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FINAL REPORT

TRAFFIC GENERATED PM_{10} "HOT SPOTS"

A study for the
California Department of Transportation

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Abstract

In the summer of 1994 the Crocker Nuclear Laboratory Air Quality Group found increased PM_{10} concentrations downwind of a California freeway, an urban roadway and a heavily traveled intersection. While the freeway and urban roadway only increased concentrations 5 to 7 $\mu g/m^3$, the increase across the intersection was approximately ten times greater, i.e. about 80 $\mu g/m^3$. The emission rates from the freeway and the urban roadway were estimated at 18 to 24 mg/VKT and 19 to 34 VKT, respectively. The emission rate from the intersection was estimated to range from 259 to 1295 mg/VKT. The intersection study was a preliminary experiment, however, and the majority of the intersection PM_{10} emissions could not be attributed to any particular source type.

In 1995, the Air Quality Group investigated paved road PM_{10} emissions generated at intersections in greater depth. We sampled at the same intersection with a more robust sampling array, and we increased the duration and frequency of sampling to four samples per day for three and one half days. The measured concentration change across the intersection in 1995 averaged 5 to 25 $\mu g/m^3$ at the closest downwind sampler during typical summertime conditions. The corresponding $PM_{2.5}$ concentrations increased by 0 to 13 $\mu g/m^3$ at the closest downwind sampler. The PM_{10} emission rate estimate ranged from 84 to 389 mg/VKT, while the $PM_{2.5}$ emission rate estimate ranged from 10 to 142 mg/VKT. It should be noted that direct vehicular emissions were not subtracted from the measured downwind increase, so that the measured "re-entrained" dust emission factor is a slight overestimate.

These results indicate that the intersection is not likely to be a “PM_{10} hot spot” unless the background concentration is already close to the 150 $\mu g/m^3$ 24-hour standard. Furthermore, the elevated concentrations extended less than 100 meters downwind of the intersection in most cases. In other words, the concentrations at the far downwind sampling site (less than 100 meters downwind of the intersection) were close to the upwind concentrations during most sampling periods. The major contributor to high concentrations near the intersection was background PM_{10} from the urban area.

Introduction

Federal conformity rules require that state agencies responsible for approval and/or funding of transportation projects ensure that such projects conform to an approved or promulgated state implementation plan and to all applicable state and federal air quality standards. Because of this requirement, Caltrans needs to know whether "hot spots" of PM_{10} emissions exist at particular roadway configurations in California. If such "hot spots" exist, road construction projects might have to mitigate the PM_{10} impacts. An earlier preliminary UC Davis sampling study suggested that an intersection might be such a "hot spot" of PM_{10} emissions, so the study reported herein was designed to investigate this possibility.

The U.S. Environmental Protection Agency has published procedures for calculating PM_{10} fugitive dust emissions from paved roads in AP-42, "Compilation of Air Pollution Emission Factors."[1] The predictive equation for the calculation uses roadway silt loading and average vehicle weight as input parameters. Silt loading is defined as the areal density of material on the road surface that passes through a 200 mesh (75μm) screen. The equation is not designed to predict the emissions of particular vehicles or classes of vehicles. It also does not allow for site-specific peculiarities, but is designed to be applied nationwide.

In an earlier Caltrans-funded UC Davis study, we found that the AP-42 equation predicted higher emissions than we measured. We did not measure roadway silt loading during the earlier study, but instead relied on the procedure outlined in AP-42 to search tables of measured roadway silt loadings for roadways similar to those where we measured the emissions. The measured fugitive dust emissions from a high-VMT freeway added only about 5 $\mu g/m^3$ to the overall 50 $\mu g/m^3$ background. The predicted emissions were about an order of magnitude higher. In a pilot study carried out at an urban intersection, we found that the intersection added about 80 $\mu g/m^3$ to the approximately 70 $\mu g/m^3$ background. The predicted emissions are a factor of four or more higher than the measured emissions. The measured mass at the intersection could not be accounted for by the aerosol composition, however, leading us to suspect that there may be an additional source of PM_{10} (possible organic material) that was not measured. However, the poor agreement between gravimetric and reconstructed mass could also be due to faulty mass measurements. Although the filters were reweighed and reanalyzed, and provided results consistent with the first analyses, it was not possible to repeat the pre-sampling weights. Nevertheless, the filter pre-weights were in agreement with other filters from the same lot.

The purpose of the study described here was to conduct a detailed investigation of the intersection to resolve some of the uncertainties associated with the earlier study. This study included measuring silt loading on the approaches to the intersection, and time-resolved upwind-downwind concentration measurements collected to facilitate calculating emission factors as a function of the time of day.

Methods

Sampling was carried out at the intersection of Stockton Boulevard and Florin Road in Sacramento, CA from noon on August 23 through 9 p.m. on August 26, 1995. Table 1 shows the traffic and weather conditions during the tests. At the beginning of the study, we vacuumed approximately 20 m^2 of the approach lanes to the intersection to obtain road surface silt loadings. Note that the silt loading measurements were carried out upstream of the intersection. It was too dangerous to vacuum the intersection itself, as there were vehicles present at nearly all times.

Table 1. Traffic and weather conditions during each measurement period

Test ID	Date	Start Time	End Time	Total Traffic (vehicles/ hour)	Wind Speed (m/s)	Wind Direction (Degrees)
95-024	8/23/95	12:00	16:00	3,838	2.53 ±0.58	234.9 ±15.8
95-025	8/23/95	16:00	19:00	4,517	3.50 ± 0.42	237.3 ± 7.9
95-026	8/23/95	19:00	06:00 (8/24)	1,536	2.21 ± 0.57	200.4 ±24.9
95-027	8/24/95	06:00	10:01	2,417	2.45 ± 0.60	200.7 ±24.0
95-028	8/24/95	11:43	16:00	3,897	2.91 ± 1.46	237.7 ±11.9
95-029	8/24/95	16:00	20:55	3,973	3.01 ± 0.52	225.7 ±10.7
95-030	8/24/95	20:55	05:55 (8/25)	1,064	2.13 ± 0.25	182.7 ±14.2
95-031	8/25/95	05:55	10:01	2,221	2.28 ± 0.53	219.8 ±17.8
95-032	8/25/95	11:07	15:58	4,093	2.73 ± 0.50	232.0 ±12.9
95-033	8/25/95	15:58	21:00	4,479	2.83 ± 0.64	220.2 ±16.8
95-034	8/25/95	21:00	05:56 (8/26)	1,294	2.44 ± 0.36	289.3 ± 8.5
95-035	8/25/95	05:56	10:00	1,463	1.41 ± 0.56	208.3 ±30.8
95-036	8/25/95	11:01	16:06	3,694	0.99 ± 0.96	280.6 ±63.0
95-037	8/25/95	16:06	19:00	3,699	1.96 ± 0.46	237.0 ±19.1

Emission measurements

We used a modified upwind-downwind sampling method with a box model to calculate the particle emission rates at the intersection. The traditional upwind-downwind method uses a single sampler upwind and a single sampler downwind of a line source to measure the concentrations. The effect of the source is found by subtracting the upwind concentration from the downwind concentration. We modified the traditional upwind-downwind sampling method to more accurately account for the vertical distribution of the particle flux and to examine the concentrations at additional downwind locations. This sampling method with vertical measurements is sometimes referred to as exposure profiling. The additional downwind locations can be compared to a dispersion model or used directly to estimate downwind deposition, dispersion, and transport. Appendix B shows the results of dispersion modeling using the CALINE4 model with data collected in this measurement study.

Sampler placement

Figure 1 shows a schematic diagram of the Florin Road/Stockton Boulevard intersection and the locations of the samplers. Note that the intersection is not at a right angle as the diagram indicates. Florin Road runs E-W (90°-270°), but Stockton Boulevard actually runs slightly NW-SE (160°-340°). The upwind site (U1) consisted of PM_{10} and $PM_{2.5}$ samplers at 3 meters and 9 meters above the ground. The near downwind site (D1) had PM_{10} and $PM_{2.5}$ samplers at these same heights and a PM_{10} sampler at 1m. It also had wind speed and temperature at 0.5m, 1m, 2m, 4m, and 8m, wind direction at 2m, and solar radiation at 2m. The D1 site also had a DRUM impactor at 3m for detailed particle size data. The downwind D2 site had a PM_{10} sampler at 3m, and the downwind D4 site had both PM_{10} and $PM_{2.5}$ samplers at 3 meters.

The D1 sampling site was 9m downwind of the downwind corner of the intersection. The D2 site was 50m downwind, and the D4 site was 88.5m downwind of the corner. Both these sites were located in the parking lot of a grocery store. The upwind site, U1, was 49m upwind of the upwind corner of the intersection near a hedge separating the tire store from a hamburger restaurant.

Particle measurements

We measured particles in the PM_{10} and $PM_{2.5}$ size ranges with Single IMPROVE Modules (Eldred, 1988) designed for this purpose. Figure 2 shows a diagram of the $PM_{2.5}$ module. The particle size cut on this sampler is obtained by a cyclone of the AIHL (State of California Air and Industrial Hygiene Laboratory) design with a 2.5 µm D_{50}. The PM_{10} module is similar, but the particle sizing is accomplished by a Sierra-Anderson PM_{10} inlet instead of the cyclone illustrated. We made detailed particle size measurements at the first downwind location using a multistage DRUM impactor configured to collect particles in four size ranges; 0.07-1.15 µm, 1.15-2.5 µm, 2.5-5 µm, and 5-10 µm.

Meteorological measurements

We measured meteorological parameters continuously at the downwind D1 site. These parameters included wind speed and temperature at 0.5m, 1m, 2m, 4m, and 8m above the surface, and wind direction and radiation at 2m. The data were recorded on Campbell Scientific CR-10 data loggers in 10-minute averages. These battery powered, automatic weather stations and their sensors meet all federal (EPA PSD standards) and state agency requirements.

Road silt loading measurements

We collected the road surface material using a Hoover Porta-Power II canister vacuum, model number S1315, with removable bags (type R) using the procedure described in AP-42, Appendix D. We vacuumed an area of 20 to 25 m^2 across all lanes approaching the intersection from each direction. The area vacuumed extended from the curb on the inside edge of the road to the gutter at the outside edge at a location next to the traffic counter hose. The vacuum cleaner bags were weighed before and after use, and the mass collected was obtained by difference. We sieved the sample according to the procedure recommended by the EPA in AP-42, Appendix E to separate the silt fraction. This fraction is defined as the amount of material that passes through a 200 mesh (75 µm) screen. The silt loading is defined as the mass of that material divided by the area vacuumed.

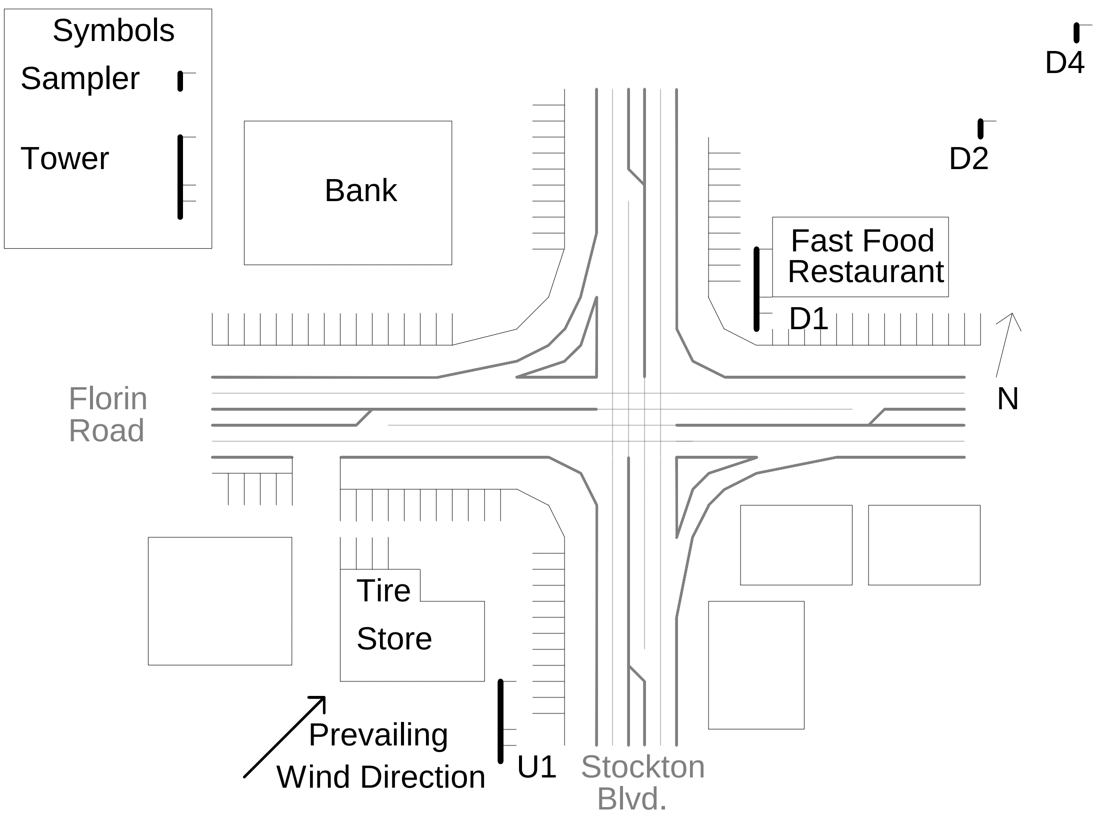


Figure 1. Sampling site at Florin Road and Stockton Boulevard showing the locations of the upwind and downwind samplers (not drawn to scale or exact geometry).

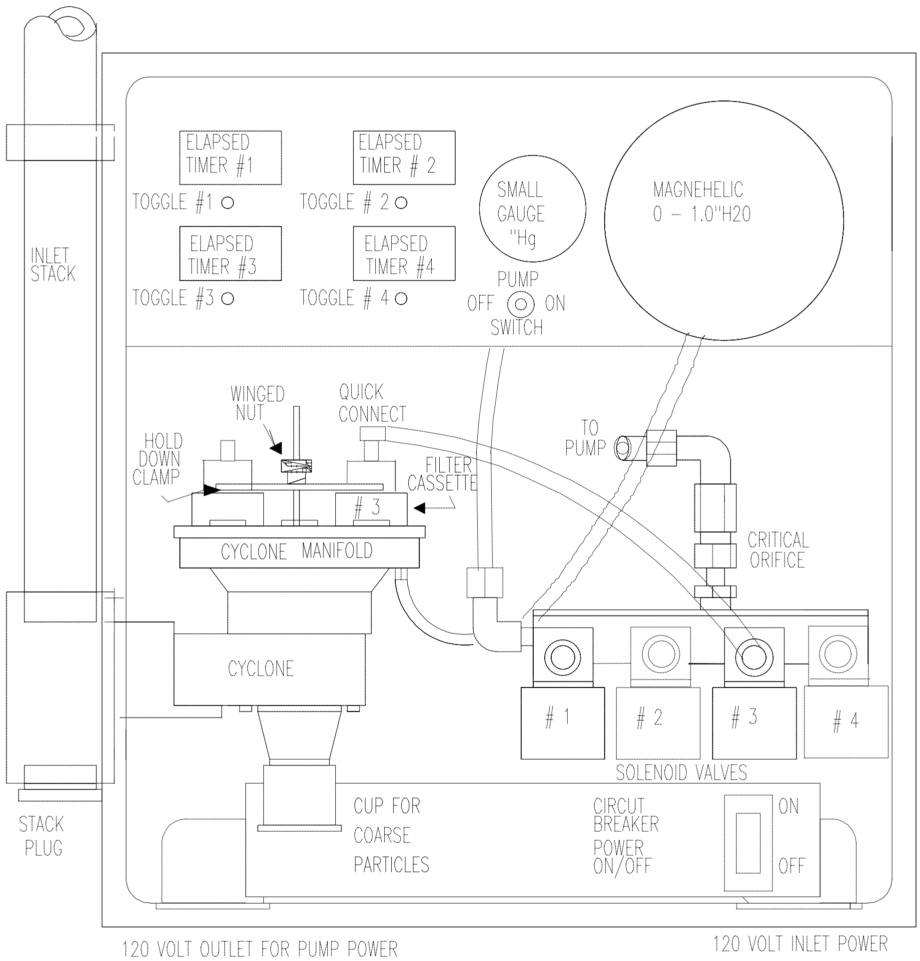


Figure 2. IMPROVE $PM_{2.5}$ sampling module.

Results

Traffic

Sacramento County monitored traffic volume using hose counters at all four approaches to the intersection. The traffic counts began at 10:00 a.m. on Wednesday, August 23 and ended at 2 p.m. on Monday, August 28. The counts were recorded hourly. UC Davis staff supplemented the automatic counts with a manual count for ten minutes each hour. Figure 3 shows the traffic volume at each of the approaches to the intersection. Each approach carried a similar volume of traffic.

Road surface silt loading

Table 2 shows the surface loading and silt loading measurements for each of the approaches to the Florin Road/Stockton Boulevard intersection. Note that the westbound Florin Road loading was significantly higher than the other approaches. It is not clear why this was the case, although there may have been a heavy deposit of material near the edge of the traveled lanes that was picked up in the vacuum cleaner. The size distribution of the surface loading did not vary appreciably between the four approaches sampled, so the higher weight on the westbound lanes was not caused by a small amount of very large particles.

Meteorology

The meteorology was generally consistent throughout the test. A front moved through on Saturday, though, and the effect on the wind direction can be clearly seen in Figure 4. The wind direction was near the ideal 225° during most of the daylight hours. During the night, the wind direction was more from the south, so the effect of Stockton Boulevard traffic was less pronounced. The stability parameter WDSTD indicates that the winds were acceptable for all time periods except Saturday afternoon from noon to 4:00 p.m. During this time the wind direction fluctuated rapidly, violating our requirement for stable winds.

