110	≥105
Study Site (25’ Freeway) with barrier at:		
40 ft	155-230	<155, >230
60 ft	150-300	<150, >300
Hypothetical 40’ Freeway with barrier at:		
60 ft	140-325	<140, >325
80 ft	≥145	<145

4.3 Modeling of Complex Building Structures

The final model simulation is for a multiple building wake-downwash. While not involving vegetative barriers directly, this hypothetical case was included in the current study at the request of the District for several reasons. First, multi-building exposures to nearby roadway emitted pollutants are common in the District and other urban areas, and it was suggested that the current modeling effort, including annual average concentrations, could provide insight into the exposures of residents. Second, a number of studies have investigated such building configurations, including at least one that attempted to model the effects of vegetation that was designed to remove pollutants (Pugh et al., 2012).

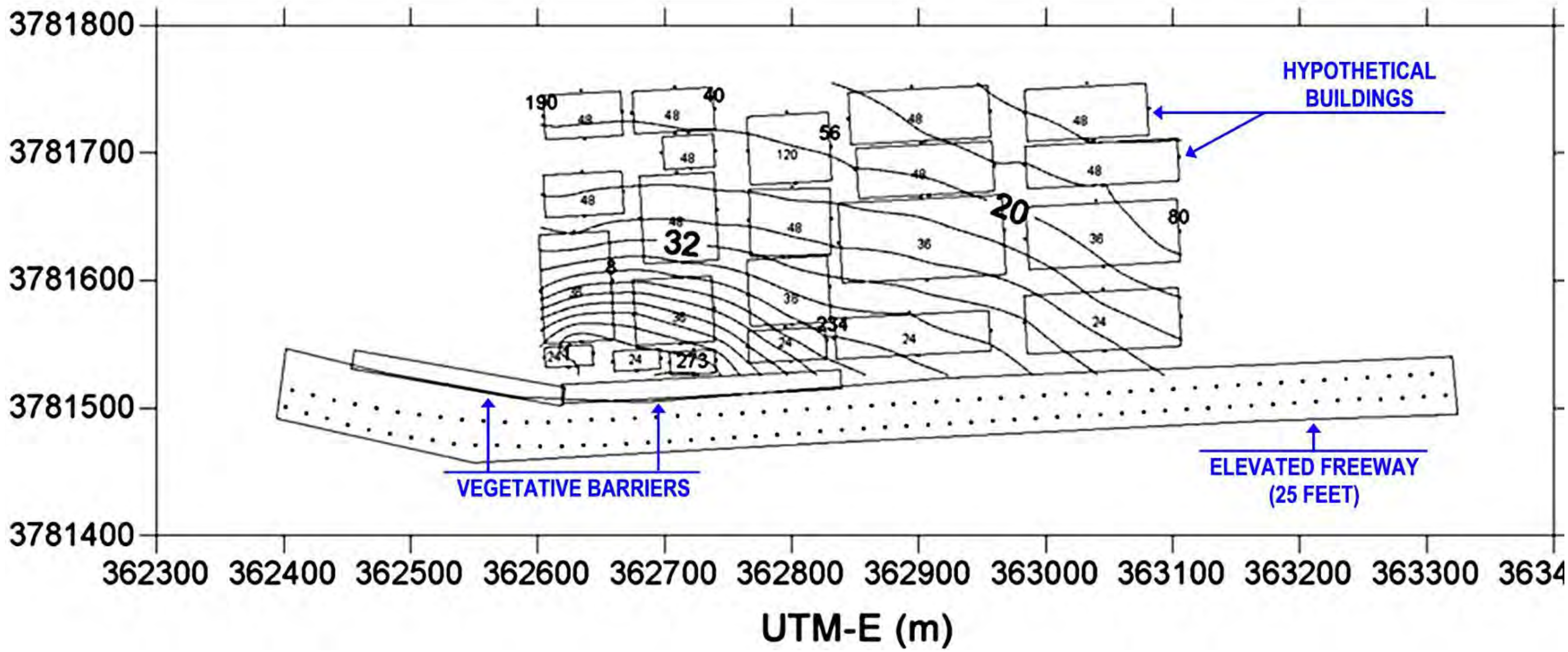
In the current study (Figure 4-4), a hypothetical collection of buildings was devised to portray multi-family dwellings of the sort found near freeways in the San Fernando Valley. The building footprints selected actually exist in Van Nuys, CA, with only minor adjustments, three kilometers WNW of the study site—near the White Oak Avenue and Highway 101 interchange—specifically the buildings in the southwest quadrant from the intersection of Yarmouth Avenue and Killion Street, but flipped around an east-west axis (i.e., a mirror image), and translated to the study site. Based on an examination of Google Earth Street-View images of this neighborhood, building heights stair-step upwards ranging from two- to four-story as one gets farther from the freeway, and this stair-step behavior is simulated approximately. Twelve-foot-tall stories are assumed. The only building height that was completely invented was the ten-story tower. Building heights greater than ten stories are rare in the San Fernando Valley.

Four receptor locations, as portrayed by small crosses, are placed equidistant between corners around each building. Receptor heights start at ground level, then breathing height, then at 12-foot increments upwards, as far as there are stories. No receptors are placed above the rooftop of its particular building. Receptor numbers for select receptors are presented in the figure. Point-source locations on the freeway are displayed by small dots. Freeway and vegetative barrier heights are varied in the modeling; footprints of these obstacles are displayed in the figures.

One year (2011) of Van Nuys Airport meteorological data was employed in the modeling. Meteorological data roughness is used as listed in the surface meteorological input file (i.e., AERMOD's URBAN option is again not used here, in order to avoid its default one-meter roughness height and anthropogenic heat assumption). Resulting annual average relative NOx concentrations due to the freeway segment are represented in Figure 4-4 by the (bold) isolines of constant predicted concentration at ground level. (Concentrations at other elevations are provided in accompanying data files but are not shown in the figure.) The results in this case are consistent with a pattern of downwash and elevated concentrations downwind of the vegetative barrier.

The previously described sound wall is not included in the modeling, so there is no eastern hot spot present. Model results with complex buildings do not look dramatically different from those without buildings, mostly because the buildings closest to the sources are no higher than the elevated freeway itself. The buildings farthest from the freeway are higher than the freeway (i.e. higher than 25 feet), but they are frequently too far from the sources (e.g., distance greater than 5 x 36 feet height of mid-range building, or 180 feet, or 55 m) for building wake downwash from southerly or southeasterly winds to be much of a factor.

Figure 4-4
Layout and Results of Unit Impact of Roadway Dispersion in Hypothetical Multi-building Scenario



Note –Numbers in small font are building heights (ft), those in larger font are receptor number labels; bold isopleth labels represent ground-level unit concentrations. Inside buildings, contour lines are shown only for continuity—they do not represent indoor concentrations

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5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Study Findings

Summarized below are conclusions reached based on the results of the sampling study and the conceptual modeling study of the dispersion of on-road vehicle pollutants downwind of a heavily trafficked freeway, both with and without near-roadway barriers.

1. Roadside barriers, whether vegetative or other, have the potential to either increase or decrease near roadway concentrations (compared to the case of no barrier), depending on a number of factors, including roadway height, barrier height, wind speed, and others. The effects of these and other factors upon dispersion are reasonably estimated based on modeling for the case of meteorology observed and configuration of the subject study site.

2. Substantial effort was made to identify the optimum vegetative barrier study site for model calibration, but no ideal site was found in the SCAQMD. The study site ultimately selected and sampled for five days in June 2012 was an elevated freeway segment with adjacent vegetative barrier in Lake Balboa, California. Measured data were used successfully to validate application of the AERMOD air quality model at the study site.

3. Downwind measurements of NOx concentrations during the brief field study showed isopleth concentrations that were generally parallel to the freeway as expected. However, under the sea breeze conditions that were targeted in the monitoring program, the downwind study area tended to be in the wake downwash of the freeway and of one or more barriers, resulting in a complex pattern of downwind concentrations, both measured and modeled. In all cases, the highest monitored location was located immediately behind the vegetated barriers, which was also the closest sampling location to the freeway.

4. In analyzing measured data, treating barriers as roughness elements was unproductive. Instead, treating them as buildings with potential for downwash yielded more predictable results.

5. For the study site, measurement data suggested, and modeling estimates tended to confirm, that a taller barrier resulted in lower ground-level concentrations in the downwind cavity, which is presumed to be due to greater dilution.

6. From the current study data, the point-source approach to modeling barriers in AERMOD was best at wind speeds above 3.2 m/s, and the volume-source approach was best at wind speeds of 1.6 – 3.2 m/s; neither approach was very good at lower wind speeds (although the volume-source approach was probably best). The point-source approach works better at higher wind speeds because building-wake downwash, which occurs at higher wind speeds and is associated with vegetative and other roadside barriers, can be simulated.

7. Modeling results, which examined hypothetical barrier heights ranging from 33 – 100 feet, further suggested that as barriers were reduced in height, the modeled source concentrations increased and shifted closer to the freeway. Conversely, the taller a barrier was,[35] the farther from the freeway the modeled contribution shifted, to the point where the maximum was no longer always right at the edge of the freeway, but further away. The distribution of impacts also broadened, forming zones where concentrations were heightened.

8. The sensitivity of modeling results to relatively small changes in wind speed in the field study pointed to the need for great care in air quality modeling practice, particularly under lower wind conditions.

9. For a hypothetical at-grade roadway, but other specific conditions of the current study site, modeling results suggested that a barrier has a near-field air quality benefit, a (smaller) disbenefit at intermediate distances, and no significant effect at further distances.

10. Results from an exploratory modeling study of the dispersion of unit freeway emissions in the vicinity of a hypothetical adjacent multi-building block of structures downwind of a vegetative barrier (as referenced in Section 4-3 and depicted in Figure 4-4) were consistent with a pattern of downwash and elevated concentrations partially downwind of the barrier. Other possible effects on measured concentrations from the subject vegetative barriers, such as pollutant removal by deposition, were considered, but no significant effects could be documented.

11. While direct individual comparisons are problematic due to differences in sites, conditions, etc., the current modeling results tended to be consistent with previously reported study results to the extent that previous modeling conditions (including roadway height) were sufficiently detailed to compare. Where roadway heights were not reported, consistency could not be evaluated.

[35] The height where this occurred was not determined precisely—it could vary depending on the height of the freeway or other factors.

5.2 Recommendations

Consideration of the downwash effects from roadside barriers provides a new perspective on dispersion from roadways and on the potential for providing benefits from barriers in the near-roadway environment. Key elements that are new from this work are documentation of the importance of roadway elevation in understanding downwind effects and the identification of at-grade roadways as possible sites where the benefits of roadside barriers can be maximized. Importantly, however, the analysis indicates that it is not possible to generalize the benefits of freeway barriers. For this reason, it is recommended that when a project includes such barriers, data be collected on the key parameters determined to influence the calculation of those benefits, including freeway height, barrier height relative to the freeway, appropriate wind directions and other meteorological data, etc. These factors need to be accounted for in any assessment of potential benefits of near-roadway barriers, vegetated or otherwise.

###

Appendix A

Literature Review

Appendix A1
Summaries and Relevance of Most Pertinent Documents Reviewed

"Fine Spatial and Temporal Variability of Particle Number Concentrations within Communities and in the Vicinity of Freeway Sound Walls," C. Sioutas, University of Southern California, prepared for the California Air Resources Board, April 26, 2011.
The main focus of this recent measurement study was ultrafine particles, but one element included measuring (summer 2009) and documenting the impact of sound walls on downwind concentrations of CO, NOx, and particles. Sound wall-related measurements were conducted at four sites in the LA basin. Two sites were downwind of highly trafficked freeways (I-710 and I-5) with sound walls and two matched sites on those freeways had no sound walls. Measurements were collected 3-4 hours per day (after the sea breeze was fully developed), for 5 weekdays at each site, in the spring. (Personal communication with CARB project manager, who provided a portion of the dataset to Sierra, August 2011) The study reported that with the roadside barrier, the dynamics of pollutant dispersion "changed dramatically" and it described the relative (normalized) effects. Additional measurement studies of barriers were recommended, including monitoring for the effects of vegetative barriers.

"Soundwall Impacts on Near-road Air Quality," M. McCarthy et al., Sonoma Technology, Inc., prepared for California Department of Transportation, January 31, 2011.
This recent report summarizes research on the impact of noise barriers, including vegetation barriers, on near-road air quality, and evaluates the limitations and the potential for barriers to improve near-road air quality. The main study findings are presented in five broad areas.

- Winds Perpendicular to the Road, Downwind: concentrations are lower immediately downwind of sound walls, but sound walls may loft pollutants, causing higher concentrations downwind than would occur without the sound wall; compared to measurement studies, models tend to over-predict the near field benefit of sound walls; there is "some certainty that the on-road pollution plume can reattach to the surface; however, the evidence that concentrations are higher downwind relative to the no-sound wall case is more tenuous."
- Winds Parallel to the Road: essentially no studies.
- Winds Perpendicular to the Road, Upwind: "…concentrations upwind of a road can be higher during low-wind conditions."
- On-road Impacts: "…on-road concentrations are increased by the presence of sound walls."
- Vegetation Barriers: vegetative barriers can reduce near-road concentrations by filtration (this has not yet been well-quantified), and by altering wind flow; that latter effect is more important; "Studies comparing sound walls and vegetative barriers…are needed to quantify potential benefits of vegetative barriers at removing pollution in the real world."

"Ambient Concentrations of Criteria and Toxic Pollutants in Close Proximity to Freeway with Heavy-Duty Diesel Traffic," A. Polidori and P. Fine, South Coast Air Quality Management District, April 2012.

Not a barrier study per se, but important because it is a report from longer term measurements on multiple distances from the busy I-710 freeway (~20% of traffic is HD trucks). Sites were upwind (Del Amo), and downwind at 15 and 80 m. A comprehensive suite of continuous PM and meteorological measurements were made in Feb-March and July-Aug 2009, along with 24-hour FRM and other filter-based measurements, BC, OC and EC, selected gaseous pollutants, speciated VOC, and more. The study results suggested that: "…motor-vehicle emissions from the I-710 increase the atmospheric concentration of most combustion-related pollutants above background levels, especially within the first 80 meters from the edge of the freeway". The study also cited the importance of ultra-fine particles and elemental carbon particles out to 300-400 meters, noting that these have been linked to respiratory problems and other adverse health effects.

"Tracer Studies to Characterize the Effects of Roadside Noise Barriers on Near-road Pollutant Dispersion under Varying Atmospheric Stability Conditions," D. Finn et al., National Oceanic and Atmospheric Administration, Atmospheric Environment 44(2010) 204-214.

This SF_6 tracer study attempted to systematically evaluate the effect of atmospheric stability upon how pollutant dispersion by roadside barriers. The study conducted full scale field testing with a simulated line source and large grid of sampled receptor points downwind of the model barrier. Wind and turbulence were characterized by an array of 3-D sonic anemometers. Study results showed that dispersion was greater for the barrier grid vs. non-barrier (control) case. There was a concentration deficit in the wake of the barrier compared to control at all atmospheric stabilities, and this reduction was "typically in excess of 50% and often much greater". However, the results also showed that "The barrier tended to trap very high concentrations in the 'roadway' (i.e., upwind of the barrier) in stable, low wind speed conditions. This might be cause for potential human health concerns in some circumstances."

"A Wind Tunnel Study of the Effect of Roadway Configurations on the Dispersion of Traffic-related Pollution," D.K. Heist, et al., Atmospheric Environment, 43(2009) 5101-5111.

This wind tunnel based study examined and compared the effects of different roadway configurations upon downwind concentrations. The study found in pertinent part that, compared to the base case of an at-grade roadway with no sound walls (and stable atmosphere with perpendicular wind), each alternative evaluated had the effect of reducing pollutant concentrations downwind. The elevated roadway showed the least benefit, and the depressed roadway with sound barriers both upwind and downwind showed the greatest benefit. "Ground level concentrations were found to be substantially reduced by the addition of a barrier to the flat terrain case, but much smaller differences were observed as the location of the barrier was changed."

"Technical Noise Supplement," prepared by ICF Jones & Stokes, for California Department of Transportation, November 2009.
A key point from this voluminous noise barrier design report is the following:

> *In spite of a general perception of its effectiveness in lowering noise levels, shielding by shrubbery and trees typically used in landscaping along highways proves an imperceptible amount of noise reduction (less than 1dB), according to CALTRANS research.*

"Practical Mitigation Measures for Diesel Particulate Matter: Near-road Vegetation Barriers," Contract AS-04-01:Developing Effective and Quantifiable Air Quality Mitigation Measures, by M. Fuller et al., for California Department of Transportation, July 14, 2009.
This research attempts to assess the benefits of "vegetative screens near roadways". It provides a brief review of sound wall literature, develops a conceptual dry deposition model, and applies it to the case of an elementary school in Davis, California that is adjacent to a cut section of roadway.

"Impacts of Noise Barriers on Near-road Air Quality," R. Baldauf et al., Atmospheric Environment, 42 (2008) 7502-7507.
This measurement study investigated near-roadway air pollutant concentrations at a site adjacent to I-440 in Raleigh, North Carolina. The primary purpose of the study was to identify appropriate monitoring techniques, but the study also evaluated the effects of road-side barriers on near-road air quality. Two transects were used at perpendicular distances of about 20 to 300 m from the roadway edge.