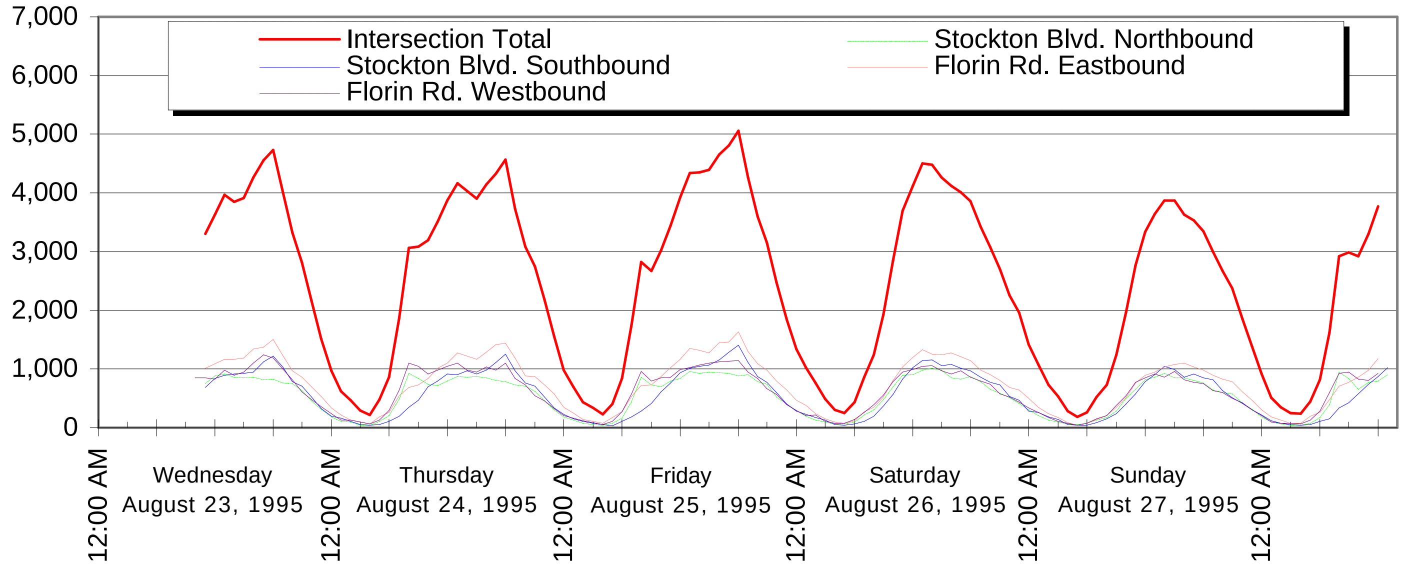


Figure 3. Traffic volume at the four approaches to the Florin Road/Stockton Boulevard intersection

The wind speed showed a diurnal variation with a low of about 2m/s during the night and a high of nearly 5m/s during the day, as shown in Figure 5. Note that there are several time periods with missing data at 8m that correspond to the times when the tower was lowered to service the aerosol samplers. The 3m anemometer, wind vane, and thermometer were located on a separate stand that was not disturbed throughout the experiment. The wind speed at 8m was higher than at 3m, as expected. This pattern was consistent for each day except Saturday when the front passed through. During this time the wind speeds dropped to lower values than we observed on the other days.

Table 2. **Silt loading on the approaches to the Florin Road/Stockton Boulevard intersection**

Road	Collection Date	Area Vacuumed (m^2)	Moisture (%)	Silt (%)	Silt Loading (g/m^2)	Surface Loading (g/m^2)
Florin Road East (Westbound)	08/23/95	20	0.42	3.99	0.0543	1.421
Florin Road West (Eastbound)	08/23/95	20	0.71	2.65	0.0034	0.139
Stockton Boulevard South (Northbound)	08/23/95	21.9	1.22	4.44	0.0016	0.045
Stockton Boulevard North (Southbound)	08/23/95	24.6	0.43	2.32	0.0020	0.090
Average			*0.69*	*3.35*	*0.015*	*0.424*
Standard Deviation			*±0.38*	*±1.02*	*±0.026*	*±0.666*

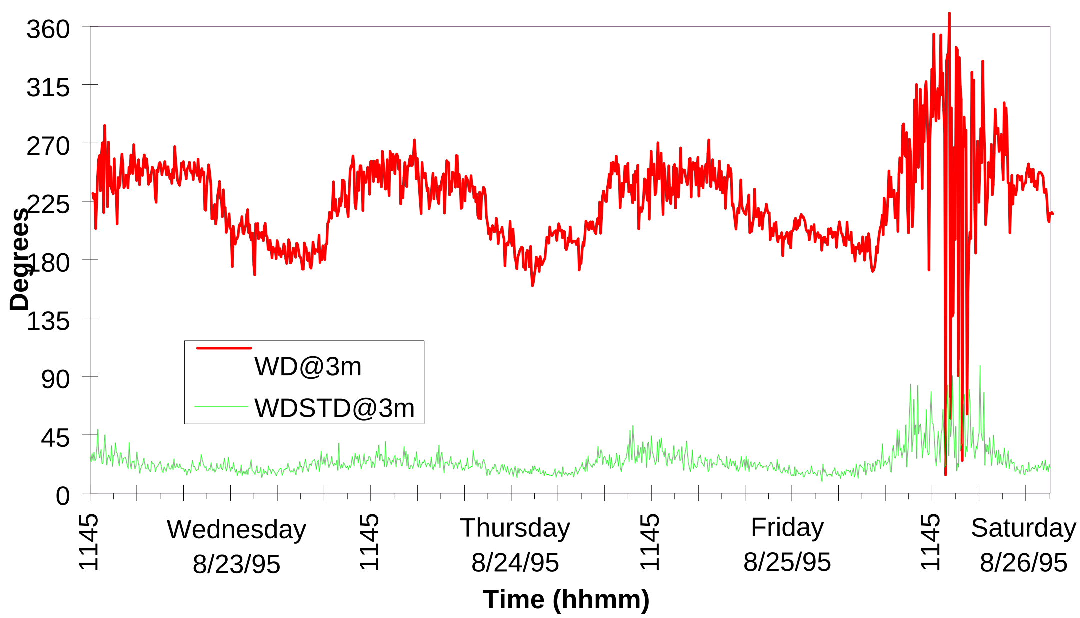


Figure 4. **Wind direction and standard deviation during the test periods**

The temperature and relative humidity also showed a pronounced diurnal variation (Figure 6). The 3m and 8m temperatures tracked each other quite closely, and varied between 30-35°C during the day and 15°C at night. The relative humidity varied inversely with the temperature, as expected, and ranged from a low of about 20% during the day to a high of 65-80% at night.

Particulate Matter Concentrations

The PM_{10} mass concentrations are shown in Table 3 for each sampler location and time period, along with the meteorology and traffic data. The concentrations measured at D1, the downwind location corresponding to the downwind site sampled in 1994, are lower than the 1994 measurements. The highest concentration measured was 68.1 $\mu g/m^3$ at the 3m height on August 23 from 4:00 to 7:00 p.m. The largest PM_{10} increase across the intersection, 29 $\mu g/m^3$, also occurred at the 3m height on August 23 from 4:00 to 7:00 p.m. An increase of about the same magnitude occurred on the same day from noon to 4:00 p.m. at the D1 9m height and at the D2 site.

The $PM_{2.5}$ mass concentrations are shown in Table 4 for each sampler location and time period. The highest concentration, 23.9 $\mu g/m^3$, was measured at the D1 site at 3m on August 24 from 11:43 a.m. to 4 p.m. This also corresponded to the highest increase in $PM_{2.5}$ mass across the intersection, 13.3 $\mu g/m^3$.

The upwind PM_{10} concentrations were consistent with each other (within ±9%) for all sampling periods except Saturday, August 26, from 11 a.m. to 4 p.m. During that period the wind shifted numerous time, as shown in Figure 4. Interestingly, the $PM_{2.5}$ mass concentrations at the upwind site were not as consistent as the PM_{10} concentrations. Normally, we would expect the $PM_{2.5}$ concentrations to be more uniform vertically than the PM_{10} concentrations. For this study, the upwind 9m $PM_{2.5}$ concentrations were about 20% lower, on average, than the 3m concentrations. The largest difference (50%) occurred on Saturday, August 26, from 11 a.m. to 4 p.m.

Figure 7 shows the average PM_{10} and $PM_{2.5}$ concentrations at the first downwind site for each time period of the test (averaged over all three heights). There is a pronounced diurnal variation for PM_{10}, as expected, with lower concentrations during the nighttime hours. The $PM_{2.5}$ concentrations do not show much diurnal pattern. Particles in that small size range do not deposit as quickly as the larger particles.

Figure 8 shows the average PM_{10} and $PM_{2.5}$ concentrations of the composite variables soil, soot, organic matter, and sulfate. These composites are calculated from the elemental concentration measurements based on formulas used in the Interagency Monitoring of Protected Visual Environments (IMPROVE) program. The soil composite is primarily in the coarse mode between 2.5 and 10 μm in aerodynamic size, as we would expect from a soil source. The soot composite is almost evenly split between the two modes, with a slightly higher fraction in the fine mode. The organic matter is also evenly split. This indicates that there is a coarse mode source that is not likely to be from combustion. Combustion generally produces finer particles, especially near the source where these samples were collected. The sulfate composite is mostly in the fine mode, as we expect from its chemistry. Sulfate particles are primarily formed in the atmosphere from gas reactions.

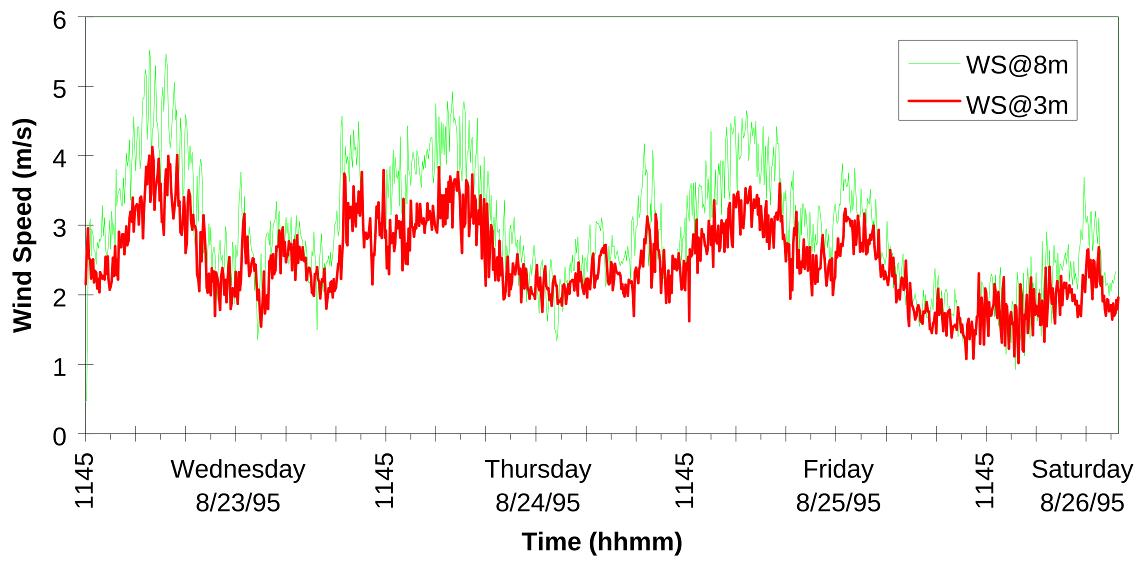


Figure 5. Wind speed at 3m and 8m during the test periods

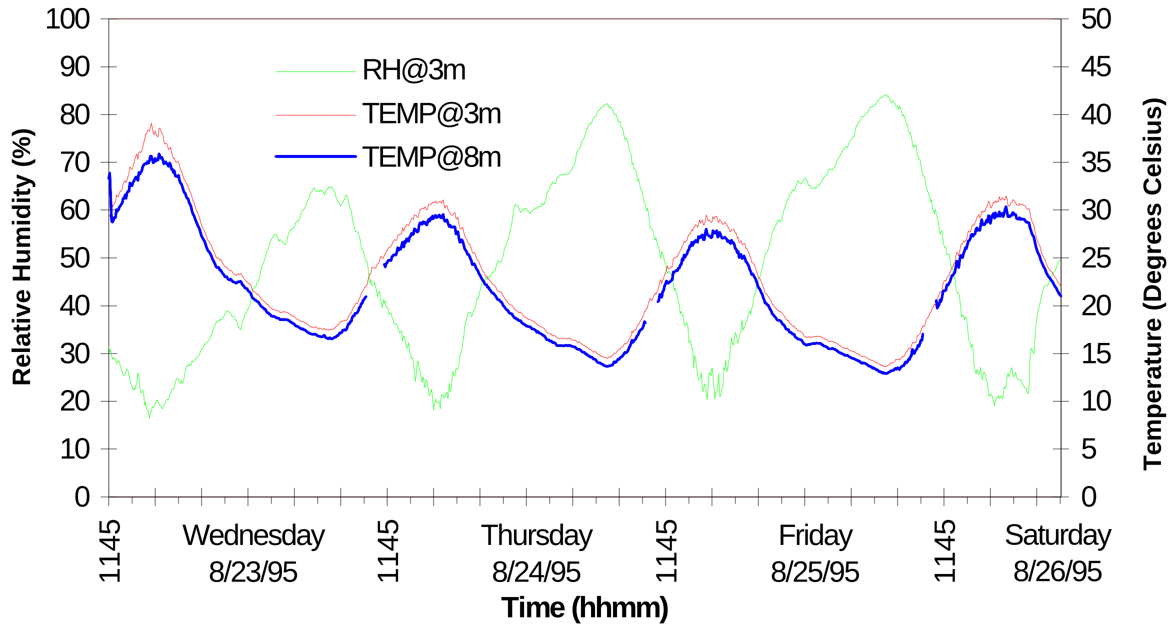


Figure 6. Temperature and relative humidity during the test periods

Figure 9 shows the mass concentrations of zinc and lead, two heavy metals that were present in concentrations above the minimum detectable limit nearly all the time. Zinc was present mostly in the coarse mode while lead was more evenly split between the coarse and fine mode. We do not know the source of zinc in this case. Lead was once a good tracer of automobile tailpipe emissions, but with the elimination of lead from gasoline in California, the lead emissions have dropped to near zero. Also, combustion sources generally produce fine particle lead. Here, the lead had a large coarse mode component. The source of lead, then, is probably resuspended material from the roadway, as evidenced by the higher readings at 1m and much lower readings at 9m, at the first downwind site. Lead concentrations were also elevated compared to upwind at the 1m and 3m levels for several other sampling periods at the first downwind site, but not as markedly.

Both zinc and lead show one period (different periods for each element) with unusually high concentrations. We do not know why these periods of high concentration occurred. The $PM_{2.5}$ zinc concentrations at 9m on August 24, 1995 from noon to 4:00 p.m. were an order of magnitude higher than any other sample. This is a real measurement, but no other samples were as high. The 3m sample for this period was also elevated, but only by a factor of about two. Both the PM_{10} and $PM_{2.5}$ lead concentrations samples were unusually high at several downwind sites on August 26, 1995 from 6:00 to 10:00 a.m. Again, these are undoubtedly real measurements, but we do not know what caused them.

Appendix A contains complete test data, including PM_{10} and $PM_{2.5}$ mass, particle composition, meteorological data, traffic information, and emission rates.

Emission Rates

We calculated emission rates using the box model described in the 1994 report. In brief, the model calculates the mass flux of pollutant across the downwind plane of a “virtual box”. The measured upwind concentrations are used as background, and the flux downwind is obtained by measuring the vertical profile of concentrations and wind speeds. The mass flux is the product of the concentration and the wind speed and is related to the mass emissions of pollutant within the box. The emission rate in grams per vehicle kilometer traveled is given by

$$E_v = 3.6 \times v_n \times h_b \times C_p \times \cos(\theta) / N_0 \qquad (1)$$

where E_v is the emission rate in g/VKT,
v_n is the wind velocity in m/s,
h_b is the height of the box in meters,
C_p is the pollutant concentration in $\mu g/m^3$,
N_0 is the number of vehicles/hr,
θ is the angle of the wind to the ideal direction, and
3.6 converts the units to g/VKT.

As in the earlier work, we set the box height to 3m to calculate the emission rates. The vertical profile data collected at the D1 downwind site confirmed that the box height was at least 3m, but less than 9m. Note that the emission rate is directly proportional to the box height.

Figure 10 shows the PM_{10} and $PM_{2.5}$ mass emission rates calculated for each time period of the study. Inspection of the results at the downwind D1 site revealed that the 1m and 3m samplers were within the layer affected by the roadway downwind of the intersection. Furthermore, except for August 24 from 6 to 10 a.m. and August 26 from 11 a.m. to 4 p.m., the PM_{10} measurements at 3m and 9m at the upwind site were within 9% of each other. Because of the similarity of the two upwind concentrations, the emission rates were calculated by averaging the concentration at the 1m and 3m heights downwind, and subtracting the 3m and 9m average concentration at the upwind site. This difference was used as C_p in equation (1). The intersection was modeled as a superposition of two line sources, Florin Road and Stockton Boulevard. The emission factor (in g/VKT) was assumed to be the same for each road, but the traffic density and the wind angle were treated separately for each line source. As shown in Table 5, the PM_{10} mass emission rates ranged from 60 to 238 mg/VKT. The $PM_{2.5}$ mass emission rates ranged from <7 to106 mg/VKT. For comparison, the PM_{10} emission rates we measured in the 1994 study ranged from 18 to 25 mg/VKT on the freeway and 260 to 1300 mg/VKT at the intersection.

The PM_{10} emission rate exhibited a diurnal pattern with the highest rate during the morning hours (6-10 a.m.) and lower rates throughout the remainder of the day. The rates were also lower on the weekend than on the week days. The $PM_{2.5}$ emission rate also shows a diurnal pattern, with higher rates during the early afternoon hours and lower rates at other times. Note that the $PM_{2.5}$ rates were not defined for the afternoon of August 25. The $PM_{2.5}$ mass data for that time period were invalidated due to a sampling error. Also, all emission rates for August 26 from 11:00 a.m. to 4:00 p.m. were invalid due to shifting winds.

The United States Environmental Protection Agency's *Compilation of Air Pollution Emission Factors,* AP-42, indicates that the silt loading and average vehicle weight are the factors controlling the PM_{10} emissions from a paved road. If there are no other controlling factors the emission rates (in terms of mg/VKT) should vary little throughout the day, at least if the surface silt loading is in equilibrium and the average vehicle weight does not change appreciably. The measured emission rates shown in Figure 10 do vary, though, so something must be changing. All the variables in Equation (1) are well defined except for the box height. If the box height varies throughout the day, it would affect our emission calculation. It is also possible that the silt loading, the moisture content of the surface loading, or the average vehicle weight may vary throughout the day, or that some other controlling parameter is responsible.