"Summary of Noise Barriers Constructed by December 31, 2007," Federal Highway Administration, U.S. Department of Transportation, accessible here:
http://www.fhwa.dot.gov/environment/noise/noise_barriers/inventory/summary/
This on-line database provides a listing of sound barriers throughout the US, including 491.4 miles of barriers in California. Information is provided on barrier height, length, type (e.g. original or retrofit), material of construction, year of build, original and adjusted cost, etc. The predominant types are concrete and block. Earthen berms (which may or may not be landscaped with vegetative barriers) are much less common (there are 11 in all of California). Vegetative barriers are not considered by CALTRANS to be effective sound barriers and are not included in this listing.

"The Effects of Roadside Structures on the Transport and Dispersion of Ultrafine Particles from Highways," Bowker et al., Atmospheric Environment, 41(2007) 8128-8139.
This study examined the effects of roadside structures on dispersion by using the Quick Urban and Industrial Complex (QUIC) model and comparing with mobile measurements of ultrafine particles. The authors found that "…the comparisons suggested that QUIC adequately reproduced the complex flow and dispersion patterns around the roadside structures, demonstrating potential value as a diagnostic tool for this application. Further

evaluation of this model will likely be necessary before using this model in regulatory and urban planning applications."

"Keeping the Noise Down – Highway Traffic Noise Barriers," U.S. Department of Transportation, Federal Highway Administration.
This succinct brochure is written for the lay public, and makes the key points listed below.

- Noise barriers can reduce traffic loudness by as much as half (i.e., cutting noise level by 5-10 dB).
- Earth berms reduce noise by about 3 dB more than vertical walls of same height. Walls require less space but are usually limited to 25 ft height. (The trees and hedges that people often refer to as 'vegetative barriers' may be berms, with vegetation for aesthetics or other reasons.)
- A wall that breaks line of site reduces noise by 5 dB, plus another 1.5 dB reduction for each added meter of height.
- An effective noise barrier requires a rigid material at least 20 kg/m2.
- "30 m of dense vegetation can reduce noise by 5 dB. However, it is not feasible to plant enough trees and other vegetation along a highway to achieve such a reduction. Trees and other vegetation can be planted for psychological relief but not to physically lessen noise levels."

Appendix A2
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Appendix B

Field Measurements Plan

Conceptual Research Studies to Assess the Feasibility and Cost-effectiveness of Near-Roadway Pollution Mitigation Strategies

Field Measurements Plan

Prepared by

T&B Systems
environmental research associates
26074 Avenue *Hall Suite 9*
Valencia, California 91355

Revision May 30, 2012

TABLE OF CONTENTS

1. BACKGROUND

T&B Systems, working as a subcontractor to Sierra Research, will provide high resolution roadside measurements to assist Sierra Research in the use of computer models and methods recognized or used by the EPA for modeling of roadside pollutant impacts. Through the program development, a site has been selected in the San Fernando Valley to conduct the measurements. During the field study effort, one week of measurements will be made to characterize the distribution and gradients of pollutants at various distances downwind of a highway using adjacent locations that provide a vegetative barrier and no barrier. The goal is to make the needed measurements to collect a data set to evaluate the differences in downwind concentrations related to these two types of physical layouts. This plan summarizes the planned efforts and identifies the goals and responsibilities of the various team members.

2. SAMPLING LOCATION

The selected location is at the Tapia Bros. Farm, in the Sepulveda Basin region of the southern San Fernando Valley. **Figure 1** shows the general location with the regions of open and vegetative barrier identified. Much of the terrain may be different at the time of the study as the planting of the fields changes with the seasons. The traverse routes will depend on the available roads at the time of the study and as of May 29, 2012 the two north/south dirt roads shown in Figure 1, do not exist. Therefore, the propose routes for sampling will be on the perimeter road surrounding the field. This will provide the different downwind distances through the diagonal of the road. The proposed location of the meteorological masts are shown in the figure, with two masts proposed. One will have two levels of wind and the other with one level.

Figure 1. Overall layout of the field site.

Contact was made with the owner of the property and a tentative approval was provided. Liability insurance information was provided to the farm on May 30. The contact information is as follows:

Tapia Bros.
Burbank & Havenhurst
Contact: Tom
Office – 818.787.4358
Stand – 818.905.6155

3. MEASUREMENTS TO BE MADE

Two types of measurements will be made, fixed site and mobile. Equipment to be used, and the source of the equipment, is identified below.

Fixed site

The equipment at the fixed site will be set up at the start of the sampling week. With the exception of the sensor atop the mast, all equipment will be removed at the completion of each sampling day to minimize the potential loss of equipment due to vandalism.

Measurement	Make/Model	Sampling parameters	Equipment Source	Comments
Wind Speed and Direction at two levels (appx 3m and 8 m) with temperature and solar radiation.	RM Young AQ	1-s scans (not recorded but used in the calculations), 1-min, 15-min, hourly averages, vector and scalar wind calculations, recorded on CSI CR1000 logger	T&B Systems	A tripod with a maximum height of about 8 meters will be provided. The location of this system will be swapped with the second system about half way through the sampling program.
Wind Speed and Direction at one level (appx. 3-meters)	RM Young AQ	1-s scans (not recorded but used in the calculations), 1-min, 15-min, hourly averages, vector and scalar wind calculations, recorded on CSI CR1000 logger	T&B Systems	A tripod with a maximum height of about 3 meters will be provided. The location of this system will be swapped with the second system about half way through the sampling program.
Size segregated particulate matter	TSI DustTrak DRX	Relative size segregated measurements at 2-s intervals stored internally in the DRX. Data will also be recorded for one channel (PM10) on the data logger at the same intervals as the meteorology.	SCAQMD	DRX provided by SCAQMD.

Mobile

All equipment will be installed in a sampling vehicle that is equipped with a 12 VDC to 120 VAC pure sine wave inverter and adequate AGM batteries to power the system for at least four hours of continuous sampling plus the transit time from Valencia to the field and back. Provisions will be made to make a rapid switch from vehicle to ground power when AC power is available. The equipment to be used and source of the equipment is identified below. All data will be collected using 2-second scans with both the individual scans and 1-minute averages recorded.

Measurement	Make/Model	Sampling parameters	Equipment Source	Comments
Vehicle position, speed and direction of travel	Garmin eTrex GPS	2-s scans and 1-min averages	T&B Systems	
Data recording	Campbell Scientific CR1000	2-s scans and 1-min averages	T&B Systems	
NO/NOx/NO2	API 200E	2-s scans and 1-min averages	T&B Systems	
CO	API 300E	2-s scans and 1-min averages	T&B Systems	
Size segregated particulate matter	TSI DustTrak DRX	Relative size segregated concentration stored internally with 2-s scans. 2-s scans and 1-min averages recorded on CSI CR1000 logger from one channel (PM10)	SCAQMD	DRX provided by SCAQMD.
On-board data display	Windows 7 based Netbook computer	Location plots and "strip chart" plots of variables in real time.	T&B Systems	
Vehicle speed	Carchip connection to vehicle OBD	Vehicle speed	Sierra Research	Provides a backup and additional data on when the vehicle is and is not moving.

<u>Sampling Strategy</u>

The goal of the sampling is to collect data in enough locations downwind of the freeway that gradients can be seen downwind of the open and vegetated regions, when the winds are near perpendicular to the freeway. The seasonal timing of the data collection period is such that there is a reasonable probability during June that these types of conditions will persist for the weeklong sampling study. On a given sample day, the monitoring van will drive a fixed pattern within the test area, stopping to collect approximately 10 minutes of data at each of three designated downwind distances from the freeway for each of the open and vegetated regions on the freeway. As the available roads now look to be around the perimeter field, the sampling will follow the road, stopping at designated locations for the collection of the averaged data. The GPS recorded vehicle speed and Carchip data could then be used to document the periods where the vehicle was stationary. Following two complete sample loops, the van will sample upwind (south) of the freeway and then make a stop at the location of the stationary DRX for comparison purposes. The cycle would then be repeated for a total of about four hours. **Figure 2** shows the proposed sampling locations around the perimeter and at the upwind location.

This sampling configuration may be modified as necessary to accommodate changes in the field conditions.

Figure 2. Proposed stopping locations for collection of average data (shown in red) based on the anticipated southeast winds. Also shown is the proposed upwind sampling location.

4. MEASUREMENT SCHEDULE

The goal of the measurement effort is to collect information downwind of the freeway during a period with consistent wind speed and direction, and traffic congestion. Given the normal diurnal cycle of winds, and the late spring/early summer schedule of the sea breeze being present, the sampling period of late May through mid-June will likely provide the best possibility of the correct conditions. Furthermore, the timing of the arrival of the sea breeze around noon, local time, will provide the start of the sampling window. This window is expected to continue through about 1700 to 1800 local time. This time period overlaps the expected freeway congestion that should start at about 1500 to 1600. Thus, the window of opportunity for sampling will be from about 1300 through 1800.

A typical sampling day will start with the calibration of the van equipment in Valencia in the mid to late morning, followed by travel to the field site. The tripods will be set up at the sites with the two level wind system anticipated to be installed at the eastern location first. The tripods will remain at the site for the sampling week. Upon arrival at the site each sampling day, the data logger and DRX will be installed, all times in the data recording synchronized, and the sampling started. At the conclusion of the sampling day, the tripod data logger and DRX data will be downloaded, the systems removed and taken back to the Valencia office. A zero/span check will then be performed on the instruments upon arrival back at the Valencia office.

Outfitting and testing of all equipment will be performed during the week of May 28. The first weeklong window for sampling will be the week of June 4, with this week anticipated to be the week of sampling, based on the current weather forecast. Once the week of sampling starts, work will continue until the end of the five consecutive day period. The budget doesn't allow for multiple restarts of the sampling effort.

5. DATA DELIVERABLES

Upon completion of the field survey, the data will be reviewed and validated to provide a data set with any needed calibrations applied, and invalid data removed. The mobile vehicle data will be in a comma delimited format with data files that provide two-second interval scans, and one-minute averages. The data from the meteorological tower will be provided in individual files for each reporting interval (1-min, 5-min, hourly). The size segregated DRX data will be provided in delimited files, as reported from the DRX.

Appendix C

Field Study Notes & Carchip Trip Log

Sample Date: June 4, 2012

Mobile Sampling Start: 1459

Mobile Sampling End: 1755

Background Run: 1815-1826

Approximate times at each sample point (from the notes):

Sample Point						
1	**2**	**3**	**4**	**5**	**6**	**7**
1458	1555	1544	1510	1521	1533	
1607	1703	1652	1619	1629	1640	
	1746		1725	1736		1714

Sampling location coordinates and instrument details:

Location	**Latitude**	**Longitude**	**Notes**
1	34.16587	-118.48605	
2	34.16651	-118.48670	
3	34.16725	-118.48669	
4	34.16557	-118.48930	
5	34.16598	-118.48954	
6	34.16641	-118.48920	
7	34.16580	-118.48695	Near site 1 but inside the gate, as the gate was locked.
DustTrak	34.16626	-118.48688	Sample inlet approximately 1.5 m above ground. Using the DustTrak 8832 with a 2.5 zero not in the data as it was taken off line before the filter was installed.
Met West	34.16583	-118.48937	Single level wind speed/wind direction at 2.7 meters
Met East	34.16627	-118.48687	Two level wind speed/wind direction at 2.7 and 7.6 meters. Values w/o the “2” are from the 7.6m level, values with the “2” are from the 2.7m level. Values for scalar wind speed, vector wind speed, unit vector wind direction, vector wind direction and the Yamartino calculated sigma-theta are provided. Temperature and RH at 2.5 meters Solar radiation at 1.9 meters

Key notes for the sampling day

- The CO values in the raw data had a zero offset of -0.05 ppm. This offset was applied to the data in the final submission.
- The background run was made after the field sampling.
- There were no periods noted with local interference from trucks or other vehicles in the adjacent baseball field or from farm activity.
- One period around 1754 on the NO/NOx/NO2 analyzer was invalidated due to a glitch of some sort. These data are labeled as -920 for an instrument malfunction.
- The PM2.5 data recorded on the data logger are limited to 250 g/m^3. The digital data from the DRX provide the full dynamic range.

Sample Date: June 6, 2012

Mobile Sampling Start: 1252

Mobile Sampling End: 1741

Background Run: 1515-1525

Approximate times at each sample point (from the notes):

Sample Point					
1	**2**	**3**	**4**	**5**	**6**
1252	1350	1339	1305	1316	1327
1401	1500	1450	1414	1426	1437
1528	1625	1614	1541	1552	1603
1637	1736	1725	1651	1702	1713

Sampling location coordinates and instrument details:

Location	Latitude	Longitude	Notes
1	34.16587	-118.48605	
2	34.16651	-118.48670	
3	34.16725	-118.48669	
4	34.16557	-118.48930	
5	34.16598	-118.48954	
6	34.16641	-118.48920	
DustTrak	34.16626	-118.48688	Sample inlet approximately 1.5 m above ground. Using the DustTrak 8520 with a 2.5 □ i should be noted that the entry on 0604 for the DustTrak should reflect this to be the 8520 unit, not the 8832.
Met West	34.16583	-118.48937	Single level wind speed/wind direction at 2.7 meters
Met East	34.16627	-118.48687	Two level wind speed/wind direction at 2.7 and 7.6 meters. Values w/o the "2" are from the 7.6m level, values with the "2" are from the 2.7m level. Values for scalar wind speed, vector wind speed, unit vector wind direction, vector wind direction and the Yamartino calculated sigma-theta are provided. Temperature and RH at 2.5 meters Solar radiation at 1.9 meters

Key notes for the sampling day

- The CO values in the raw data had a zero offset of -0.13 ppm. This offset was applied to the data in the final submission.
- The background run was made in the middle of the sampling.
- There were periods noted with local interference from trucks or other vehicles in the adjacent baseball field or from farm activity and those have been noted in the data as a value of -971. These occurred (as noted in our notes) at approximately 1322, 1332, 1456, 1618, 1623, 1650 and 1707. Additionally, one set of points was invalidated on the DustTrak 8520 at about 1609 that was obvious interference.
- A zero filter check performed on the DustTrak 8520 at the beginning and end showed an average offset of about +0.002 mg/m3. This offset was removed in the validated data.

Sample Date: June 7, 2012

Mobile Sampling Start: 1226

Mobile Sampling End: 1740

Background Run: 1540-1546

Approximate times at each sample point (from the notes):

Sample Point							
1	**2**	**3**	**4**	**5**	**6**	**8**	**9**
1226	1325	1314	1239	1250	1301		
1338			1352			1403	1415
1427	1439	1450	1524	1513	1502		
1547	1559	1610	1645	1634	1622		
1657	1704		1728	1717			

Sampling location coordinates and instrument details:

Location	Latitude	Longitude	Notes
1	34.16587	-118.48605	
2	34.16651	-118.48670	
3	34.16725	-118.48669	
4	34.16557	-118.48930	
5	34.16598	-118.48954	
6	34.16641	-118.48920	
8	34.16560	-118.48870	
9	34.16565	-118.48825	
DustTrak	34.16626	-118.48688	Sample inlet approximately 1.5 m above ground. Using the DustTrak 8520 with a 2.5□ impactor and omni inlet head. It should be noted that the entry on 0604 for the DustTrak should reflect this to be the 8520 unit, not the 8832.
Met West	34.16583	-118.48937	Single level wind speed/wind direction at 2.7 meters
Met East	34.16627	-118.48687	Two level wind speed/wind direction at 2.7 and 7.6 meters. Values w/o the "2" are from the 7.6m level, values with the "2" are from the 2.7m level. Values for scalar wind speed, vector wind speed, unit vector wind direction, vector wind direction and the Yamartino calculated sigma-theta are provided. Temperature and RH at 2.5 meters Solar radiation at 1.9 meters

Key notes for the sampling day

- The CO values in the raw data had a zero offset of -0.15 ppm. This offset was applied to the data in the final submission. Offsets were also corrected for the NO/NOx/NO2. The offsets were +1.5, -1.0 and -2.5, respectively.
- The sampling started at 1657 at point 1 was shortened due to the gate being locked.
- The background run was made in the middle of the sampling.
- There were periods noted with local interference from trucks or other vehicles in the adjacent baseball field or from farm activity and those have been noted in the data as a value of -971. These occurred (as noted in our notes) at approximately 1322, 1334, 1354, 1410, 1412, 1436, 1632 and 1703. The interference at 1334 and 1412 appeared to affect all parameters and data were invalidated taking into account the response times of the instruments.
- A zero filter check performed on the DustTrak 8520 at the beginning and end showed an average offset of about +0.002 mg/m3. This offset was removed in the validated data.