Table 3. PM_{10} mass concentrations at each location for each test

	Sampler location and height							Meteorology		Traffic
Test date and time	U1 (3m)	U1 (9m)	D1 (1m)	D1 (3m)	D1 (9m)	D2 (3m)	D4 (3m)	Wind Speed	Wind Direction	Vehicles /hour
8/23/95 12:00 PM	33.8	30.9	49.1	37.1	57.0	59.6	36.7	2.53	234.9	3,838
8/23/95 4:00 PM	39.1	37.9	56.0	68.1	56.3	49.2	39.3	3.50	237.3	4,517
8/23/95 7:00 PM	21.8	21.4	29.2	29.7	28.9	28.6	23.3	2.21	200.4	1,536
8/24/95 6:00 AM	28.2	28.6	47.1	50.6	32.0	41.2	36.7	2.45	200.7	2,417
8/24/95 11:43 AM	36.5	37.2	61.3	49.2	55.1	32.0	38.9	2.91	237.7	3,897
8/24/95 4:00 PM	33.4	30.8	49.6	43.7	42.2	38.3	33.5	3.01	225.7	3,973
8/24/95 8:55 PM	25.5	27.0	33.8	33.3	31.3	29.5	26.9	2.13	182.7	1,064
8/25/95 5:56 AM	26.4	25.9	53.1	42.5	31.1	27.3	32.6	2.28	219.8	2,221
8/25/95 11:07 AM	28.5	30.8	43.9		36.1	32.2	31.5	2.73	232.0	4,093
8/25/95 3:58 PM	27.4	27.1	40.0		27.8	30.4	27.5	2.83	220.2	4,479
8/25/95 9:00 PM	20.1	19.0	27.0	21.4	23.8	24.1	22.3	2.44	189.3	1,294
8/26/95 5:56 AM	22.4	21.8	36.6	26.8	26.0	24.8	27.3	1.41	208.4	1,463
8/26/95 11:01 AM	30.7	19.6	36.8	35.3	36.1	30.6	27.6	0.99	280.6	3,694
8/26/95 4:06 PM	25.9	25.8	38.5	34.6	28.8	35.4	31.0	1.96	237.0	3,699
Mean	26.8	26.2	40.2	39.4	34.8	32.4	29.2	2.23	207.1	2,812

* Sample invalid due to sampling error

Table 4. $PM_{2.5}$ mass concentrations at each location for each test

	Sampler location and height							Meteorology		Traffic
Test date and time	U1 (3m)	U1 (9m)	D1 (1m)	D1 (3m)	D1 (9m)	D2 (3m)	D4 (3m)	Wind Speed	Wind Direction	Vehicles /hour
8/23/95 12:00 PM	6.7	5.7		10.4	6.9		7.3	2.53	234.9	3,838
8/23/95 4:00 PM	6.7	6.8		13.2	8.3		8.8	3.50	237.3	4,517
8/23/95 7:00 PM	12.5	12.7		12.4	10.8		11.1	2.21	200.4	1,536
8/24/95 6:00 AM	14.6	11.5		17.0	12.5		13.9	2.45	200.7	2,417
8/24/95 11:43 AM	11.5	10.0		23.9	12.3		12.9	2.91	237.7	3,897
8/24/95 4:00 PM	12.1	9.1		13.9	11.9		10.5	3.01	225.7	3,973
8/24/95 8:55 PM	15.5	15.2		17.5	15.3		17.2	2.13	182.7	1,064
8/25/95 5:56 AM	17.0	12.5		18.8	13.8		22.8	2.28	219.8	2,221
8/25/95 11:07 AM	13.2	11.0		*	14.6		15.1	2.73	232.0	4,093
8/25/95 3:58 PM	15.1	8.3		*	8.6		10.9	2.83	220.2	4,479
8/25/95 9:00 PM	11.2	10.0		11.7	9.9		11.8	2.44	189.3	1,294
8/26/95 5:56 AM	11.5	10.9		13.2	11.4		13.2	1.41	208.4	1,463
8/26/95 11:01 AM	15.0	7.5		14.7	11.8		11.8	0.99	280.6	3,694
8/26/95 4:06 PM	9.7	9.6		10.9	10.1		10.3	1.96	237.0	3,699
Mean	11.7	10.		10.1	11.1		12.	2.23	207.1	2,812

* Sample invalid due to sampling error

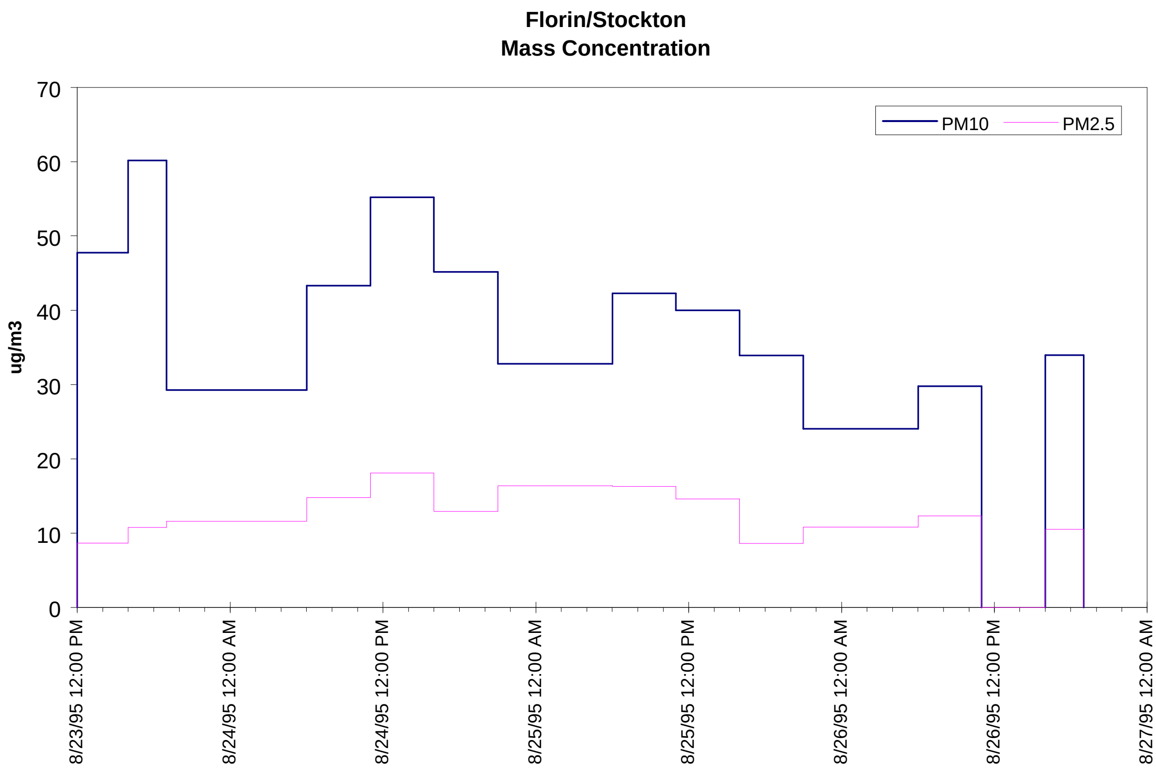


Figure 7. PM_{10} and $PM_{2.5}$ mass concentration at 3m at the first downwind site

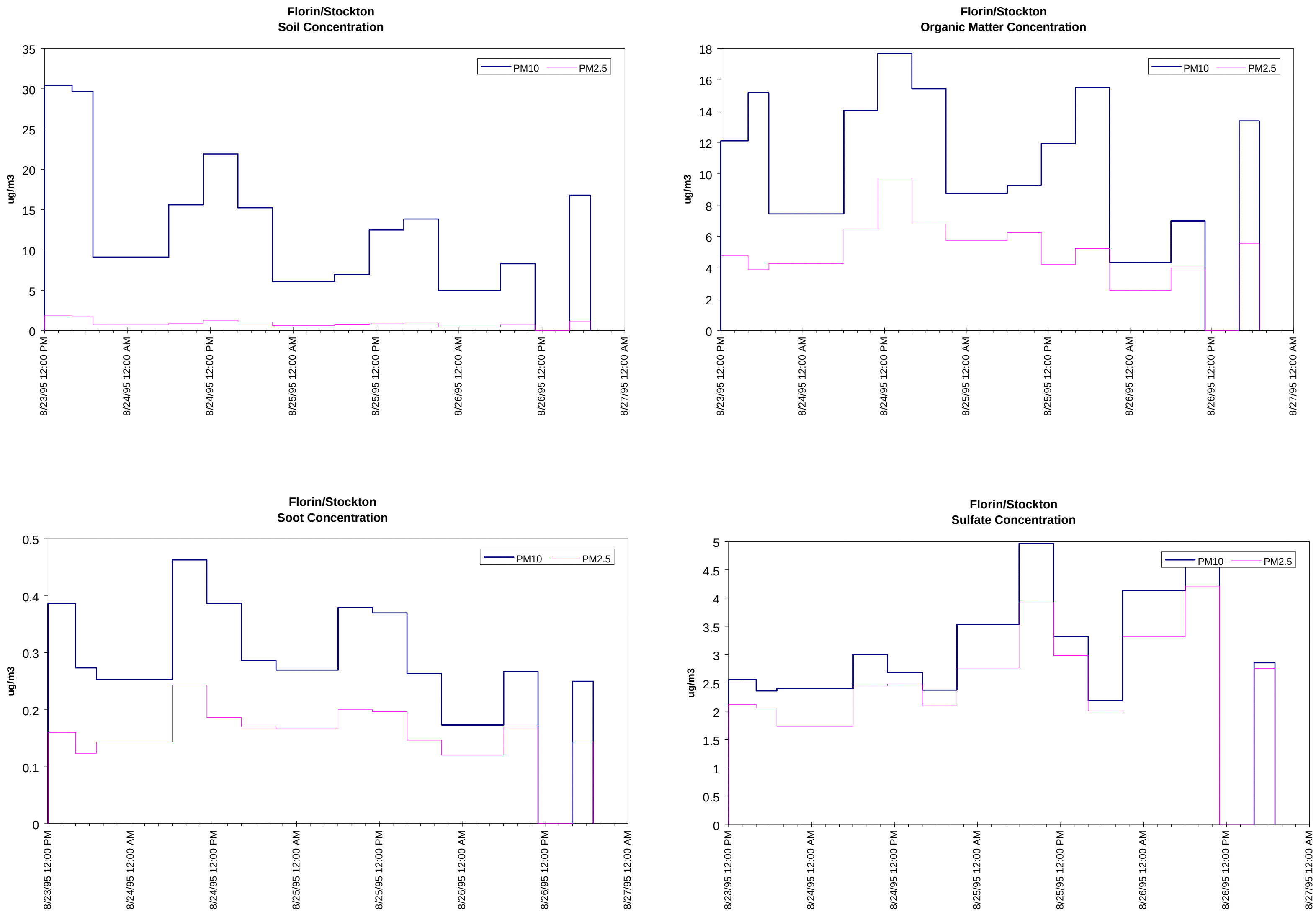
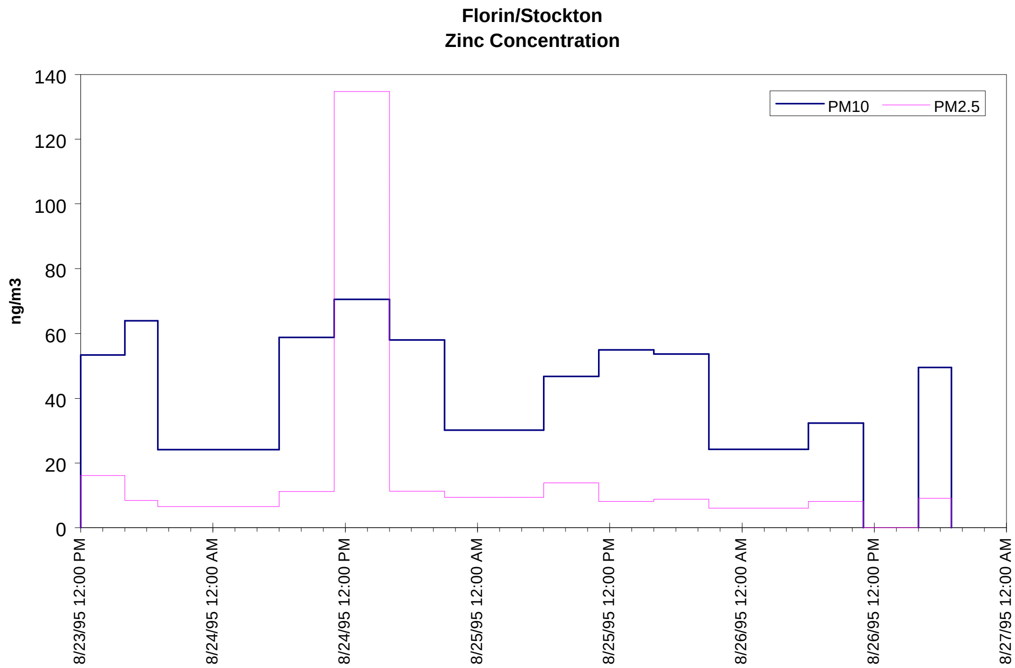


Figure 8. Mass concentration of PM_{10} and $PM_{2.5}$ soil, organic matter, soot, and sulfate at 3m at the first downwind site



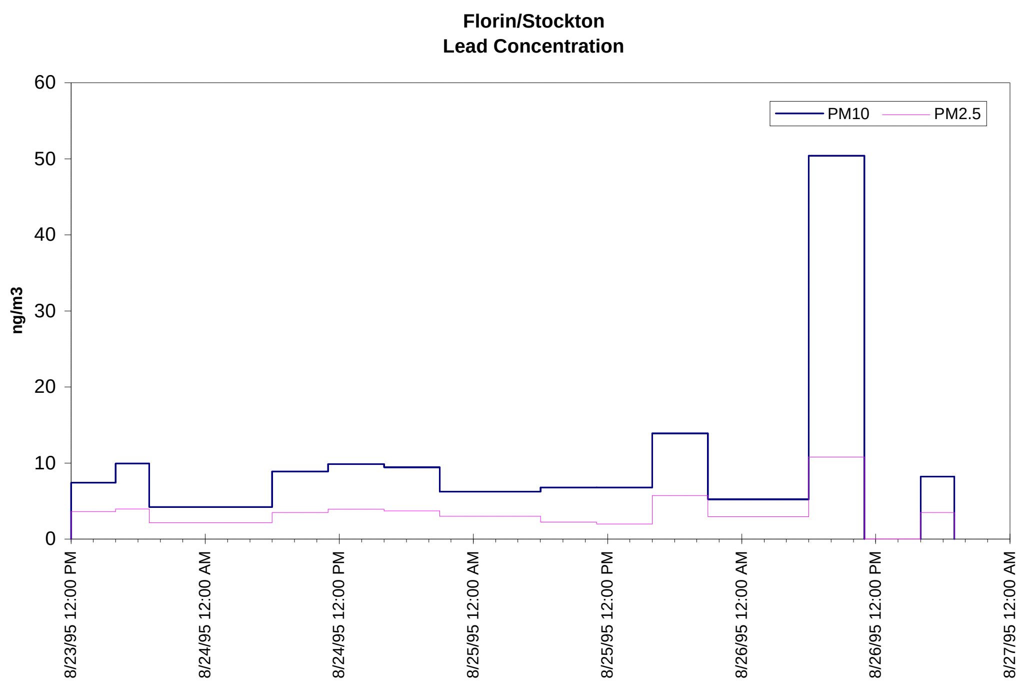


Figure 9. Mass concentration of PM_{10} and $PM_{2.5}$ zinc and lead at 3m at the first downwind site

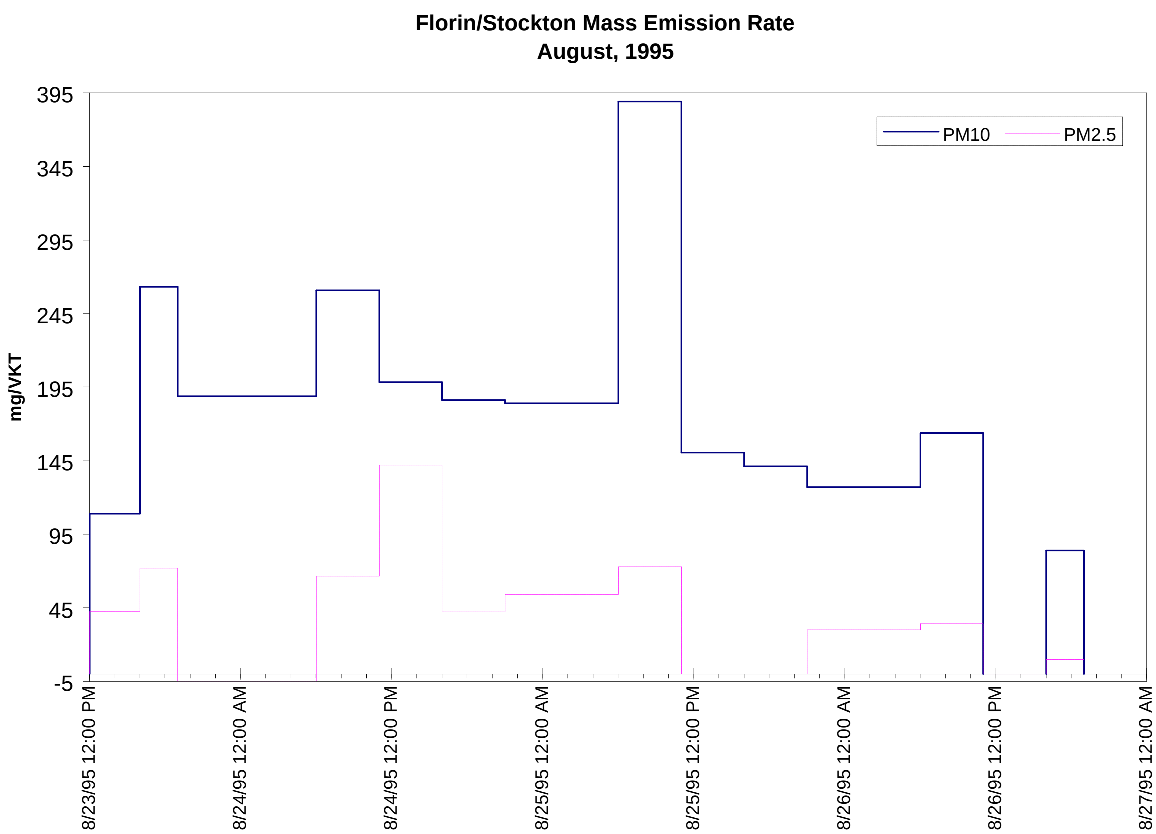


Figure 10. Mass emission rate for each time period of test at Florin Road/Stockton Boulevard

Table 5. Emission factor calculated from the box model for each test period

Test Number	Date	Emission Factor (mg/VKT) PM10	PM2.5
95-024	Wed. 12:00	109	43
95-025	Wed. 16:00	263	72
95-026	Wed. 19:00	189	-5
95-027	Th. 06:00	261	67
95-028	Th. 11:00	198	142
95-029	Th. 16:00	186	42
95-030	Th. 21:00	184	54
95-031	Fri. 06:00	389	73
95-032	Fri. 11:00	150	--
95-033	Fri. 16:00	141	--
95-034	Fri. 21:00	127	30
95-035	Sat. 06:00	164	34
95-036	Sat. 11:00	--	--
95-037	Sat. 16:00	84	10

Figure 11 shows how the PM_{10} mass emission rates break down by composition for each time period of the study. The composition parameters were calculated from the elemental concentration and light absorption measurements, so they do not necessarily add up to the mass measurement. The mass was determined by a separate gravimetric measurement Soil dust and organic matter (calculated by the hydrogen concentration) make up most of the PM_{10}. There are also minor contributions from soot and sulfate. The unallocated emissions vary from a high of nearly 50% of the mass on August 25 from 6-10 a.m. to several periods of nearly zero (i.e. almost all the mass was accounted for) . In two periods, the sum of the composition measurements exceeds the mass measurement; for the last sample period the sum exceeds the mass to a significant degree.