Sample Date: June 8, 2012

Mobile Sampling Start: 1252

Mobile Sampling End: 1740

Background Run: 1450-1518

Approximate times at each sample point (from the notes):

Sample Point										
1	**2**	**3**	**4**	**5**	**6**	**40**	**AA**	**A**	**B**	**C**
1252	1304	1315	1239	1341	1330	1352	1405	1417	1428	1439
1538	1549	1601	1525		1614	1625		1637		1649
					1701	1713		1725		

Sampling location coordinates and instrument details:

Location	Latitude	Longitude	Notes
1	34.16587	-118.48605	
2	34.16651	-118.48670	
3	34.16725	-118.48669	
4	34.16557	-118.48930	
5	34.16598	-118.48954	
6	34.16641	-118.48920	
40	34.16566	-118.48986	
AA	34.16567	-118.49045	
A	34.16581	-118.49021	
B	34.16624	-118.48990	
C	34.16662	-118.48954	
DustTrak	34.16626	-118.48688	Sample inlet approximately 1.5 m above ground. Using the DustTrak 8520 with a 2.5 □ i should be noted that the entry on 0604 for the DustTrak should reflect this to be the 8520 unit, not the 8832.
Met West	34.16583	-118.48937	Single level wind speed/wind direction at 2.7 meters
Met East	34.16627	-118.48687	Two level wind speed/wind direction at 2.7 and 7.6 meters. Values w/o the “2” are from the 7.6m level, values with the “2” are from the 2.7m level. Values for scalar wind speed, vector wind speed, unit vector wind direction, vector wind direction and the Yamartino calculated sigma-theta are provided. Temperature and RH at 2.5 meters Solar radiation at 1.9 meters

Key notes for the sampling day

- The CO values in the raw data had a zero offset of -0.186 ppm. This offset was applied to the data in the final submission. Offsets were also corrected for the NO/NOx/NO2. The offsets were +2, -1 and -3 ppb, respectively.
- The background run was made in the middle of the sampling.
- There were periods noted with local interference from trucks or other vehicles in the adjacent baseball field or from farm activity and those have been noted in the data as a value of -971. These occurred (as noted in our notes) at approximately 1310, 1342 and 1609.
- A zero filter check performed on the DustTrak 8520 at the beginning and end showed an average offset of about +0.002 mg/m3. This offset was removed in the validated data.

Sample Date: June 11, 2012

Mobile Sampling Start: 1200

Mobile Sampling End: 1600

Background Run: 1430-1445

Approximate times at each sample point (from the notes):

Sample Point					
1	**3**	**6**	**40**	**A**	**C**
1202	1214	1226	1238	1250	1302
1317	1330	1343	1354	1406	1418
1446	1458	1511	1523	1535	1546

Sampling location coordinates and instrument details:

Location	Latitude	Longitude	Notes
1	34.16587	-118.48605	
3	34.16725	-118.48669	
4	34.16557	-118.48930	
6	34.16641	-118.48920	
40	34.16566	-118.48986	
A	34.16581	-118.49021	
C	34.16662	-118.48954	
DustTrak	34.16626	-118.48688	Sample inlet approximately 1.5 m above ground. Using the DustTrak 8520 with a 2.5□ impactor and omni inlet head. It should be noted that the entry on 0604 for the DustTrak should reflect this to be the 8520 unit, not the 8832.
Met West	34.16583	-118.48937	Two level wind speed/wind direction at 2.7 and 7.6 meters. Values w/o the "2" are from the 7.6m level, values with the "2" are from the 2.7m level. Values for scalar wind speed, vector wind speed, unit vector wind direction, vector wind direction and the Yamartino calculated sigma-theta are provided. Temperature and RH at 2.5 meters Solar radiation at 1.9 meters
Met East	34.16627	-118.48687	Single level wind speed/wind direction at 2.7 meters

Key notes for the sampling day

- Arrival at the site was early due to the movement of the two meteorological stations. The two level system was moved to the west side of the site (Met West) while the single level system was moved to the east (Met East). The coordinates above reflect the change. Additionally, the decommission was started earlier to allow time to remove the equipment.
- The CO values in the raw data had a zero offset of -0.215 ppm. This offset was applied to the data in the final submission. Offsets were also corrected for the NO/NOx/NO2. The offsets were -1, -2.5 and -2.5 ppb, respectively.
- The background run was made in the middle of the sampling.
- There were periods noted with local interference from trucks or other vehicles in the adjacent baseball field or from farm activity and those have been noted in the data as a value of -971. These occurred (as noted in our notes) at approximately 1202, 1318, 1338, 1524, 1525, 1529, 1532, 1540 and 1545. Starting around 1529 a front end loader was in use that influenced the PM values. It may have also influenced the gaseous measurements.
- A zero filter check performed on the DustTrak 8520 at the beginning and end showed an average offset of about +0.002 mg/m3. This offset was removed in the validated data.

View / Trip Log / Summary

	Start Time	Duration	Distance Miles	Maximum Speed MPH	Time in Top Speed Band	Brakes Hard	Brakes Extreme	Accelerations Hard	Accelerations Extreme	Driver	Vehicle
Trip 1	06/01/2012 04:08 PM	0:43:10	8.1	63	0:00:32	1	0	0	0	anyone	any
Trip 2	06/01/2012 04:59 PM	0:13:48	6.5	65	0:01:12	0	0	0	0	anyone	any
Trip 3	06/01/2012 05:17 PM	0:01:49	0.0	1	0:00:00	0	0	0	0	anyone	any
Trip 4	06/04/2012 09:44 AM	0:00:53	0.0	1	0:00:00	0	0	0	0	anyone	any
Trip 5	06/04/2012 10:10 AM	0:34:38	23.2	76	0:14:23	0	0	0	0	anyone	any
Trip 6	06/04/2012 10:47 AM	0:02:13	0.6	45	0:00:00	0	0	0	0	anyone	any
Trip 7	06/04/2012 11:02 AM	0:00:40	0.1	8	0:00:00	0	0	0	0	anyone	any
Trip 8	06/04/2012 01:13 PM	0:01:22	0.1	9	0:00:00	0	0	0	0	anyone	any
Trip 9	06/04/2012 01:19 PM	0:02:42	0.2	11	0:00:00	0	0	0	0	anyone	any
Trip 10	06/04/2012 01:32 PM	0:00:47	0.0	4	0:00:00	0	0	0	0	anyone	any
Trip 11	06/04/2012 01:56 PM	0:18:04	2.0	43	0:00:00	0	0	0	0	anyone	any
Trip 12	06/04/2012 02:36 PM	0:05:30	0.9	37	0:00:00	0	0	0	0	anyone	any
Trip 13	06/04/2012 02:46 PM	0:05:05	2.2	50	0:00:00	0	0	0	0	anyone	any
Trip 14	06/04/2012 02:54 PM	0:03:04	0.0	9	0:00:00	0	0	0	0	anyone	any
Trip 15	06/04/2012 03:07 PM	0:01:56	0.2	8	0:00:00	0	0	0	0	anyone	any
Trip 16	06/04/2012 03:19 PM	0:00:44	0.0	6	0:00:00	0	0	0	0	anyone	any
Trip 17	06/04/2012 03:30 PM	0:02:10	0.1	8	0:00:00	0	0	0	0	anyone	any
Trip 18	06/04/2012 03:41 PM	0:02:15	0.2	9	0:00:00	0	0	0	0	anyone	any
Trip 19	06/04/2012 03:53 PM	0:01:05	0.0	6	0:00:00	0	0	0	0	anyone	any
Trip 20	06/04/2012 04:04 PM	0:01:38	0.1	10	0:00:00	0	0	0	0	anyone	any
Trip 21	06/04/2012 04:16 PM	0:02:16	0.2	11	0:00:00	0	0	0	0	anyone	any
Trip 22	06/04/2012 04:27 PM	0:00:37	0.0	7	0:00:00	0	0	0	0	anyone	any
Trip 23	06/04/2012 04:38 PM	0:00:59	0.0	8	0:00:00	0	0	0	0	anyone	any
Trip 24	06/04/2012 04:49 PM	0:01:42	0.1	11	0:00:00	0	0	0	0	anyone	any
Trip 25	06/04/2012 05:01 PM	0:00:53	0.0	9	0:00:00	0	0	0	0	anyone	any
Trip 26	06/04/2012 05:12 PM	0:01:08	0.0	10	0:00:00	0	0	0	0	anyone	any
Trip 27	06/04/2012 05:23 PM	0:01:35	0.1	12	0:00:00	0	0	0	0	anyone	any
Trip 28	06/04/2012 05:34 PM	0:00:37	0.0	8	0:00:00	0	0	0	0	anyone	any
Trip 29	06/04/2012 05:43 PM	0:02:03	0.2	12	0:00:00	0	0	0	0	anyone	any
Trip 30	06/04/2012 05:53 PM	0:00:38	0.0	0	0:00:00	0	0	0	0	anyone	any
Trip 31	06/04/2012 05:55 PM	0:06:59	0.9	47	0:00:00	0	0	0	0	anyone	any
Trip 32	06/04/2012 06:08 PM	0:56:29	28.5	78	0:07:20	1	0	0	0	anyone	any
Trip 33	06/04/2012 07:07 PM	0:01:21	0.0	1	0:00:00	0	0	0	0	anyone	any
Trip 34	06/06/2012 10:48 AM	0:00:51	0.0	1	0:00:00	0	0	0	0	anyone	any
Trip 35	06/06/2012 10:49 AM	0:16:43	3.0	60	0:00:02	0	0	0	0	anyone	any
Trip 36	06/06/2012 11:40 AM	0:31:33	25.5	76	0:18:00	0	0	0	0	anyone	any
Trip 37	06/06/2012 12:35 PM	0:03:15	0.2	9	0:00:00	0	0	0	0	anyone	any
Trip 38	06/06/2012 12:43 PM	0:06:49	0.2	9	0:00:00	0	0	0	0	anyone	any
Trip 39	06/06/2012 01:01 PM	0:02:09	0.2	8	0:00:00	0	0	0	0	anyone	any
Trip 40	06/06/2012 01:14 PM	0:00:32	0.0	7	0:00:00	0	0	0	0	anyone	any
Trip 41	06/06/2012 01:25 PM	0:00:46	0.0	8	0:00:00	0	0	0	0	anyone	any
Trip 42	06/06/2012 01:36 PM	0:02:11	0.1	7	0:00:00	0	0	0	0	anyone	any
Trip 43	06/06/2012 01:48 PM	0:00:38	0.0	6	0:00:00	0	0	0	0	anyone	any
Trip 44	06/06/2012 01:59 PM	0:01:33	0.1	6	0:00:00	0	0	0	0	anyone	any
Trip 45	06/06/2012 02:10 PM	0:02:33	0.2	7	0:00:00	0	0	0	0	anyone	any
Trip 46	06/06/2012 02:24 PM	0:00:27	0.0	7	0:00:00	0	0	0	0	anyone	any
Trip 47	06/06/2012 02:35 PM	0:00:36	0.0	6	0:00:00	0	0	0	0	anyone	any
Trip 48	06/06/2012 02:46 PM	0:02:22	0.1	7	0:00:00	0	0	0	0	anyone	any
Trip 49	06/06/2012 02:59 PM	0:00:34	0.0	6	0:00:00	0	0	0	0	anyone	any
Trip 50	06/06/2012 03:09 PM	0:17:21	4.4	40	0:00:00	0	0	0	0	anyone	any
Trip 51	06/06/2012 03:37 PM	0:02:23	0.2	7	0:00:00	0	0	0	0	anyone	any
Trip 52	06/06/2012 03:50 PM	0:00:27	0.0	6	0:00:00	0	0	0	0	anyone	any
Trip 53	06/06/2012 04:01 PM	0:00:59	0.0	6	0:00:00	0	0	0	0	anyone	any
Trip 54	06/06/2012 04:12 PM	0:02:13	0.1	7	0:00:00	0	0	0	0	anyone	any
Trip 55	06/06/2012 04:23 PM	0:00:39	0.0	6	0:00:00	0	0	0	0	anyone	any
Trip 56	06/06/2012 04:34 PM	0:01:05	0.1	7	0:00:00	0	0	0	0	anyone	any
Trip 57	06/06/2012 04:45 PM	0:03:39	0.2	11	0:00:00	0	0	0	0	anyone	any
Trip 58	06/06/2012 05:00 PM	0:00:53	0.0	4	0:00:00	0	0	0	0	anyone	any
Trip 59	06/06/2012 05:11 PM	0:01:00	0.0	6	0:00:00	0	0	0	0	anyone	any
Trip 60	06/06/2012 05:22 PM	0:02:14	0.1	7	0:00:00	0	0	0	0	anyone	any
Trip 61	06/06/2012 05:34 PM	0:00:37	0.0	6	0:00:00	0	0	0	0	anyone	any
Trip 62	06/06/2012 05:45 PM	0:00:12	0.0	1	0:00:00	0	0	0	0	anyone	any
Trip 63	06/06/2012 05:51 PM	0:25:48	8.8	53	0:00:00	1	0	0	0	anyone	any
Trip 64	06/06/2012 07:18 PM	0:19:45	14.5	75	0:06:38	0	0	0	0	anyone	any
Trip 65	06/06/2012 07:39 PM	0:00:47	0.0	1	0:00:00	0	0	0	0	anyone	any