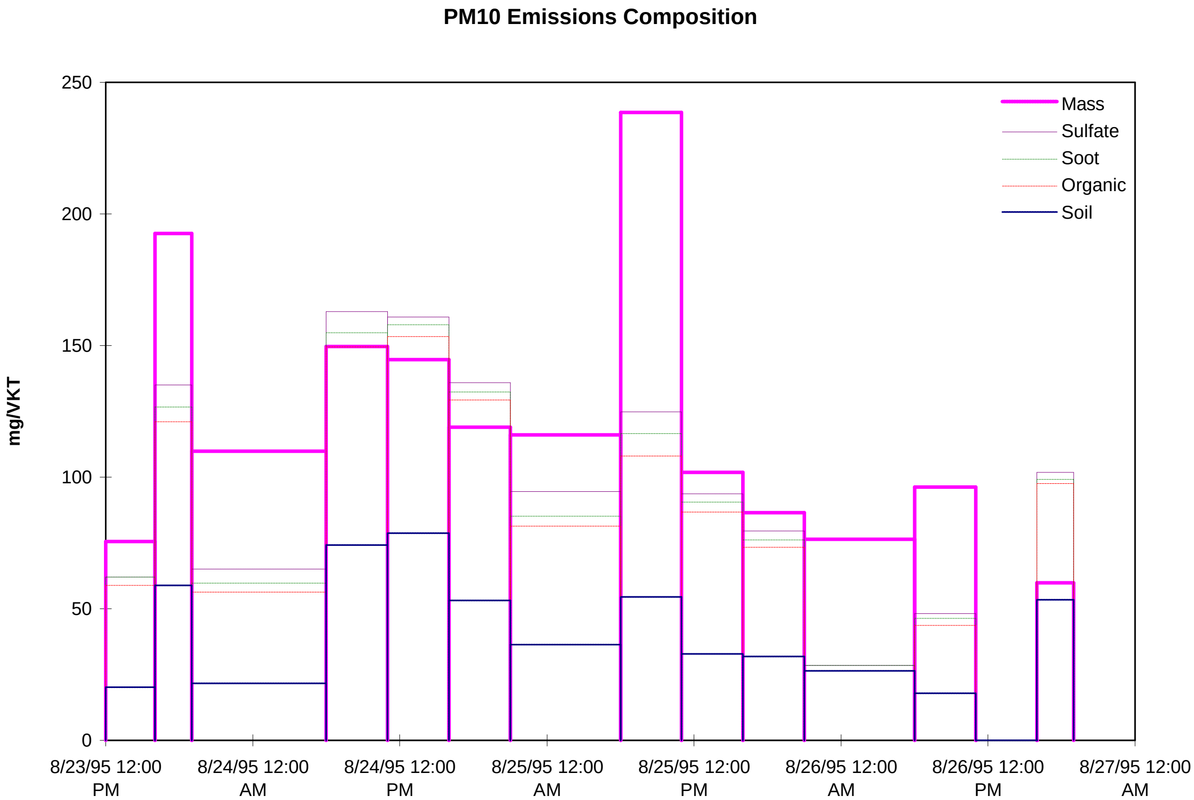


Figure 11. Composition of the PM_{10} mass emissions

Figure 12 shows the composition of the $PM_{2.5}$ mass emission rates for each time period of the study. Soil dust is a smaller fraction of the $PM_{2.5}$ mass emissions than for PM_{10}. The largest component of the $PM_{2.5}$ mass emissions is generally organic matter (calculated by the hydrogen concentration). Soot and sulfate also contribute a small amount. The unallocated emissions vary even more for the $PM_{2.5}$ mass than for the PM_{10} mass emissions.

Figure 13 shows the variation with time of each of the four major components of the PM_{10} and $PM_{2.5}$ mass emission rates. As expected, the soil emissions are primarily in the coarse particle size from 2.5-10 μm, as are the ambient concentrations. Organic matter emissions are also mostly in the coarse mode, and may be due to suspended particles of tire material or oils and grease on dust particles. The organic matter concentrations, though, are primarily in the fine mode. The soot emissions are primarily in the fine size range below 2.5 μm, as are the ambient concentrations. The measured concentrations of sulfate are primarily in the fine size range, (greater than 90%), but the emission rate from the intersection seems to be more evenly split between PM_{10} and $PM_{2.5}$. This implies that there may be some sulfate associated with the resuspended material from the roadway.

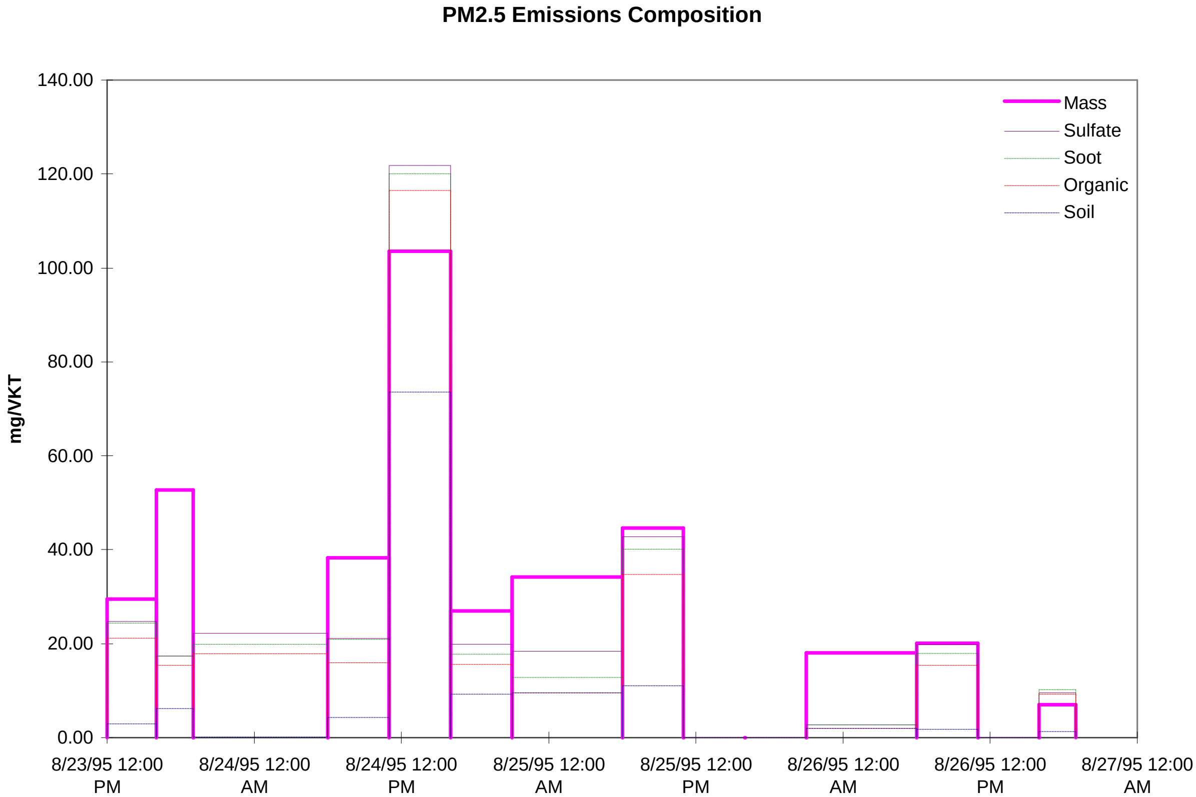


Figure 12. Composition of the $PM_{2.5}$ mass emissions

Figure 14 shows the variation with time of the emissions of the heavy metals zinc and lead. For zinc, the emission rate is more heavily weighted toward the coarse particles than are the ambient concentrations. For lead, the split is about the same. The emission rate of zinc shows a pronounced diurnal pattern, but the lead emissions were remarkably uniform. The only large difference in the lead emissions occurred on Saturday morning at the time when the unusually high concentrations were measured at all the downwind sites.

Figure 15 shows a cross-section profile of the PM_{10} mass from upwind to downwind for Thursday, August 24, 1995. The mass increased just downwind of the intersection, then decreased to near background levels at the far downwind site. The pattern holds for three of the four time periods shown, and is typical of the four days measured. The fourth time period shows an increase at the far downwind site that may have been due to activity in the grocery store parking lot.

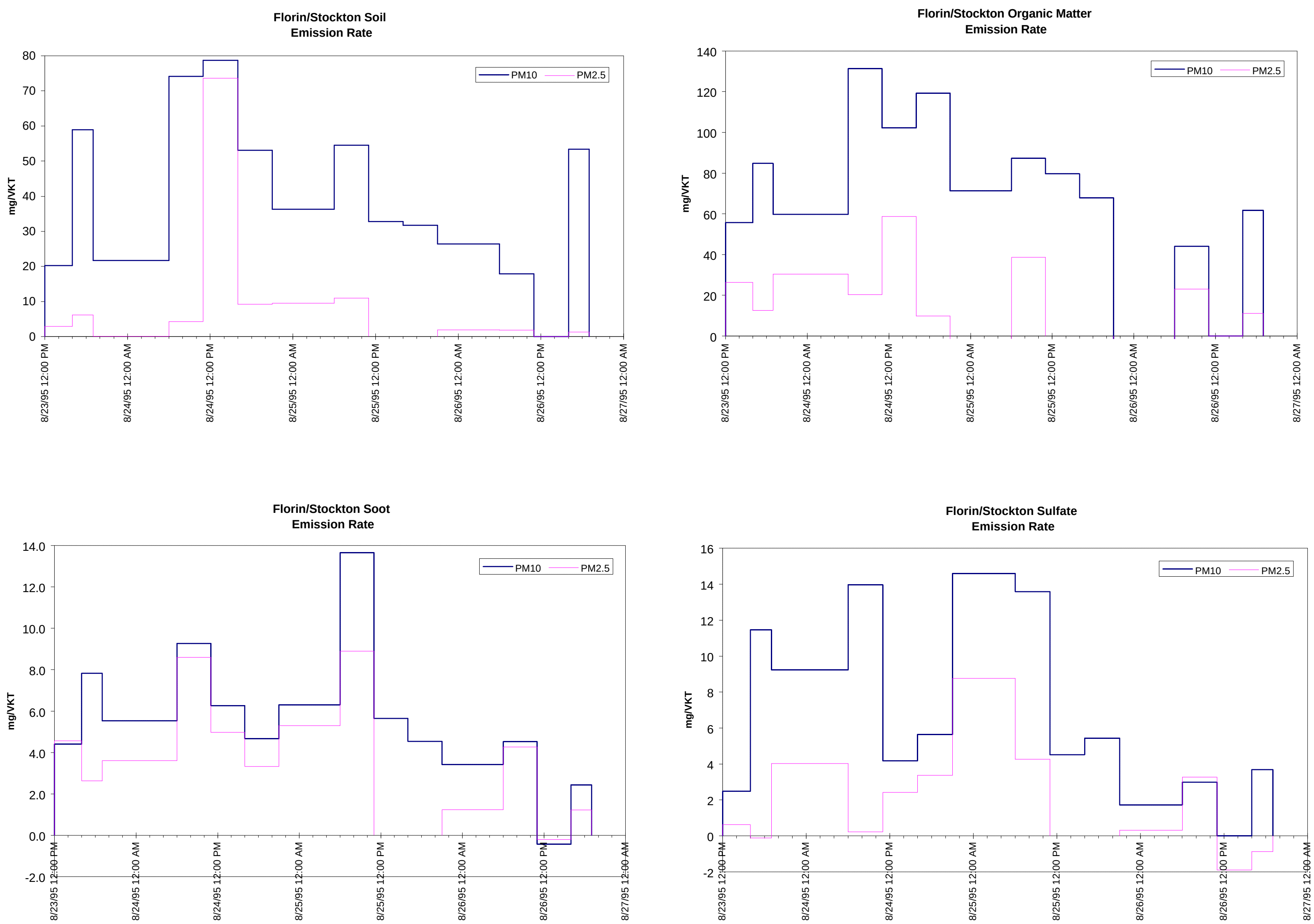


Figure 13. Emission rates of PM_{10} and $PM_{2.5}$ soil, organic matter, soot, and sulfate

Figure 16 shows the same pattern for the four composite variables soot, soil, sulfate, and organic material. Generally, the far downwind concentration was significantly elevated above background only for the morning period from 6:00-10:00 a.m. For most other periods, the far downwind concentration for any composite variable was only slightly elevated, if at all, above background. The far downwind (D4) soil concentration was higher than the nearer D2 concentration during the afternoon hours corresponding with activity in the store parking lot. Almost all other times showed a smooth decrease from near downwind to far downwind. Figure 17 shows the pattern for the heavy metals zinc and lead.

Figure 18 shows a surprising finding of this study. On Saturday, August 26, 1995, from 6:00-10:00 a.m. the PM_{10} and $PM_{2.5}$ lead concentrations increased at all downwind locations. The increase at the first downwind site was especially great. The concentrations decreased dramatically at the second and third downwind sites, but were still significantly elevated above background. Approximately 30% of the lead was in the fine fraction. We could not identify the source of this airborne lead, but it is not a measurement artifact.

Discussion

Comparison to calculated emission factors

The EPA recommends calculating emission factors from paved roads using a procedure described in AP-42, *Compilation of Air Pollutant Emission Factors*. The AP-42 calculation uses the roadway silt loading and the average vehicle weight as input parameters to the following equation for PM_{10}.

$$E = 4.6 \times \left(\frac{sL}{2}\right)^{0.65} \left(\frac{W}{3}\right)^{1.5}$$

For $PM_{2.5}$, AP-42 replaces the factor of 4.6 by 2.1 in the above equation. Table 2 lists the silt loading on each approach to the intersection, and lists the average of the four values. Table 5 shows the results of this calculation for PM_{10} using the measured silt loadings and estimated average vehicle weight. We estimated the average vehicle weight by periodically counting the percentage of passenger cars, light and medium trucks, and heavy trucks and buses. Note that PART5, the EPA model used to calculate emission factors using AP-42 equations, recommends using a default value of 3 tons if better information is not available. Using our estimated fleet average vehicle weight of 2.15 tons and three possible silt loading values, Table 6 lists the emission factors calculated for the Florin Road/Stockton Boulevard intersection. The silt loadings listed in Table 2 show that three approaches had very similar low values, while one approach had much higher loading. The emission factors were calculated using the lowest, the highest, and the average silt loading.

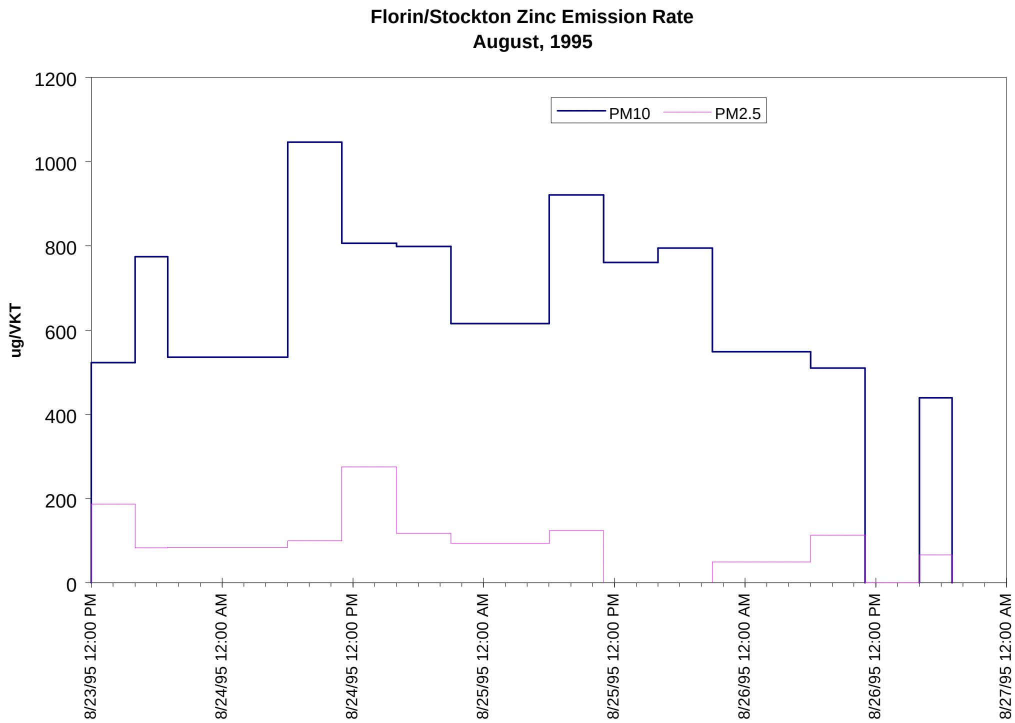
Table 7 shows the measured and calculated emission factors for PM_{10} and $PM_{2.5}$ for this study. Using the AP-42 method, the calculated emission factors for PM_{10} and $PM_{2.5}$ fall within the range of the measured emission rates for this study. This result is different from the 1994 result because this study used the measured silt loadings from the intersection approaches. For the 1994 study, we used silt loading values obtained from the table provided in AP-42, following the recommended procedures for selecting representative values. The values selected from the AP-42 tables for the 1994 work were 900-3800 mg/m^2, while the measured values for this study were 1.6-54 mg/m^2. Note that the highest silt loading occurred on the approach nearest to the first downwind sampler. The measured PM_{10} emission factor was midway between the calculated factors using the average silt loading and the highest silt loading. The measured $PM_{2.5}$ emission factor, however, was closer to the calculated factor using the average silt loading than the highest silt loading.

Table 6. Average vehicle weight

Vehicle type	Fraction	Weight (tons)	Fractional weight
Passenger cars	.842	2	1.684
Trucks/Vans	.143	2.5	0.358
Heavy trucks/Buses	.015	7	0.105
		Average weight	2.147

Table 7. Calculated vs. measured emission factors for PM_{10} and $PM_{2.5}$

Silt Loading (mg/m^2)	Vehicle Weight (tons)	PM_{10} Emission Factor (mg/VKT)	$PM_{2.5}$ Emission Factor (mg/VKT)
1.6	2.15	27	12
15	2.15	116	53
54	2.15	267	122
Measured Emission Factor		188 ± 80	51 ±39



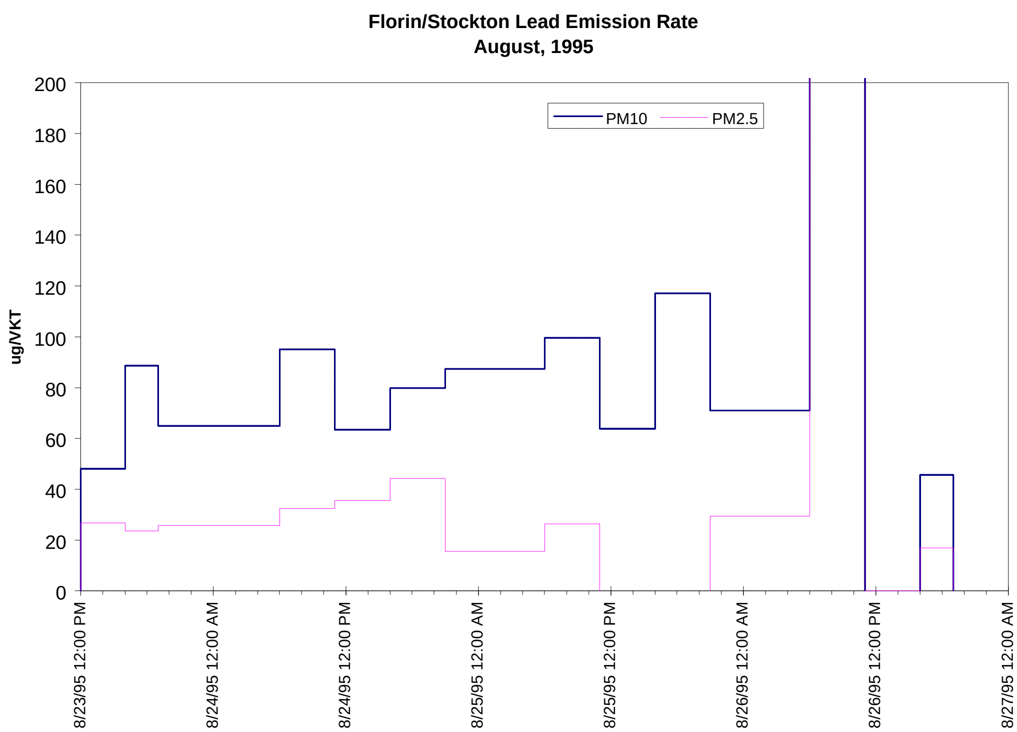


Figure 14. Mass emission rates of PM_{10} and $PM_{2.5}$ zinc and lead

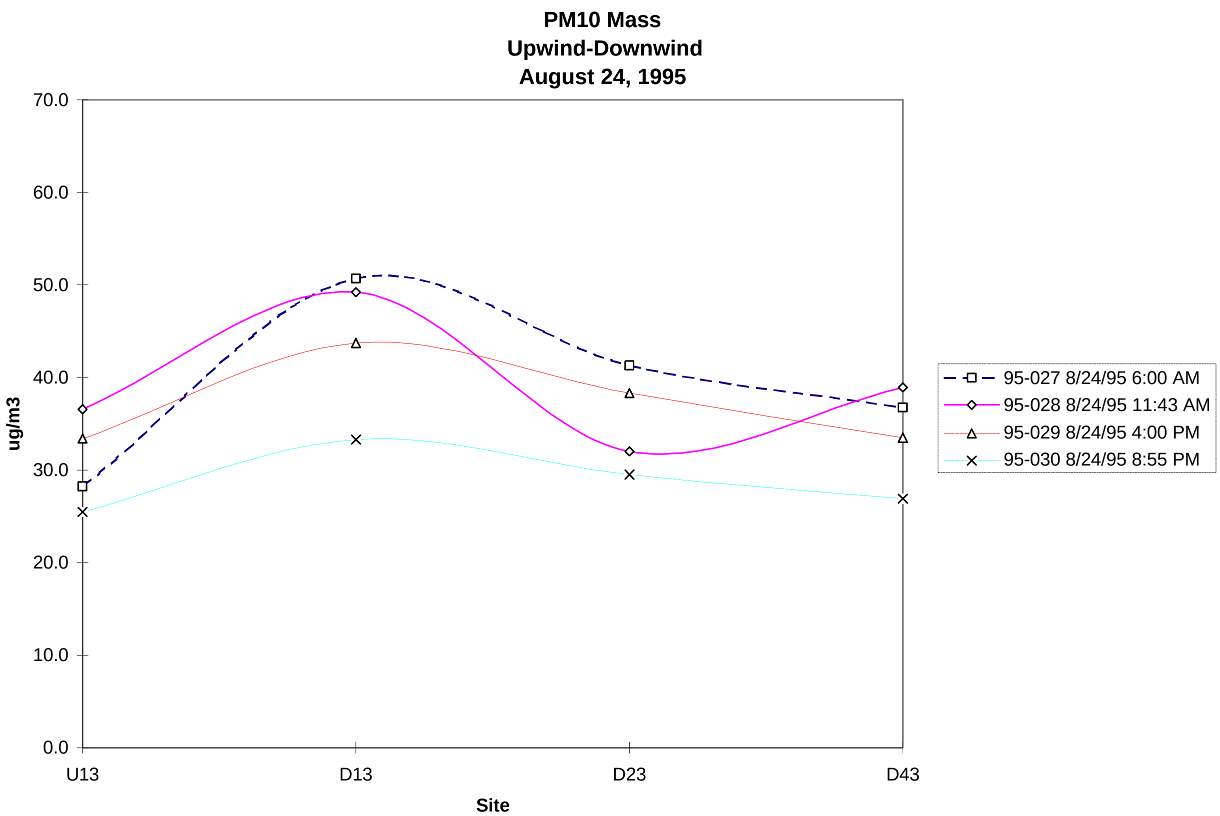


Figure 15. Upwind-downwind pattern for PM_{10} mass at 3m on August 24, 1995

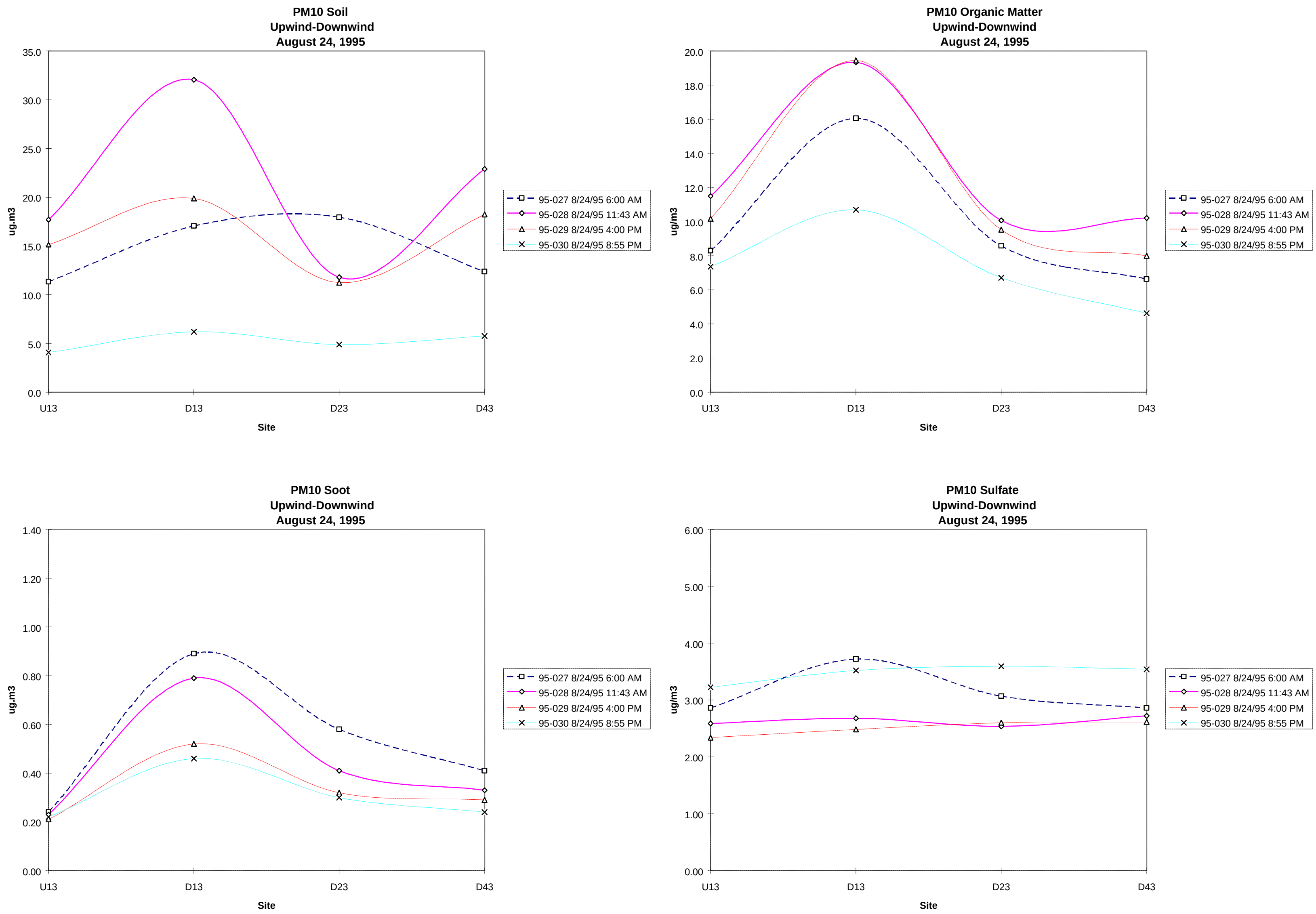
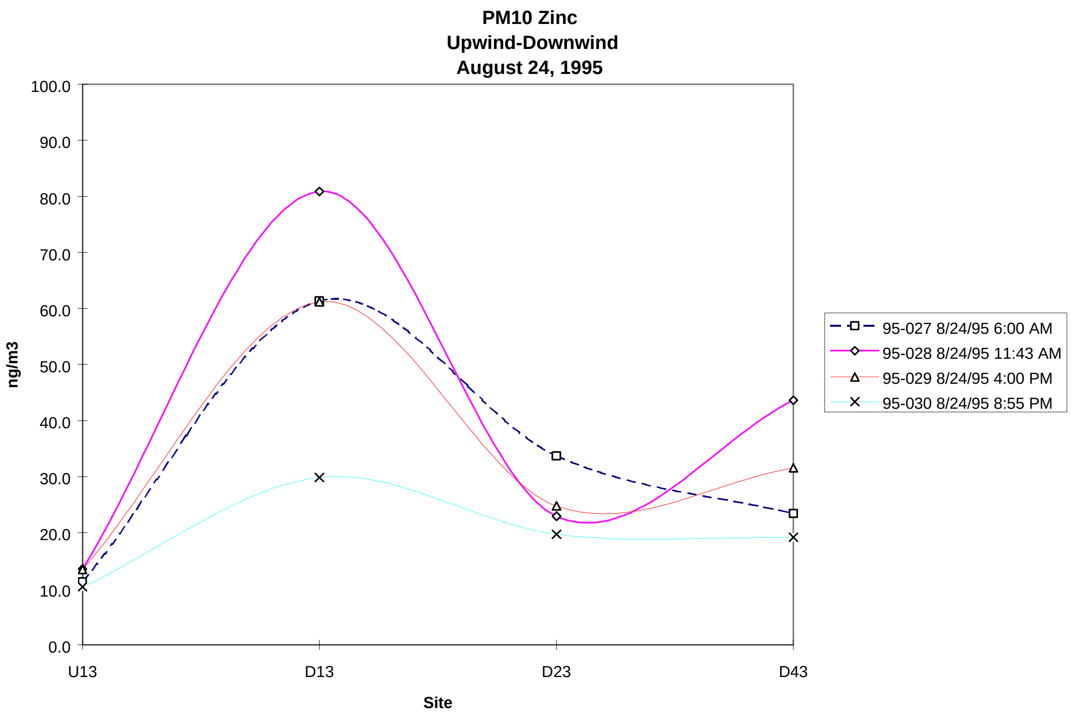


Figure 16. Upwind-downwind pattern for PM_{10} and $PM_{2.5}$ soil, organic matter, soot, and sulfate at 3m on August 24, 1995



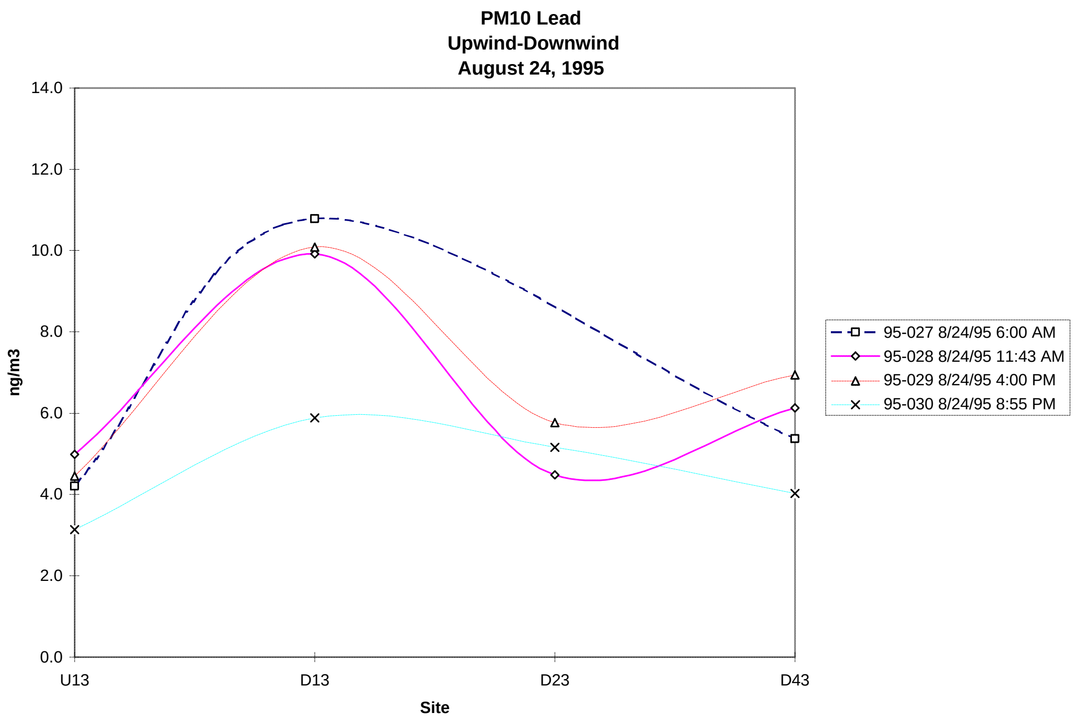
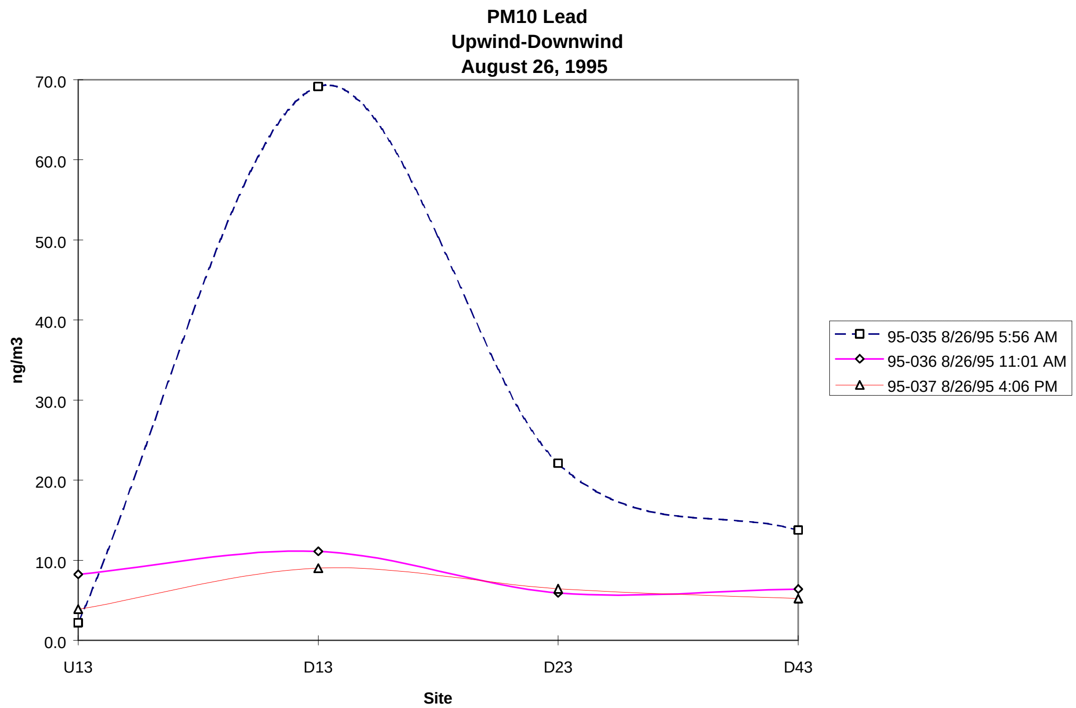


Figure 17. Upwind-downwind pattern of PM_{10} zinc and lead at 3m on August 24, 1995



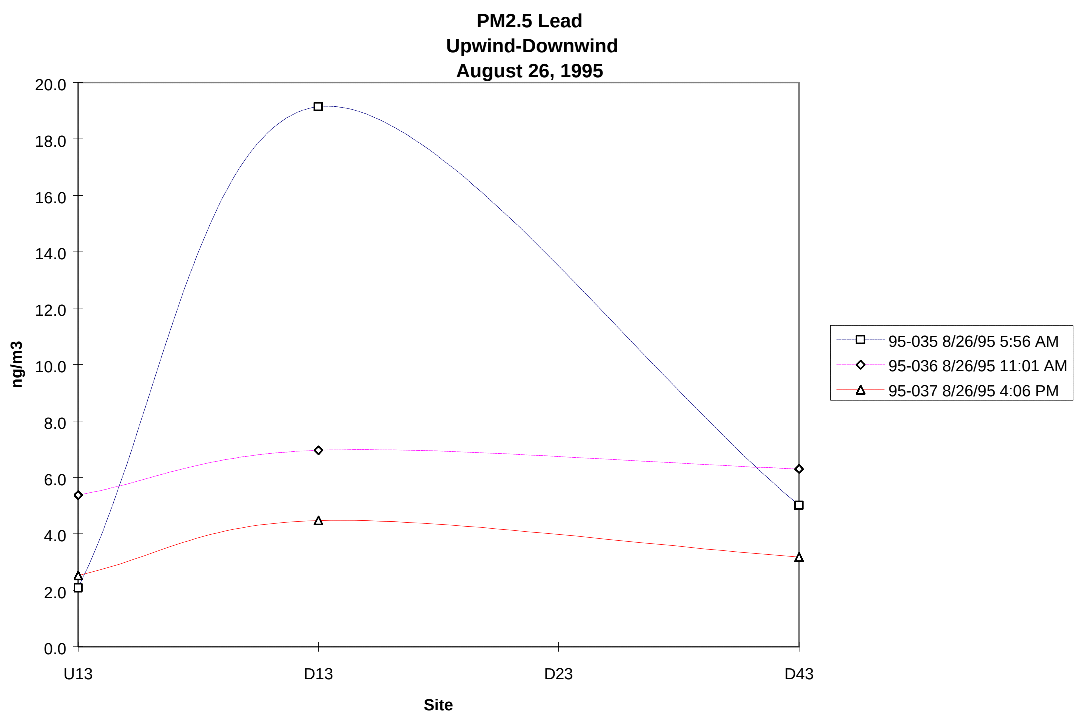


Figure 18. Upwind-downwind pattern of PM_{10} and $PM_{2.5}$ lead on August 26, 1995

Comparison to 1994 results

The emission rates we obtained in this study were lower than the mass emission rate we obtained in 1994. The PM_{10} mass emission rate we obtained in 1994 may have been flawed by an incorrect pre-weight. There is no way to be certain that this is the case, but the results of this study suggest it may have been. In 1994, we had only a single upwind and a single downwind sample at 2m above the surface. We also collected data for only a single time period. Although we repeated all possible measurements in 1994, we were unable to repeat the filter pre-weights.