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	Start Time	Duration	Distance Miles	Maximum Speed MPH	Time in Top Speed Band	Brakes Hard	Brakes Extreme	Accelerations Hard	Accelerations Extreme	Driver	Vehicle
Trip 65	06/06/2012 07:39 PM	0:00:47	0.0	1	0:00:00	0	0	0	0	anyone	any
Trip 66	06/07/2012 10:58 AM	0:15:16	1.0	44	0:00:00	0	0	0	0	anyone	any
Trip 67	06/07/2012 11:37 AM	0:26:35	22.0	78	0:14:21	0	0	0	0	anyone	any
Trip 68	06/07/2012 12:11 PM	0:03:32	0.2	7	0:00:00	0	0	0	0	anyone	any
Trip 69	06/07/2012 12:19 PM	0:06:04	0.2	6	0:00:00	0	0	0	0	anyone	any
Trip 70	06/07/2012 12:35 PM	0:02:35	0.2	6	0:00:00	0	0	0	0	anyone	any
Trip 71	06/07/2012 12:48 PM	0:00:32	0.0	6	0:00:00	0	0	0	0	anyone	any
Trip 72	06/07/2012 12:59 PM	0:01:09	0.0	6	0:00:00	0	0	0	0	anyone	any
Trip 73	06/07/2012 01:10 PM	0:02:20	0.1	7	0:00:00	0	0	0	0	anyone	any
Trip 74	06/07/2012 01:23 PM	0:00:35	0.0	7	0:00:00	0	0	0	0	anyone	any
Trip 75	06/07/2012 01:33 PM	0:00:55	0.0	2	0:00:00	0	0	0	0	anyone	any
Trip 76	06/07/2012 01:35 PM	0:01:22	0.1	8	0:00:00	0	0	0	0	anyone	any
Trip 77	06/07/2012 01:47 PM	0:03:13	0.2	5	0:00:00	0	0	0	0	anyone	any
Trip 78	06/07/2012 02:01 PM	0:01:03	0.0	6	0:00:00	0	0	0	0	anyone	any
Trip 79	06/07/2012 02:13 PM	0:00:49	0.0	4	0:00:00	0	0	0	0	anyone	any
Trip 80	06/07/2012 02:24 PM	0:02:20	0.1	6	0:00:00	0	0	0	0	anyone	any
Trip 81	06/07/2012 02:36 PM	0:01:03	0.1	7	0:00:00	0	0	0	0	anyone	any
Trip 82	06/07/2012 02:48 PM	0:01:03	0.0	6	0:00:00	0	0	0	0	anyone	any
Trip 83	06/07/2012 02:59 PM	0:02:14	0.1	6	0:00:00	0	0	0	0	anyone	any
Trip 84	06/07/2012 03:11 PM	0:00:34	0.0	6	0:00:00	0	0	0	0	anyone	any
Trip 85	06/07/2012 03:22 PM	0:00:57	0.0	6	0:00:00	0	0	0	0	anyone	any
Trip 86	06/07/2012 03:35 PM	0:11:12	3.2	44	0:00:00	0	0	0	0	anyone	any
Trip 87	06/07/2012 03:56 PM	0:01:41	0.1	6	0:00:00	0	0	0	0	anyone	any
Trip 88	06/07/2012 04:07 PM	0:00:55	0.0	7	0:00:00	0	0	0	0	anyone	any
Trip 89	06/07/2012 04:18 PM	0:01:56	0.1	6	0:00:00	0	0	0	0	anyone	any
Trip 90	06/07/2012 04:33 PM	0:00:52	0.0	7	0:00:00	0	0	0	0	anyone	any
Trip 91	06/07/2012 04:42 PM	0:00:57	0.0	6	0:00:00	0	0	0	0	anyone	any
Trip 92	06/07/2012 04:54 PM	0:02:47	0.2	7	0:00:00	0	0	0	0	anyone	any
Trip 93	06/07/2012 05:02 PM	0:01:41	0.1	6	0:00:00	0	0	0	0	anyone	any
Trip 94	06/07/2012 05:13 PM	0:02:53	0.2	7	0:00:00	0	0	0	0	anyone	any
Trip 95	06/07/2012 05:26 PM	0:01:07	0.0	4	0:00:00	0	0	0	0	anyone	any
Trip 96	06/07/2012 05:39 PM	0:01:53	0.2	8	0:00:00	0	0	0	0	anyone	any
Trip 97	06/07/2012 05:46 PM	0:20:33	6.8	49	0:00:00	0	0	0	0	anyone	any
Trip 98	06/07/2012 06:53 PM	0:22:47	16.5	78	0:06:55	0	0	0	0	anyone	any
Trip 99	06/07/2012 07:19 PM	0:00:42	0.0	1	0:00:00	0	0	0	0	anyone	any
Trip 100	06/08/2012 10:23 AM	0:23:46	16.5	75	0:10:15	0	0	1	0	anyone	any
Trip 101	06/08/2012 11:02 AM	0:13:26	7.9	76	0:03:52	1	0	0	0	anyone	any
Trip 102	06/08/2012 11:21 AM	0:02:52	0.2	6	0:00:00	0	0	0	0	anyone	any
Trip 103	06/08/2012 11:28 AM	0:03:04	0.2	11	0:00:00	0	0	0	0	anyone	any
Trip 104	06/08/2012 11:35 AM	0:06:27	1.2	42	0:00:00	0	0	0	0	anyone	any
Trip 105	06/08/2012 12:26 PM	0:06:25	1.6	47	0:00:00	0	0	0	0	anyone	any
Trip 106	06/08/2012 12:34 PM	0:03:28	0.2	8	0:00:00	0	0	0	0	anyone	any
Trip 107	06/08/2012 12:48 PM	0:02:18	0.2	7	0:00:00	0	0	0	0	anyone	any
Trip 108	06/08/2012 01:01 PM	0:01:09	0.1	6	0:00:00	0	0	0	0	anyone	any
Trip 109	06/08/2012 01:13 PM	0:00:44	0.0	5	0:00:00	0	0	0	0	anyone	any
Trip 110	06/08/2012 01:25 PM	0:02:29	0.1	5	0:00:00	0	0	0	0	anyone	any
Trip 111	06/08/2012 01:39 PM	0:01:19	0.0	5	0:00:00	0	0	0	0	anyone	any
Trip 112	06/08/2012 01:50 PM	0:00:33	0.0	4	0:00:00	0	0	0	0	anyone	any
Trip 113	06/08/2012 02:01 PM	0:02:11	0.1	6	0:00:00	0	0	0	0	anyone	any
Trip 114	06/08/2012 02:14 PM	0:01:31	0.0	3	0:00:00	0	0	0	0	anyone	any
Trip 115	06/08/2012 02:17 PM	0:00:15	0.0	0	0:00:00	0	0	0	0	anyone	any
Trip 116	06/08/2012 02:26 PM	0:01:03	0.0	4	0:00:00	0	0	0	0	anyone	any
Trip 117	06/08/2012 02:37 PM	0:01:20	0.0	5	0:00:00	0	0	0	0	anyone	any
Trip 118	06/08/2012 02:48 PM	0:34:50	7.1	47	0:00:00	1	0	0	0	anyone	any
Trip 119	06/08/2012 03:34 PM	0:02:27	0.2	7	0:00:00	0	0	0	0	anyone	any
Trip 120	06/08/2012 03:46 PM	0:01:04	0.1	6	0:00:00	0	0	0	0	anyone	any
Trip 121	06/08/2012 03:58 PM	0:00:59	0.0	6	0:00:00	0	0	0	0	anyone	any
Trip 122	06/08/2012 04:09 PM	0:02:19	0.1	6	0:00:00	0	0	0	0	anyone	any
Trip 123	06/08/2012 04:22 PM	0:01:32	0.1	5	0:00:00	0	0	0	0	anyone	any
Trip 124	06/08/2012 04:34 PM	0:02:01	0.1	6	0:00:00	0	0	0	0	anyone	any
Trip 125	06/08/2012 04:46 PM	0:02:02	0.1	4	0:00:00	0	0	0	0	anyone	any
Trip 126	06/08/2012 04:58 PM	0:01:48	0.1	7	0:00:00	0	0	0	0	anyone	any
Trip 127	06/08/2012 05:10 PM	0:01:33	0.1	5	0:00:00	0	0	0	0	anyone	any
Trip 128	06/08/2012 05:22 PM	0:01:54	0.1	7	0:00:00	0	0	0	0	anyone	any
Trip 129	06/08/2012 05:33 PM	0:01:38	0.1	6	0:00:00	0	0	0	0	anyone	any