An examination of the 1994 data shows that the emission rate calculated using reconstructed mass is within the range of emission rates we measured in this study. In the 1994 study, the overall ambient concentrations were twice the concentrations measured in this study. This suggests that the elemental concentrations and the reconstructed mass from the 1994 study remain valid, but that the gravimetric mass measurement at the downwind site is invalid.

There is also a much larger difference between this study and the 1994 study in the calculated emission rates using AP-42. In the 1994 study, we used "representative" silt loadings obtained from the tables provided in AP-42. These turned out to be 100-1000 times higher than the loadings we measured in this study by vacuuming the road. The highest silt loading we measured, 54 mg/m^2, is at the 15th percentile of the distribution given in AP-42 for high ADT roads (>5000 vehicles per day). The average silt loading, 1.5 mg/m^2, is at the 5th percentile.

Upwind-downwind comparison

The upwind-downwind patterns show that the effect of the intersection does not extend a great distance downwind. For the most part, the elevated concentrations fall nearly to background levels less than 100m downwind of the intersection. There were several time periods when this did not happen, and several time periods when the far downwind concentrations were higher than the second downwind concentrations. The times when this occurred suggest that activity in the grocery store parking lot may have suspended PM_{10} material into the air.

Comparison to Air Resources Board Area Source Methods

The California Air Resources Board has published methods to calculate area source emissions (ARB, 1991). The procedures recommend allocating VMT to freeways, major streets, and local and collector streets, then applying an emission factor to each allocated component. The most recent recommended emission factors were developed using silt loading values of 0.02 g/m^2 for freeways, 0.035 g/m^2 for high-ADT roads, and 0.32 g/m^2 for low-ADT roads. Using these silt loading values and an average vehicle weight of 2.4 tons, the Air Resources Board emission factor for freeways is 163 mg/VKT, for major streets it is 234 mg/VKT, and for local and collector streets it is 986 mg/VKT. Our measured silt loadings ranged from 0.002-0.054 g/m^2, and averaged 0.015 g/m^2, on the approaches to the Florin/Stockton intersection. This is a factor of 2-21 lower than the silt loadings used by the Air Resources Board to calculate emission factors for paved roads. Our measured emission factor for the intersection is 188 $\pm$ 80 mg/VKT, and includes all roadway sources, not just resuspended dust. This is a factor of 1.2 - 5.2 lower than the calculated emission factors used by the Air Resources Board uses for major streets or local and collector streets.

Comparison to model results

The measured emission factors, intersection parameters, and meteorological conditions were used as input to CALINE4, a commonly used line source dispersion model, to estimate the downwind concentrations at each sampler location. Complete results of this investigation are given in Appendix B, and are summarized here.

The model overpredicts the 24-hour average of measured concentrations by 20% on average (the range was 11-28%) at the first downwind sampler at 1 meter height. For individual sampling periods, the model performs best at the first downwind site at 3 meters, and is worst at the first downwind site at 9 meters. This suggests that the downwind 9m sampler may have been affected by an elevated source. Visual observations confirmed that this could be the case; during the afternoon to early evening the plume from a hamburger restaurant grill hit the downwind 9m sampler, but missed the upwind sampler.

A major advantage of using a model is in examining the effect of "worst-case" conditions. It is far easier to model these conditions than to encounter them in a field study. For the most unfavorable wind direction, the model results indicate that the intersection may contribute up to 15 $\mu g/m^3$ at the first downwind site at 1m above ground. This could lead to exceedances of the standard if the background concentration is greater than about 135 $\mu g/m^3$. The actual concentration increase may be less than 15 $\mu g/m^3$. The predicted contribution to PM_{10} concentrations at locations up to 88m downwind is minor (approximately 4 $\mu g/m^3$).

The dispersion model results can be extrapolated to predict concentrations downwind of intersections with different traffic volumes. The AP-42 predictive equation predicts that PM_{10} emissions scale linearly with traffic volume. CALINE4 would also scale the emissions linearly. Observations suggest that the actual emissions per vehicle decrease for high volume roadways so that the linear assumption may be incorrect. A linear relationship between PM_{10} emissions and VMT would tend to overestimate the effect of increased traffic on downwind PM_{10} concentrations, though, so can be used as a conservative estimate. It is not known how much error is introduced by making the linear assumption. Figure 2 of Appendix B shows a linear relationship between PM_{10} concentration and traffic volume. The linear relationship predicts that an intersection such as Sunrise and Greenback, which has 4400 vehicles per hour, could increase 24-hour downwind PM_{10} concentrations by 10-30 $\mu g/m^3$. This prediction should be tested by measurements.

Conclusions and recommendations

This study has shown that the intersection of Florin Road and Stockton Boulevard is not a "hot spot" of PM_{10} or $PM_{2.5}$ emissions on typical summer days. The PM_{10} emission rates are on the order of 190 mg/VKT; the $PM_{2.5}$ emission rates are on the order of 50 mg/VKT. The PM_{10} emission factor is slightly higher than the calculated emission factor using the EPA's AP-42 procedure and the average measured silt loading. The measured $PM_{2.5}$ emission factors were very close to the calculated emission factor, although the variability in the measured factor was high. The measured silt loadings, though, were much lower than the values found in the tables provided in AP-42. This underscores the need to use measured silt loading when emission rates are estimated using the AP-42 method. Note that this agreement is not an endorsement of the AP-42 methodology. The AP-42 method is based on empirical correlations and not fundamental relationships. As such, it is not satisfying and UC Davis remains committed to searching for a better method.

The emission rates measured in this study are much lower than those measured during the 1994 pilot study. The earlier study suffered from a sparse data set (only one set of upwind and downwind samples), and may have had a faulty pre-weight on the downwind filter. This could explain the very high mass concentrations measured during that study. The elemental concentrations and reconstructed mass measurements of the earlier study remain valid.

The emission rates we measured are also lower than those used by the California Air Resources Board to estimate area source emissions. If our measured rates are close to the average throughout California, the PM_{10} emission inventory for PM_{10} road dust is in error. At the very least, the database of road silt loading data for California roads needs to be expanded. Roads representative of the categories used in the inventory should be tested. A better strategy would be to include measurements of the emission rates of these representative roads along with the silt loading measurements. The search should also continue for a better surrogate for PM_{10} emissions than silt loading.

We found some unusual results in this study. Zinc was measured above minimum detectable limits most of the time, and was primarily in the coarse mode. Zinc may be a tracer of tire wear; this possibility should be investigate further. There was also one period of unusually high zinc on a $PM_{2.5}$ sample. It did not show up on the PM_{10} sample, but is a strong signal in the $PM_{2.5}$ sample. The PM_{10} and $PM_{2.5}$ samples were collected by different instruments, so it may be an artifact. Lead was also measured above minimum detectable limits nearly all the time, and was evenly split between the coarse and fine mode. This indicates that there is a coarse mode source of lead. It may be that lead from automotive emissions of years past are now bound to soil particles on the roadway and are re-entrained into the air by passing vehicles. If so, this source should be stronger at older intersections than at newer ones where there is little “old” lead present. We found one period of very high lead concentrations at all downwind sites. We do not know the source of this lead. Note that even the highest lead concentration measured, 0.069 $\mu g/m^3$ during one 4-hour period, was well below the state standard of 1.5 $\mu g/m^3$ averaged over a 30-day period.

All the species measured at the intersection dispersed almost completely back to background levels within 100 meters of the intersection. Furthermore, the measured and predicted 24-hour concentration increases due to the intersection were about 15 $\mu g/m^3$, well below the current PM_{10} standard of 150 $\mu g/m^3$. For this reason, and given the uncertainties associated with surface silt loadings, particularly for projects that have not yet been built, it appears that regional emission budgets would be a better approach to controlling possible exceedances of the standard. On a regional basis, the statistical uncertainties of surface silt loadings at particular intersections would be reduced. It is further recommended that efforts be started to determine whether a quantitative relationship can be developed between silt loading (or some other representative parameter) and VKT/hr.

It should be noted that future PM standards may focus on particles having an aerodynamic diameter of 2.5 μm or less. If so, the vehicular contribution may become a more significant fraction of the standard, while the re-entrained dust contribution would decline in significance.

Acknowledgments

A number of individuals outside the Air Quality Group assisted with this project. Keith Jones of Caltrans arranged for the traffic counts and provided safety equipment to our staff. The Sacramento County Public Works Department, Transportation Division actually collected the traffic data. Doug Maas was especially helpful coordinating the traffic data collection and compiling the results. The manager of Boston Market allowed us to use several spaces in his parking lot and supplied electrical power during an emergency. The manager of Pak-n-Sav allowed us to use space in his parking lot and supplied electrical power throughout the study. Dan Chang and Vicente Garza of the UC Davis Department of Civil Engineering and Tom Kear of the Institute for Transportation Studies helped through discussions of the project and coordination with their companion study of CO emissions.

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APPENDIX A

APPENDIX B

1995 SUMMER CALTRANS   Test ID 95-024

Array: CT   Location: Intersection of Florin Rd. and Stockton Blvd.

Date:	08/23/95, Wednesday	Practice:	Transportation
Test Times:	12:00 to 16:00	Operation:	Urban Intersection
Test Duration:	04.00 dec. hrs	Commodity:	Paved Road

Valid Meteorology:	Yes
Valid Wind Direction:	Yes
Valid Wind Speed:	Yes
Wind Direction Rating:	4.0 of 4.0
Field Rating:	3.0 of 4.0

Ave Vehicle Passes: 3838 vehicle counts/hour (axles/2)

Temperature:	34.88	+/-	2.75	degrees Celsius
Relative Humidity:	23.53	+/-	3.81	%
Solar Radiation:	841.3	+/-	60.1	W/m²
Richardson Number:	-0.172	+/-	0.028	

Silt Content:	3.3	+/-	1.0	%
Silt Loading:	0.016	+/-	0.026	g/m²
Moisture Content:	0.69	+/-	0.38	%

Wind Dir. - Ideal:	225.0	+/-	45.0	degrees
Wind Dir. - Ave Resultant:	234.5	+/-	15.8	degrees
Wind Dir. - Ave Unit:	234.9	+/-	15.3	degrees

Wind Speed - Ave Resultant:	2.53	+/-	0.58	m/s
Wind Speed - Ave Scalar:	2.63	+/-	0.41	m/s

Size	Loc	Ht (m)	DnWind (m)	CrsWind (m)	Mass (ug/m³)	$PM_{2.5}/PM_{10}$ (%)	RCMA (ug/m³)	RCMA% (%)	OMH (ug/m³)	SOIL (ug/m³)	NHSO (ug/m³)	SOOT (ug/m³)	ZN (ng/m³)	PB (ng/m³)
Height =		9.0m												
PM2.5	U19	9.0	-80.0	61.0	5.74	18.5%	6.15	107.0%	2.67	1.53	1.82	0.12	4.54	0.65
PM2.5	D19	9.0	4.0	0.0	6.93	12.1%	8.07	116.0%	3.62	2.03	2.19	0.23	8.21	3.11
Height =		3.0m												
PM2.5	U13	3.0	-80.0	61.0	6.75	19.9%	8.07	120.0%	4.07	1.49	2.32	0.18	6.50	2.27
PM2.5	D13	3.0	4.0	0.0	10.47	28.2%	10.64	102.0%	5.97	1.93	2.14	0.60	24.01	4.10
PM2.5	D43	3.0	84.0	79.0	7.31	19.9%	8.31	114.0%	3.43	2.48	2.21	0.18	8.07	1.91
Height =		9.0m												
PM10	U19	9.0	-80.0	61.0	30.97	%	29.30	95.0%	8.72	18.13	2.18	0.26	12.34	3.49
PM10	D19	9.0	4.0	0.0	57.06	%	42.11	74.0%	10.15	28.99	2.56	0.41	33.49	5.71
Height =		3.0m												
PM10	U13	3.0	-80.0	61.0	33.88	%	29.06	86.0%	6.46	20.18	2.21	0.21	10.76	3.57
PM10	D13	3.0	4.0	0.0	37.10	%	31.46	85.0%	9.72	19.29	2.05	0.40	43.50	6.80
PM10	D43	3.0	84.0	79.0	36.72	%	37.14	101.0%	9.29	24.89	2.68	0.28	29.07	6.92
Height =		1.0m												
PM10	D11	1.0	4.0	0.0	49.13	%	46.12	94.0%	16.47	25.88	2.83	0.94	82.90	9.74

Array: CT Location: Intersection of Florin Rd. and Stockton Blvd.

Date:	08/23/95, Wednesday	Practice:	Transportation	Valid Meteorology:	Yes
Test Times:	16:00 to 19:00	Operation:	Urban Intersection	Valid Wind Direction:	Yes
Test Duration:	03.00 dec. hrs	Commodity:	Paved Road	Valid Wind Speed:	Yes
				Wind Direction Rating:	4.0 of 4.0
				Field Rating:	3.0 of 4.0

Ave Vehicle Passes: 4517 vehicle counts/hour (axles/2)

Temperature:	35.20	+/-	2.12	degrees Celsius
Relative Humidity:	23.07	+/-	3.10	%
Solar Radiation:	338.3	+/-	219.5	W/m²
Richardson Number:	-0.079	+/-	0.027	

Silt Content:	3.3	+/-	1.0	%
Silt Loading:	0.016	+/-	0.026	g/m²
Moisture Content:	0.69	+/-	0.38	%

Wind Dir. - Ideal:	225.0	+/-	45.0	degrees
Wind Dir. - Ave Resultant:	237.3	+/-	7.9	degrees
Wind Dir. - Ave Unit:	237.3	+/-	8.0	degrees

Wind Speed - Ave Resultant:	3.50	+/-	0.42	m/s
Wind Speed - Ave Scalar:	3.53	+/-	0.34	m/s

Size	Loc	Ht (m)	DnWind (m)	CrsWind (m)	Mass (ug/m³)	$PM_{2.5}/PM_{10}$ (%)	RCMA (ug/m³)	RCMA% (%)	OMH (ug/m³)	SOIL (ug/m³)	NHSO (ug/m³)	SOOT (ug/m³)	ZN (ng/m³)	PB (ng/m³)
Height =		9.0m												
PM2.5	U19	9.0	-80.0	61.0	6.83	17.9%	6.82	100.0%	3.15	1.63	1.96	0.08	5.25	1.73
PM2.5	D19	9.0	4.0	0.0	8.34	14.7%	6.72	81.0%	3.34	1.38	1.87	0.13	4.95	
Height =		3.0m												
PM2.5	U13	3.0	-80.0	61.0	6.70	17.1%	7.42	111.0%	3.43	1.71	2.15	0.13	3.66	1.98
PM2.5	D13	3.0	4.0	0.0	13.20	19.3%	9.23	70.0%	4.42	2.42	2.04	0.34	11.91	3.96
PM2.5	D43	3.0	84.0	79.0	8.85	22.4%	8.72	99.0%	4.39	2.11	2.07	0.16	9.00	2.24
Height =		9.0m												
PM10	U19	9.0	-80.0	61.0	37.99	%	31.70	83.0%	9.20	19.97	2.32	0.20	11.75	3.88
PM10	D19	9.0	4.0	0.0	56.39	%	53.46	95.0%	13.09	37.73	2.38	0.26	27.81	6.36
Height =		3.0m												
PM10	U13	3.0	-80.0	61.0	39.14	%	35.46	91.0%	8.05	24.91	2.32	0.18	13.66	3.63
PM10	D13	3.0	4.0	0.0	68.14	%	56.57	83.0%	16.37	34.88	4.07	1.25	90.31	13.30
PM10	D23	3.0	60.0	51.0	49.26	%	39.04	79.0%	10.95	25.40	2.36	0.33	31.68	3.04
PM10	D43	3.0	84.0	79.0	39.37	%	35.56	90.0%	10.60	22.39	2.34	0.23	26.52	3.85
Height =		1.0m												
PM10	D11	1.0	4.0	0.0	56.01	%	44.54	80.0%	16.06	25.33	2.62	0.53	73.68	10.06

1995 SUMMER CALTRANS   Test ID   95-026

Array: CT   Location: Intersection of Florin Rd. and Stockton Blvd.

Date: 08/23/95, Wednesday
Test Times: 19:00 to 06:00
Test Duration: 11.00 dec. hrs

Practice: Transportation
Operation: Urban Intersection
Commodity: Paved Road

Valid Meteorology: Yes
Valid Wind Direction: Yes
Valid Wind Speed: Yes
Wind Direction Rating: 4.0 of 4.0
Field Rating: 2.0 of 4.0

Ave Vehicle Passes: 1536 vehicle counts/hour (axles/2)

Temperature:	22.07	+/-	3.58	degrees Celsius
Relative Humidity:	45.90	+/-	11.13	%
Solar Radiation:	4.1	+/-	17.7	W/m^2
Richardson Number:	-0.141	+/-	0.048	

Silt Content:	3.3	+/-	1.0	%
Silt Loading:	0.016	+/-	0.026	g/m^2
Moisture Content:	0.69	+/-	0.38	%

Wind Dir. - Ideal:	225.0	+/-	45.0	degrees
Wind Dir. - Ave Resultant:	199.2	+/-	24.9	degrees
Wind Dir. - Ave Unit:	200.4	+/-	25.0	degrees

Wind Speed - Ave Resultant:	2.21	+/-	0.57	m/s
Wind Speed - Ave Scalar:	2.44	+/-	0.40	m/s

Size	Loc	Ht (m)	DnWind (m)	CrsWind (m)	Mass (ug/m^3)	$PM_{2.5}/PM_{10}$ (%)	RCMA (ug/m^3)	RCMA% (%)	OMH (ug/m^3)	SOIL (ug/m^3)	NHSO (ug/m^3)	SOOT (ug/m^3)	ZN (ng/m^3)	PB (ng/m^3)
Height =		9.0m												
PM2.5	U19	9.0	-80.0	61.0	12.73	59.4%	5.27	41.0%	3.28	0.48	1.41	0.11	3.39	1.19
PM2.5	D19	9.0	4.0	0.0	10.82	37.3%	5.89	54.0%	3.60	0.51	1.59	0.19	5.46	1.67
Height =		3.0m												
PM2.5	U13	3.0	-80.0	61.0	12.58	57.6%	7.01	56.0%	4.09	0.85	1.95	0.13	4.98	1.79
PM2.5	D13	3.0	4.0	0.0	12.46	41.8%	7.73	62.0%	4.95	0.67	1.84	0.27	7.69	2.56
PM2.5	D43	3.0	84.0	79.0	11.11	47.6%	7.03	63.0%	4.12	0.85	1.87	0.19	5.15	1.62
Height =		9.0m												
PM10	U19	9.0	-80.0	61.0	21.41	%	14.22	66.0%	6.28	5.49	2.22	0.23	7.36	1.94
PM10	D19	9.0	4.0	0.0	28.98	%	18.36	63.0%	5.64	10.07	2.42	0.23	13.92	3.12
Height =		3.0m												
PM10	U13	3.0	-80.0	61.0	21.82	%	13.31	61.0%	5.43	5.61	2.08	0.19	6.59	2.12
PM10	D13	3.0	4.0	0.0	29.74	%	18.09	61.0%	7.61	7.38	2.73	0.37	22.92	4.00
PM10	D23	3.0	60.0	51.0	28.60	%	19.74	69.0%	7.59	9.40	2.47	0.28	17.90	3.88
PM10	D43	3.0	84.0	79.0	23.33	%	13.87	59.0%	4.77	6.53	2.32	0.25	12.71	2.57
Height =		1.0m												
PM10	D11	1.0	4.0	0.0	29.28	%	19.40	66.0%	9.06	7.49	2.34	0.51	35.58	5.45

1995 SUMMER CALTRANS   Test ID   95-027

Array: CT   Location: Intersection of Florin Rd. and Stockton Blvd.