View / Trip Log / Summary, Continued

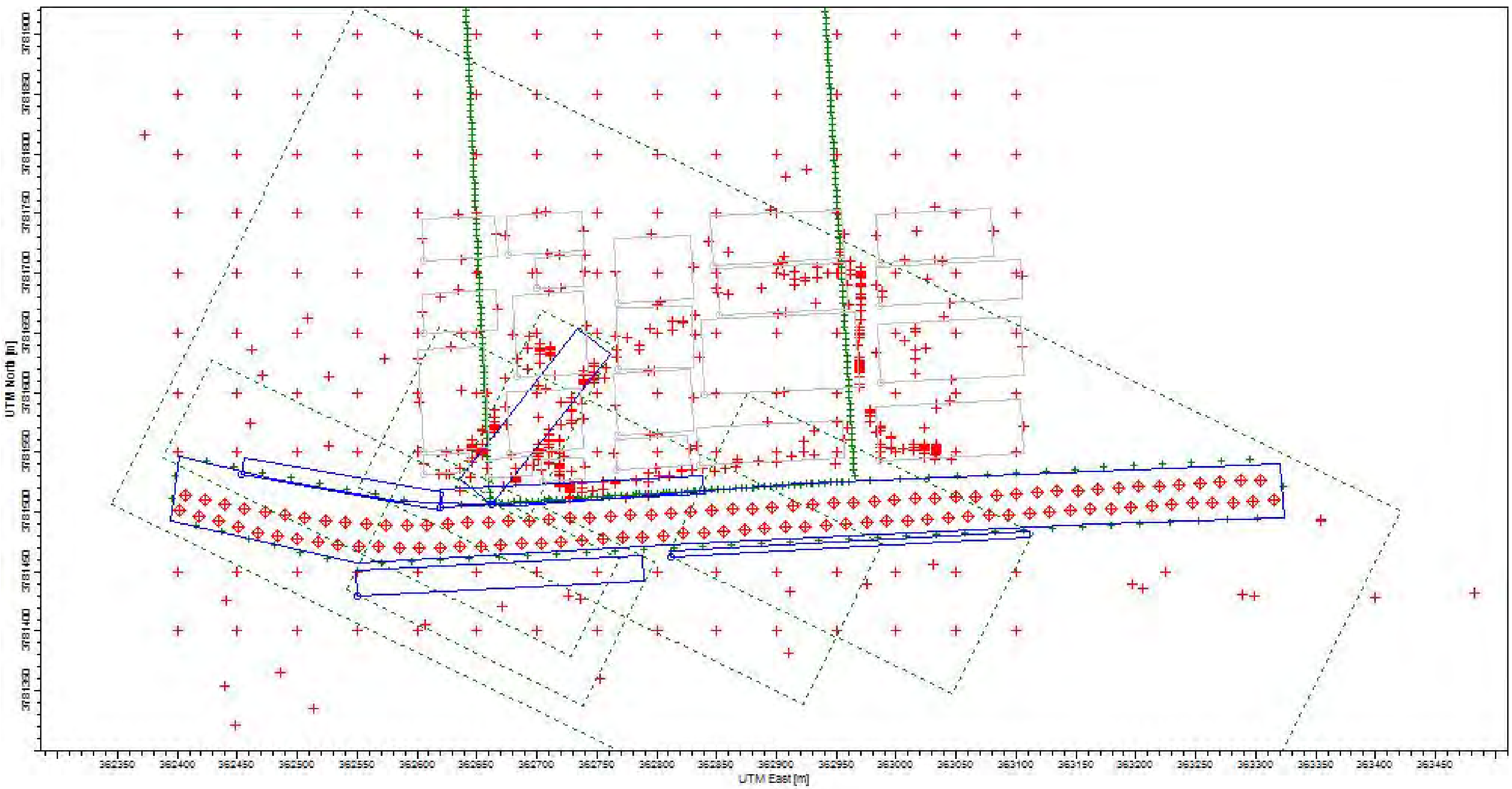
	Start Time	Duration	Distance Miles	Maximum Speed MPH	Time in Top Speed Band	Brakes Hard	Brakes Extreme	Accelerations Hard	Accelerations Extreme	Driver	Vehicle
Trip 129	06/08/2012 05:33 PM	0:01:38	0.1	6	0:00:00	0	0	0	0	anyone	any
Trip 130	06/08/2012 05:37 PM	0:02:37	0.2	8	0:00:00	0	0	0	0	anyone	any
Trip 131	06/08/2012 05:43 PM	0:01:47	0.1	9	0:00:00	0	0	0	0	anyone	any
Trip 132	06/08/2012 05:47 PM	0:41:12	23.1	80	0:06:41	0	0	0	0	anyone	any
Trip 133	06/08/2012 06:29 PM	0:00:59	0.0	1	0:00:00	0	0	0	0	anyone	any
Trip 134	06/11/2012 08:03 AM	0:00:18	0.0	0	0:00:00	0	0	0	0	anyone	any
Trip 135	06/11/2012 08:14 AM	0:29:17	22.9	78	0:13:32	1	0	0	0	anyone	any
Trip 136	06/11/2012 08:45 AM	0:01:19	0.1	13	0:00:00	0	0	0	0	anyone	any
Trip 137	06/11/2012 09:36 AM	0:04:01	0.2	7	0:00:00	0	0	0	0	anyone	any
Trip 138	06/11/2012 10:46 AM	0:27:21	2.0	47	0:00:00	0	0	0	0	anyone	any
Trip 139	06/11/2012 11:45 AM	0:04:38	0.4	29	0:00:00	0	0	0	0	anyone	any
Trip 140	06/11/2012 11:55 AM	0:06:00	1.7	47	0:00:00	1	0	0	0	anyone	any
Trip 141	06/11/2012 12:10 PM	0:01:57	0.1	7	0:00:00	0	0	0	0	anyone	any
Trip 142	06/11/2012 12:23 PM	0:01:52	0.1	6	0:00:00	0	0	0	0	anyone	any
Trip 143	06/11/2012 12:35 PM	0:01:31	0.1	5	0:00:00	0	0	0	0	anyone	any
Trip 144	06/11/2012 12:46 PM	0:02:17	0.1	7	0:00:00	0	0	0	0	anyone	any
Trip 145	06/11/2012 12:58 PM	0:01:22	0.1	5	0:00:00	0	0	0	0	anyone	any
Trip 146	06/11/2012 01:11 PM	0:04:30	0.3	6	0:00:00	0	0	0	0	anyone	any
Trip 147	06/11/2012 01:26 PM	0:01:52	0.1	5	0:00:00	0	0	0	0	anyone	any
Trip 148	06/11/2012 01:39 PM	0:02:51	0.1	5	0:00:00	0	0	0	0	anyone	any
Trip 149	06/11/2012 01:51 PM	0:01:02	0.1	5	0:00:00	0	0	0	0	anyone	any
Trip 150	06/11/2012 02:03 PM	0:01:37	0.1	5	0:00:00	0	0	0	0	anyone	any
Trip 151	06/11/2012 02:15 PM	0:01:42	0.1	5	0:00:00	0	0	0	0	anyone	any
Trip 152	06/11/2012 02:27 PM	0:17:23	5.7	55	0:00:00	1	0	0	0	anyone	any
Trip 153	06/11/2012 02:54 PM	0:02:04	0.1	6	0:00:00	0	0	0	0	anyone	any
Trip 154	06/11/2012 03:07 PM	0:03:04	0.1	5	0:00:00	0	0	0	0	anyone	any
Trip 155	06/11/2012 03:19 PM	0:01:04	0.1	5	0:00:00	0	0	0	0	anyone	any
Trip 156	06/11/2012 03:31 PM	0:02:11	0.1	5	0:00:00	0	0	0	0	anyone	any
Trip 157	06/11/2012 03:44 PM	0:01:42	0.1	6	0:00:00	0	0	0	0	anyone	any
Trip 158	06/11/2012 03:54 PM	0:01:42	0.1	5	0:00:00	0	0	0	0	anyone	any
Trip 159	06/11/2012 04:22 PM	0:02:01	0.2	7	0:00:00	0	0	0	0	anyone	any
Trip 160	06/11/2012 04:38 PM	0:00:37	0.1	11	0:00:00	0	0	0	0	anyone	any
Trip 161	06/11/2012 04:41 PM	0:04:06	0.5	51	0:00:00	0	0	0	0	anyone	any
Trip 162	06/11/2012 04:55 PM	0:20:45	7.4	53	0:00:00	0	0	1	0	anyone	any
Trip 163	06/11/2012 05:20 PM	0:23:43	15.3	80	0:07:05	1	0	0	0	anyone	any
Trip 164	06/11/2012 05:48 PM	0:00:59	0.0	1	0:00:00	0	0	0	0	anyone	any
Trip 165	06/12/2012 07:16 AM	0:00:09	0.0	0	0:00:00	0	0	0	0	anyone	any
Trip 166	06/12/2012 09:36 AM	0:00:17	0.0	0	0:00:00	0	0	0	0	anyone	any
Trip 167	06/12/2012 12:28 PM	0:08:47	4.5	60	0:00:00	0	0	0	0	anyone	any
Trip 168	06/12/2012 01:35 PM	0:09:53	3.9	60	0:00:04	0	0	2	0	anyone	any
Trip 169	06/12/2012 03:30 PM	0:12:24	4.9	49	0:00:00	0	0	1	0	anyone	any