Date:	08/24/95, Thursday	Practice:	Transportation	Valid Meteorology:	Yes
Test Times:	06:00 to 10:01	Operation:	Urban Intersection	Valid Wind Direction:	Yes
Test Duration:	04.02 dec. hrs	Commodity:	Paved Road	Valid Wind Speed:	Yes
				Wind Direction Rating:	4.0 of 4.0
				Field Rating:	3.0 of 4.0

Ave Vehicle Passes: 2417 vehicle counts/hour (axles/2)

Temperature:	18.96	+/-	1.52	degrees Celsius
Relative Humidity:	59.84	+/-	4.89	%
Solar Radiation:	249.7	+/-	216.8	W/m²
Richardson Number:	-0.158	+/-	0.069	

Silt Content:	3.3	+/-	1.0	%
Silt Loading:	0.016	+/-	0.026	g/m²
Moisture Content:	0.69	+/-	0.38	%

Wind Dir. - Ideal:	225.0	+/-	45.0	degrees
Wind Dir. - Ave Resultant:	197.1	+/-	24.0	degrees
Wind Dir. - Ave Unit:	200.7	+/-	23.0	degrees

Wind Speed - Ave Resultant:	2.45	+/-	0.60	m/s
Wind Speed - Ave Scalar:	2.66	+/-	0.55	m/s

Size	Loc	Ht (m)	DnWind (m)	CrsWind (m)	Mass (ug/m³)	$PM_{2.5}/PM_{10}$ (%)	RCMA (ug/m³)	RCMA% (%)	OMH (ug/m³)	SOIL (ug/m³)	NHSO (ug/m³)	SOOT (ug/m³)	ZN (ng/m³)	PB (ng/m³)
Height =		9.0m												
PM2.5	U19	9.0	-80.0	61.0	11.54	29.8%	9.30	81.0%	6.01	0.81	2.29	0.19	5.68	2.54
PM2.5	D19	9.0	4.0	0.0	12.59	39.2%	8.89	71.0%	5.54	0.89	2.18	0.28	7.93	2.49
Height =		3.0m												
PM2.5	U13	3.0	-80.0	61.0	14.60	51.7%	10.07	69.0%	6.33	1.04	2.48	0.23	6.26	2.52
PM2.5	D13	3.0	4.0	0.0	17.07	33.6%	11.87	69.0%	7.38	1.36	2.40	0.72	14.35	4.46
PM2.5	D43	3.0	84.0	79.0	13.91	37.8%	9.78	70.0%	5.98	0.92	2.56	0.31	16.84	3.04
Height =		9.0m												
PM10	U19	9.0	-80.0	61.0	38.65	%	21.94	57.0%	9.26	9.66	2.73	0.29	12.88	4.12
PM10	D19	9.0	4.0	0.0	32.06	%	28.08	88.0%	8.99	15.62	3.08	0.40	27.92	6.92
Height =		3.0m												
PM10	U13	3.0	-80.0	61.0	28.23	%	21.68	77.0%	8.30	10.28	2.86	0.24	11.21	4.21
PM10	D13	3.0	4.0	0.0	50.69	%	36.34	72.0%	16.05	15.68	3.72	0.89	61.34	10.79
PM10	D23	3.0	60.0	51.0	41.28	%	30.18	73.0%	8.58	17.95	3.07	0.58	33.73	
PM10	D43	3.0	84.0	79.0	36.77	%	21.35	58.0%	6.63	11.44	2.86	0.41	23.42	5.37
Height =		1.0m												
PM10	D11	1.0	4.0	0.0	47.14	%	41.42	88.0%	17.09	20.05	3.53	0.74	86.95	8.82

1995 SUMMER CALTRANS　　Test ID　95-028

Array: CT　　Location: Intersection of Florin Rd. and Stockton Blvd.

Date:	08/24/95, Thursday	Practice:	Transportation
Test Times:	11:43 to 16:00	Operation:	Urban Intersection
Test Duration:	04.28 dec. hrs	Commodity:	Paved Road

Valid Meteorology:	Yes
Valid Wind Direction:	Yes
Valid Wind Speed:	Yes
Wind Direction Rating:	4.0 of 4.0
Field Rating:	3.0 of 4.0

Ave Vehicle Passes: 3897 vehicle counts/hour (axles/2)

Temperature:	28.71	+/-	1.58	degrees Celsius
Relative Humidity:	29.52	+/-	6.13	%
Solar Radiation:	857.2	+/-	60.2	W/m²
Richardson Number:	-0.118	+/-	0.026	

Silt Content:	3.3	+/-	1.0	%
Silt Loading:	0.016	+/-	0.026	g/m²
Moisture Content:	0.69	+/-	0.38	%

Wind Dir. - Ideal:	225.0	+/-	45.0	degrees
Wind Dir. - Ave Resultant:	237.6	+/-	11.9	degrees
Wind Dir. - Ave Unit:	237.7	+/-	12.0	degrees

Wind Speed - Ave Resultant:	2.91	+/-	0.46	m/s
Wind Speed - Ave Scalar:	2.98	+/-	0.27	m/s

Size	Loc	Ht (m)	DnWind (m)	CrsWind (m)	Mass (ug/m³)	$PM_{2.5}/PM_{10}$ (%)	RCMA (ug/m³)	RCMA% (%)	OMH (ug/m³)	SOIL (ug/m³)	NHSO (ug/m³)	SOOT (ug/m³)	ZN (ng/m³)	PB (ng/m³)
Height =		9.0m												
PM2.5	U19	9.0	-80.0	61.0	10.09	27.1%	9.56	95.0%	5.90	1.22	2.28	0.15	5.91	2.15
PM2.5	D19	9.0	4.0	0.0	12.39	22.4%	11.99	97.0%	7.99	1.18	2.57	0.25	237.51	2.47
Height =		3.0m												
PM2.5	U13	3.0	-80.0	61.0	11.51	31.4%	9.98	87.0%	6.15	1.20	2.48	0.15	7.04	1.91
PM2.5	D43	3.0	84.0	79.0	12.97	33.3%	10.38	80.0%	6.08	1.36	2.69	0.26	10.08	2.91
Height =		9.0m												
PM10	U19	9.0	-80.0	61.0	37.23	%	33.94	91.0%	10.58	20.62	2.50	0.24	15.57	4.96
PM10	D19	9.0	4.0	0.0	55.11	%	45.12	82.0%	12.04	29.85	2.80	0.42	33.00	7.84
Height =		3.0m												
PM10	U13	3.0	-80.0	61.0	36.56	%	30.81	84.0%	11.50	16.50	2.59	0.23	13.55	4.98
PM10	D13	3.0	4.0	0.0	49.22	%	44.30	90.0%	19.34	21.49	2.68	0.79	80.87	9.92
PM10	D23	3.0	60.0	51.0	32.02	%	24.81	77.0%	10.07	11.79	2.54	0.41	22.93	4.48
PM10	D43	3.0	84.0	79.0	38.91	%	34.82	89.0%	10.21	21.55	2.72	0.33	43.63	6.13
Height =		1.0m												
PM10	D11	1.0	4.0	0.0	61.33	%	53.19	87.0%	21.68	27.49	3.18	0.84	97.58	11.76

1995 SUMMER CALTRANS **Test ID** **95-029**

Array: CT Location: Intersection of Florin Rd. and Stockton Blvd.

Date:	08/24/95, Thursday	Practice:	Transportation
Test Times:	16:00 to 20:55	Operation:	Urban Intersection
Test Duration:	04.92 dec. hrs	Commodity:	Paved Road

Valid Meteorology:	Yes
Valid Wind Direction:	Yes
Valid Wind Speed:	Yes
Wind Direction Rating:	4.0 of 4.0
Field Rating:	3.0 of 4.0

Ave Vehicle Passes: 3973 vehicle counts/hour (axles/2)

Temperature:	27.13	+/-	2.90	degrees Celsius
Relative Humidity:	33.22	+/-	9.76	%
Solar Radiation:	210.3	+/-	238.0	W/m^2
Richardson Number:	-0.102	+/-	0.029	

Silt Content:	3.3	+/-	1.0	%
Silt Loading:	0.016	+/-	0.026	g/m^2
Moisture Content:	0.69	+/-	0.38	%

Wind Dir. - Ideal:	225.0	+/-	45.0	degrees
Wind Dir. - Ave Resultant:	225.5	+/-	10.7	degrees
Wind Dir. - Ave Unit:	225.7	+/-	10.6	degrees

Wind Speed - Ave Resultant:	3.01	+/-	0.52	m/s
Wind Speed - Ave Scalar:	3.06	+/-	0.46	m/s

Size	Loc	Ht (m)	DnWind (m)	CrsWind (m)	Mass (ug/m^3)	$PM_{2.5}/PM_{10}$ (%)	RCMA (ug/m^3)	RCMA% (%)	OMH (ug/m^3)	SOIL (ug/m^3)	NHSO (ug/m^3)	SOOT (ug/m^3)	ZN (ng/m^3)	PB (ng/m^3)
Height =		9.0m												
PM2.5	U19	9.0	-80.0	61.0	9.15	29.7%	8.21	90.0%	5.42	0.70	1.95	0.14	5.54	1.27
PM2.5	D19	9.0	4.0	0.0	11.90	28.1%	9.83	83.0%	6.67	0.82	2.16	0.18	7.82	2.61
Height =		3.0m												
PM2.5	U13	3.0	-80.0	61.0	12.12	36.2%	10.06	83.0%	6.83	1.06	2.02	0.16	5.83	1.38
PM2.5	D13	3.0	4.0	0.0	13.99	31.9%	11.56	83.0%	6.90	2.01	2.25	0.41	14.89	4.78
PM2.5	D43	3.0	84.0	79.0	10.50	31.3%	10.50	100.0%	6.50	1.46	2.33	0.21	8.30	1.89
Height =		9.0m												
PM10	U19	9.0	-80.0	61.0	30.80	%	25.43	83.0%	9.69	13.49	2.05	0.20	11.25	4.21
PM10	D19	9.0	4.0	0.0	42.28	%	25.38	60.0%	7.80	15.41	1.91	0.25	24.62	7.06
Height =		3.0m												
PM10	U13	3.0	-80.0	61.0	33.46	%	26.82	80.0%	10.18	14.08	2.34	0.21	13.46	4.45
PM10	D13	3.0	4.0	0.0	43.75	%	40.32	92.0%	19.45	17.87	2.48	0.52	61.16	10.09
PM10	D23	3.0	60.0	51.0	38.34	%	23.69	62.0%	9.52	11.24	2.60	0.32	24.80	5.77
PM10	D43	3.0	84.0	79.0	33.51	%	27.66	83.0%	7.99	16.77	2.61	0.29	31.56	6.94
Height =		1.0m												
PM10	D11	1.0	4.0	0.0	49.68	%	44.89	90.0%	19.05	22.43	2.79	0.62	88.33	11.05

1995 SUMMER CALTRANS   Test ID   95-030

Array: CT   Location: Intersection of Florin Rd. and Stockton Blvd.

Date:	08/24/95, Thursday	Practice:	Transportation	Valid Meteorology:	Yes
Test Times:	20:55 to 05:55	Operation:	Urban Intersection	Valid Wind Direction:	Yes
Test Duration:	09.00 dec. hrs	Commodity:	Paved Road	Valid Wind Speed:	Yes
				Wind Direction Rating:	2.0 of 4.0
				Field Rating:	2.0 of 4.0

Ave Vehicle Passes: 1064 vehicle counts/hour (axles/2)

Temperature:	17.90	+/-	1.94	degrees Celsius
Relative Humidity:	63.84	+/-	8.53	%
Solar Radiation:	0.1	+/-	0.0	W/m^2
Richardson Number:	-0.185	+/-	0.032	
Wind Dir. - Ideal:	225.0	+/-	45.0	degrees
Wind Dir. - Ave Resultant:	182.3	+/-	14.2	degrees
Wind Dir. - Ave Unit:	182.7	+/-	13.8	degrees

Silt Content:	3.3	+/-	1.0	%
Silt Loading:	0.016	+/-	0.026	g/m^2
Moisture Content:	0.69	+/-	0.38	%
Wind Speed - Ave Resultant:	2.13	+/-	0.25	m/s
Wind Speed - Ave Scalar:	2.20	+/-	0.21	m/s

Size	Loc	Ht (m)	DnWind (m)	CrsWind (m)	Mass (ug/m^3)	$PM_{2.5}/PM_{10}$ (%)	RCMA (ug/m^3)	RCMA% (%)	OMH (ug/m^3)	SOIL (ug/m^3)	NHSO (ug/m^3)	SOOT (ug/m^3)	ZN (ng/m^3)	PB (ng/m^3)
Height =		9.0m												
PM2.5	U19	9.0	-80.0	61.0	15.28	56.4%	9.62	63.0%	6.44	0.37	2.66	0.14	6.56	2.50
PM2.5	D19	9.0	4.0	0.0	15.38	49.0%	9.50	62.0%	6.18	0.41	2.72	0.19	8.19	2.70
Height =		3.0m												
PM2.5	U13	3.0	-80.0	61.0	15.58	60.9%	11.34	73.0%	7.83	0.36	2.97	0.18	7.21	2.72
PM2.5	D13	3.0	4.0	0.0	17.54	52.5%	9.77	56.0%	5.27	0.97	3.16	0.37	10.60	3.23
PM2.5	D43	3.0	84.0	79.0	17.23	63.8%	9.63	56.0%	5.76	1.04	2.66	0.18	8.08	2.91
Height =		9.0m												
PM10	U19	9.0	-80.0	61.0	27.06	%	14.70	54.0%	7.07	4.37	3.07	0.19	12.50	3.34
PM10	D19	9.0	4.0	0.0	31.35	%	17.10	55.0%	6.16	7.19	3.47	0.27	18.90	5.20
Height =		3.0m												
PM10	U13	3.0	-80.0	61.0	25.54	%	14.51	57.0%	7.36	3.71	3.22	0.22	10.35	3.14
PM10	D13	3.0	4.0	0.0	33.38	%	19.90	60.0%	10.69	5.23	3.52	0.46	29.85	5.88
PM10	D23	3.0	60.0	51.0	29.52	%	15.49	52.0%	6.71	4.88	3.59	0.30	19.74	5.16
PM10	D43	3.0	84.0	79.0	26.98	%	13.13	49.0%	4.62	4.72	3.54	0.24	19.20	4.03
Height =		1.0m												
PM10	D11	1.0	4.0	0.0	33.82	%	20.97	62.0%	9.40	7.19	3.93	0.45	41.85	7.54

1995 SUMMER CALTRANS Test ID 95-031

Array: CT Location: Intersection of Florin Rd. and Stockton Blvd.

Date:	08/25/95, Friday	Practice:	Transportation
Test Times:	05:56 to 10:01	Operation:	Urban Intersection
Test Duration:	04.08 dec. hrs	Commodity:	Paved Road

Valid Meteorology:	Yes
Valid Wind Direction:	Yes
Valid Wind Speed:	Yes
Wind Direction Rating:	4.0 of 4.0
Field Rating:	3.0 of 4.0

Ave Vehicle Passes: 2221 vehicle counts/hour (axles/2)

Temperature:	16.15	+/-	1.52	degrees Celsius
Relative Humidity:	74.90	+/-	6.81	%
Solar Radiation:	247.3	+/-	215.6	W/m²
Richardson Number:	-0.214	+/-	0.062	

Silt Content:	3.3	+/-	1.0	%
Silt Loading:	0.016	+/-	0.026	g/m²
Moisture Content:	0.69	+/-	0.38	%

Wind Dir. - Ideal:	225.0	+/-	45.0	degrees
Wind Dir. - Ave Resultant:	218.3	+/-	17.8	degrees
Wind Dir. - Ave Unit:	219.8	+/-	17.5	degrees

Wind Speed - Ave Resultant:	2.28	+/-	0.53	m/s
Wind Speed - Ave Scalar:	2.39	+/-	0.34	m/s

Size	Loc	Ht (m)	DnWind (m)	CrsWind (m)	Mass (ug/m³)	$PM_{2.5}/PM_{10}$ (%)	RCMA (ug/m³)	RCMA% (%)	OMH (ug/m³)	SOIL (ug/m³)	NHSO (ug/m³)	SOOT (ug/m³)	ZN (ng/m³)	PB (ng/m³)
Height =		9.0m												
PM2.5	U19	9.0	-80.0	61.0	12.59	48.5%	8.69	69.0%	4.17	0.45	3.91	0.15	5.05	1.77
PM2.5	D19	9.0	4.0	0.0	13.89	44.6%	11.09	80.0%	5.95	0.60	4.19	0.35	7.61	0.94
Height =		3.0m												
PM2.5	U13	3.0	-80.0	61.0	17.01	64.2%	9.52	56.0%	4.63	0.72	3.99	0.18	21.26	2.38
PM2.5	D13	3.0	4.0	0.0	18.82	44.2%	12.98	69.0%	6.55	1.59	4.19	0.66	20.06	3.54
PM2.5	D43	3.0	84.0	79.0	22.83	69.8%	10.79	47.0%	5.51	1.11	3.91	0.27	7.64	2.61
Height =		9.0m												
PM10	U19	9.0	-80.0	61.0	25.90	%	15.52	60.0%	5.84	5.34	4.16	0.18	8.80	2.68
PM10	D19	9.0	4.0	0.0	31.12	%	19.21	62.0%	5.82	7.96	5.04	0.38	18.78	4.18
Height =		3.0m												
PM10	U13	3.0	-80.0	61.0	26.48	%	17.30	65.0%	6.42	5.76	4.90	0.22	10.21	2.37
PM10	D13	3.0	4.0	0.0	42.57	%	29.22	69.0%	13.48	9.25	5.56	0.93	54.90	6.83
PM10	D23	3.0	60.0	51.0	27.39	%	20.67	75.0%	8.44	6.79	5.07	0.37	23.28	4.26
PM10	D43	3.0	84.0	79.0	32.67	%	15.54	48.0%	5.93	4.43	4.78	0.39	18.74	
Height =		1.0m												
PM10	D11	1.0	4.0	0.0	53.12	%	25.84	49.0%	8.50	11.34	5.01	0.99	66.60	9.31

1995 SUMMER CALTRANS Test ID 95-032

Array: CT Location: Intersection of Florin Rd. and Stockton Blvd.