Appendix D

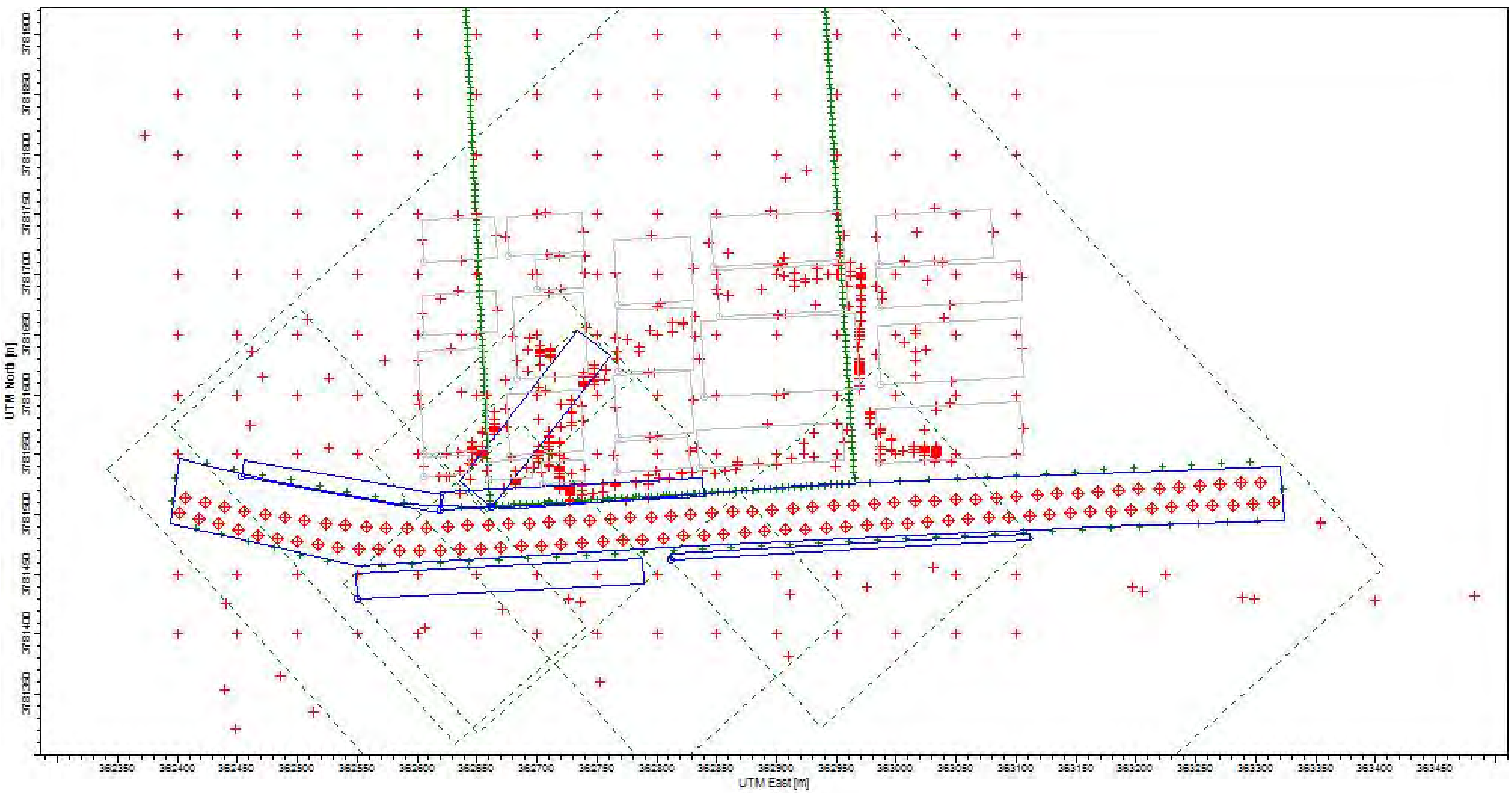
Supplemental Site Layout Drawings Showing Barriers and Associated Regions of Influence for Selected Wind Angles

The illustrations show the GEP 5*L region of influence for three different wind angles (125°, 138° and 168°) for the elevated freeway, the sound wall, and the vegetative barriers. In no case does the region of influence of the sound wall reach the western receptors, no matter the sound angle.

“Buildings” and Regions of Influence for Wind Angle 125°



“Buildings” and Regions of Influence for Wind Angle 138°



“Buildings” and Regions of Influence for Wind Angle 168°