Date:	08/25/95, Friday		Practice:	Transportation
Test Times:	11:07 to 15:58		Operation:	Urban Intersection
Test Duration:	04.85 dec. hrs		Commodity:	Paved Road

Valid Meteorology:	Yes
Valid Wind Direction:	Yes
Valid Wind Speed:	Yes
Wind Direction Rating:	4.0 of 4.0
Field Rating:	2.0 of 4.0

Ave Vehicle Passes: 4093 vehicle counts/hour (axles/2)

Temperature:	26.47	+/-	2.28	degrees Celsius
Relative Humidity:	35.67	+/-	10.00	%
Solar Radiation:	863.6	+/-	55.4	W/m^2
Richardson Number:	-0.150	+/-	0.052	

Silt Content:	3.3	+/-	1.0	%
Silt Loading:	0.016	+/-	0.026	g/m^2
Moisture Content:	0.69	+/-	0.38	%

Wind Dir. - Ideal:	225.0	+/-	45.0	degrees
Wind Dir. - Ave Resultant:	232.0	+/-	12.9	degrees
Wind Dir. - Ave Unit:	232.0	+/-	12.8	degrees

Wind Speed - Ave Resultant:	2.73	+/-	0.50	m/s
Wind Speed - Ave Scalar:	2.80	+/-	0.37	m/s

Size	Loc	Ht (m)	DnWind (m)	CrsWind (m)	Mass (ug/m^3)	$PM_{2.5}/PM_{10}$ (%)	RCMA (ug/m^3)	RCMA% (%)	OMH (ug/m^3)	SOIL (ug/m^3)	NHSO (ug/m^3)	SOOT (ug/m^3)	ZN (ng/m^3)	PB (ng/m^3)
Height =		9.0m												
PM2.5	U19	9.0	-80.0	61.0	11.02	35.6%	8.62	78.0%	4.89	0.71	2.87	0.15	5.39	1.48
PM2.5	D19	9.0	4.0	0.0	14.64	40.4%	7.74	53.0%	4.23	0.63	2.68	0.20	8.11	1.99
Height =		3.0m												
PM2.5	U13	3.0	-80.0	61.0	13.22	46.2%	10.13	77.0%	6.28	0.62	3.06	0.18	5.53	1.24
PM2.5	D43	3.0	84.0	79.0	15.14	48.0%	9.15	60.0%	4.71	1.14	3.04	0.26	8.34	2.12
Height =		9.0m												
PM10	U19	9.0	-80.0	61.0	30.88	%	24.22	78.0%	8.72	12.21	3.07	0.23	13.79	4.36
PM10	D19	9.0	4.0	0.0	36.18	%	23.00	64.0%	7.30	12.30	3.03	0.37	25.74	4.37
Height =		3.0m												
PM10	U13	3.0	-80.0	61.0	28.56	%	22.35	78.0%	9.30	9.26	3.53	0.26	10.30	2.01
PM10	D23	3.0	60.0	51.0	32.25	%	25.43	79.0%	9.48	11.88	3.65	0.42	27.13	3.86
PM10	D43	3.0	84.0	79.0	31.52	%	21.17	67.0%	6.11	11.45	3.29	0.32	22.34	4.62
Height =		1.0m												
PM10	D11	1.0	4.0	0.0	43.92	%	37.04	84.0%	16.55	15.98	3.73	0.78	84.08	9.22

1995 SUMMER CALTRANS Test ID 95-033

Array: CT Location: Intersection of Florin Rd. and Stockton Blvd.

Date:	08/25/95, Friday	Practice:	Transportation	Valid Meteorology: Yes
Test Times:	15:58 to 21:00	Operation:	Urban Intersection	Valid Wind Direction: Yes
Test Duration:	05.03 dec. hrs	Commodity:	Paved Road	Valid Wind Speed: Yes
				Wind Direction Rating: 4.0 of 4.0
				Field Rating: 3.0 of 4.0

Ave Vehicle Passes: 4479 vehicle counts/hour (axles/2)

Temperature:	25.67	+/-	2.83	degrees Celsius
Relative Humidity:	36.74	+/-	9.82	%
Solar Radiation:	224.0	+/-	252.1	W/m^2
Richardson Number:	-0.120	+/-	0.032	

Silt Content:	3.3	+/-	1.0	%
Silt Loading:	0.016	+/-	0.026	g/m^2
Moisture Content:	0.69	+/-	0.38	%

Wind Dir. - Ideal:	225.0	+/-	45.0	degrees
Wind Dir. - Ave Resultant:	219.1	+/-	16.8	degrees
Wind Dir. - Ave Unit:	220.2	+/-	16.7	degrees

Wind Speed - Ave Resultant:	2.83	+/-	0.64	m/s
Wind Speed - Ave Scalar:	2.96	+/-	0.37	m/s

Size	Loc	Ht (m)	DnWind (m)	CrsWind (m)	Mass (ug/m^3)	$PM_{2.5}/PM_{10}$ (%)	RCMA (ug/m^3)	RCMA% (%)	OMH (ug/m^3)	SOIL (ug/m^3)	NHSO (ug/m^3)	SOOT (ug/m^3)	ZN (ng/m^3)	PB (ng/m^3)
Height =		9.0m												
PM2.5	U19	9.0	-80.0	61.0	8.31	30.5%	8.20	99.0%	5.47	0.64	1.98	0.10	3.88	1.32
PM2.5	D19	9.0	4.0	0.0	8.65	31.0%	8.19	95.0%	5.24	0.85	1.95	0.15	8.82	5.70
Height =		3.0m												
PM2.5	U13	3.0	-80.0	61.0	15.18	55.3%	10.28	68.0%	7.15	0.97	2.01	0.15	4.76	1.45
PM2.5	D43	3.0	84.0	79.0	10.94	39.6%	8.97	82.0%	5.57	1.18	2.03	0.19	7.17	
Height =		9.0m												
PM10	U19	9.0	-80.0	61.0	27.17	%	21.78	80.0%	8.41	11.09	2.08	0.20	8.49	2.77
PM10	D19	9.0	4.0	0.0	27.84	%	24.57	88.0%	7.68	14.37	2.22	0.30	26.25	13.99
Height =		3.0m												
PM10	U13	3.0	-80.0	61.0	27.45	%	26.13	95.0%	12.54	11.03	2.33	0.22	9.79	3.65
PM10	D23	3.0	60.0	51.0	30.45	%	26.57	87.0%	10.32	13.67	2.29	0.29	34.07	6.05
PM10	D43	3.0	84.0	79.0	27.58	%	21.28	77.0%	7.56	11.47	2.06	0.20	21.10	4.29
Height =		1.0m												
PM10	D11	1.0	4.0	0.0	40.00	%	36.46	91.0%	16.60	16.55	2.69	0.62	80.92	13.78

1995 SUMMER CALTRANS Test ID 95-034

Array: CT Location: Intersection of Florin Rd. and Stockton Blvd.

Date:	08/25/95, Friday	Practice:	Transportation
Test Times:	21:00 to 05:56	Operation:	Urban Intersection
Test Duration:	08.93 dec. hrs	Commodity:	Paved Road

Valid Meteorology:	Yes
Valid Wind Direction:	Yes
Valid Wind Speed:	Yes
Wind Direction Rating:	3.0 of 4.0
Field Rating:	2.0 of 4.0

Ave Vehicle Passes: 1294 vehicle counts/hour (axles/2)

Temperature:	16.54	+/-	1.56	degrees Celsius
Relative Humidity:	69.09	+/-	7.28	%
Solar Radiation:	0.1	+/-	0.0	W/m²
Richardson Number:	-0.168	+/-	0.063	

Silt Content:	3.3	+/-	1.0	%
Silt Loading:	0.016	+/-	0.026	g/m²
Moisture Content:	0.69	+/-	0.38	%

Wind Dir. - Ideal:	225.0	+/-	45.0	degrees
Wind Dir. - Ave Resultant:	188.7	+/-	8.5	degrees
Wind Dir. - Ave Unit:	189.3	+/-	8.3	degrees

Wind Speed - Ave Resultant:	2.44	+/-	0.36	m/s
Wind Speed - Ave Scalar:	2.47	+/-	0.37	m/s

Size	Loc	Ht (m)	DnWind (m)	CrsWind (m)	Mass (ug/m³)	$PM_{2.5}/PM_{10}$ (%)	RCMA (ug/m³)	RCMA% (%)	OMH (ug/m³)	SOIL (ug/m³)	NHSO (ug/m³)	SOOT (ug/m³)	ZN (ng/m³)	PB (ng/m³)
Height =		9.0m												
PM2.5	U19	9.0	-80.0	61.0	10.09	52.9%	6.71	66.0%	3.06	0.36	3.18	0.11	5.25	2.03
PM2.5	D19	9.0	4.0	0.0	9.99	41.8%	6.06	61.0%	2.43	0.36	3.16	0.11	5.15	2.77
Height =		3.0m												
PM2.5	U13	3.0	-80.0	61.0	11.27	55.9%	8.10	72.0%	4.00	0.40	3.55	0.14	5.16	2.00
PM2.5	D13	3.0	4.0	0.0	11.76	54.9%	6.57	56.0%	2.72	0.50	3.19	0.17	7.02	3.09
PM2.5	D43	3.0	84.0	79.0	11.85	52.9%	6.63	56.0%	2.54	0.51	3.47	0.11	5.25	2.71
Height =		9.0m												
PM10	U19	9.0	-80.0	61.0	19.06	%	12.97	68.0%	4.64	4.53	3.67	0.13	9.15	3.11
PM10	D19	9.0	4.0	0.0	23.88	%	13.31	56.0%	3.33	5.96	3.86	0.16	15.09	4.37
Height =		3.0m												
PM10	U13	3.0	-80.0	61.0	20.15	%	13.03	65.0%	5.21	3.74	3.90	0.18	8.38	2.95
PM10	D13	3.0	4.0	0.0	21.43	%	13.94	65.0%	5.02	5.35	3.36	0.21	23.60	5.04
PM10	D23	3.0	60.0	51.0	24.13	%	11.98	50.0%	3.61	3.83	4.35	0.19	15.00	6.67
PM10	D43	3.0	84.0	79.0	22.36	%	10.55	47.0%	1.88	4.29	4.21	0.17	11.84	4.37
Height =		1.0m												
PM10	D11	1.0	4.0	0.0	27.09	%	15.76	58.0%	4.68	6.39	4.34	0.35	34.09	6.21

1995 SUMMER CALTRANS   Test ID   95-035

Array: CT   Location: Intersection of Florin Rd. and Stockton Blvd.

Date:	08/26/95, Saturday	Practice:	Transportation
Test Times:	05:56 to 10:00	Operation:	Urban Intersection
Test Duration:	04.07 dec. hrs	Commodity:	Paved Road

Valid Meteorology:	Yes
Valid Wind Direction:	Yes
Valid Wind Speed:	Yes
Wind Direction Rating:	4.0 of 4.0
Field Rating:	2.0 of 4.0

Ave Vehicle Passes: 1463 vehicle counts/hour (axles/2)

Temperature:	14.95	+/-	1.24	degrees Celsius
Relative Humidity:	78.91	+/-	5.03	%
Solar Radiation:	242.0	+/-	210.8	W/m²
Richardson Number:	-0.461	+/-	0.123	

Silt Content:	3.3	+/-	1.0	%
Silt Loading:	0.016	+/-	0.026	g/m²
Moisture Content:	0.69	+/-	0.38	%

Wind Dir. - Ideal:	225.0	+/-	45.0	degrees
Wind Dir. - Ave Resultant:	209.3	+/-	30.8	degrees
Wind Dir. - Ave Unit:	208.4	+/-	29.8	degrees

Wind Speed - Ave Resultant:	1.41	+/-	0.56	m/s
Wind Speed - Ave Scalar:	1.63	+/-	0.18	m/s

Size	Loc	Ht (m)	DnWind (m)	CrsWind (m)	Mass (ug/m³)	$PM_{2.5}/PM_{10}$ (%)	RCMA (ug/m³)	RCMA% (%)	OMH (ug/m³)	SOIL (ug/m³)	NHSO (ug/m³)	SOOT (ug/m³)	ZN (ng/m³)	PB (ng/m³)
Height =		9.0m												
PM2.5	U19	9.0	-80.0	61.0	10.96	50.2%	7.46	68.0%	2.94	0.65	3.72	0.15	3.49	1.86
PM2.5	D19	9.0	4.0	0.0	11.45	43.9%	8.13	71.0%	3.37	0.61	3.91	0.25	5.89	2.38
Height =		3.0m												
PM2.5	U13	3.0	-80.0	61.0	11.59	51.6%	8.66	75.0%	3.55	0.60	4.32	0.19	4.08	2.09
PM2.5	D13	3.0	4.0	0.0	13.26	49.4%	10.03	76.0%	4.60	0.81	4.21	0.42	10.41	19.15
PM2.5	D43	3.0	84.0	79.0	13.28	48.5%	9.55	72.0%	3.82	0.97	4.60	0.17	5.19	5.01
Height =		9.0m												
PM10	U19	9.0	-80.0	61.0	21.82	%	15.98	73.0%	5.00	6.69	4.07	0.22	7.75	2.98
PM10	D19	9.0	4.0	0.0	26.08	%	18.42	71.0%	5.23	8.16	4.73	0.30	20.93	4.32
Height =		3.0m												
PM10	U13	3.0	-80.0	61.0	22.44	%	17.03	76.0%	5.61	6.46	4.68	0.28	8.45	2.19
PM10	D13	3.0	4.0	0.0	26.80	%	20.16	75.0%	6.49	8.79	4.39	0.49	35.10	69.13
PM10	D23	3.0	60.0	51.0	24.85	%	20.29	82.0%	6.89	8.08	5.03	0.28	18.80	22.10
PM10	D43	3.0	84.0	79.0	27.38	%	15.44	56.0%	3.55	7.03	4.64	0.22	14.17	13.76
Height =		1.0m												
PM10	D11	1.0	4.0	0.0	36.60	%	22.90	63.0%	9.28	8.38	4.70	0.54	40.90	77.88

1995 SUMMER CALTRANS Test ID 95-036

Array: CT Location: Intersection of Florin Rd. and Stockton Blvd.

Date:	08/26/95, Saturday	Practice:	Transportation
Test Times:	11:01 to 16:06	Operation:	Urban Intersection
Test Duration:	05.08 dec. hrs	Commodity:	Paved Road

Valid Meteorology:	No
Valid Wind Direction:	No
Valid Wind Speed:	No
Wind Direction Rating:	0.0 of 4.0
Field Rating:	1.0 of 4.0

Ave Vehicle Passes: 3694 vehicle counts/hour (axles/2)

Temperature:	26.51	+/-	3.23	degrees Celsius
Relative Humidity:	37.45	+/-	12.30	%
Solar Radiation:	853.7	+/-	62.6	W/m^2
Richardson Number:	-0.285	+/-	0.129	

Silt Content:	3.3	+/-	1.0	%
Silt Loading:	0.016	+/-	0.026	g/m^2
Moisture Content:	0.69	+/-	0.38	%

Wind Dir. - Ideal:	225.0	+/-	45.0	degrees
Wind Dir. - Ave Resultant:	281.6	+/-	63.0	degrees
Wind Dir. - Ave Unit:	280.6	+/-	52.8	degrees

Wind Speed - Ave Resultant:	0.99	+/-	0.96	m/s
Wind Speed - Ave Scalar:	1.71	+/-	0.28	m/s

Size	Loc	Ht (m)	DnWind (m)	CrsWind (m)	Mass (ug/m^3)	$PM_{2.5}/PM_{10}$ (%)	RCMA (ug/m^3)	RCMA% (%)	OMH (ug/m^3)	SOIL (ug/m^3)	NHSO (ug/m^3)	SOOT (ug/m^3)	ZN (ng/m^3)	PB (ng/m^3)
Height =		9.0m												
PM2.5	U19	9.0	-80.0	61.0	7.58	38.6%	6.82	90.0%	3.78	0.56	2.36	0.13	4.68	4.33
PM2.5	D19	9.0	4.0	0.0	11.81	32.6%	9.84	83.0%	5.36	1.26	3.01	0.21	8.81	6.94
Height =		3.0m												
PM2.5	U13	3.0	-80.0	61.0	15.06	48.9%	17.34	115.0%	12.86	1.12	3.08	0.28	10.32	5.37
PM2.5	D13	3.0	4.0	0.0	14.78	41.8%	11.83	80.0%	6.32	1.74	3.48	0.29	12.99	6.96
PM2.5	D43	3.0	84.0	79.0	11.80	42.6%	10.42	88.0%	5.46	1.25	3.51	0.21	7.69	6.30
Height =		9.0m												
PM10	U19	9.0	-80.0	61.0	19.60	%	18.80	96.0%	7.19	9.20	2.28	0.13	23.62	5.61
PM10	D19	9.0	4.0	0.0	36.15	%	34.26	95.0%	10.89	18.95	4.15	0.28	37.01	11.28
Height =		3.0m												
PM10	U13	3.0	-80.0	61.0	30.78	%	31.97	104.0%	14.69	13.44	3.51	0.33	20.41	8.25
PM10	D13	3.0	4.0	0.0	35.30	%	30.18	86.0%	11.84	13.65	4.23	0.46	40.68	11.12
PM10	D23	3.0	60.0	51.0	30.61	%	25.46	83.0%	8.64	13.27	3.27	0.28	22.99	5.95
PM10	D43	3.0	84.0	79.0	27.68	%	19.58	71.0%	4.82	11.37	3.15	0.25	15.10	6.41
Height =		1.0m												
PM10	D11	1.0	4.0	0.0	36.85	%	35.17	95.0%	14.75	15.96	4.11	0.35	55.42	12.85

1995 SUMMER CALTRANS   Test ID   95-037

Array: CT   Location: Intersection of Florin Rd. and Stockton Blvd.

Date:	08/26/95, Saturday	Practice:	Transportation
Test Times:	16:06 to 21:00	Operation:	Urban Intersection
Test Duration:	04.90 dec. hrs	Commodity:	Paved Road

Valid Meteorology:	Yes
Valid Wind Direction:	Yes
Valid Wind Speed:	Yes
Wind Direction Rating:	4.0 of 4.0
Field Rating:	1.0 of 4.0

Ave Vehicle Passes: 3699 vehicle counts/hour (axles/2)

Temperature:	29.03	+/-	2.52	degrees Celsius
Relative Humidity:	29.36	+/-	8.58	%
Solar Radiation:	202.4	+/-	234.2	W/m²
Richardson Number:	-0.213	+/-	0.069	

Silt Content:	3.3	+/-	1.0	%
Silt Loading:	0.016	+/-	0.026	g/m²
Moisture Content:	0.69	+/-	0.38	%

Wind Dir. - Ideal:	225.0	+/-	45.0	degrees
Wind Dir. - Ave Resultant:	237.1	+/-	19.1	degrees
Wind Dir. - Ave Unit:	237.0	+/-	18.6	degrees

Wind Speed - Ave Resultant:	1.96	+/-	0.46	m/s
Wind Speed - Ave Scalar:	2.07	+/-	0.27	m/s

Size	Loc	Ht (m)	DnWind (m)	CrsWind (m)	Mass (ug/m³)	$PM_{2.5}/PM_{10}$ (%)	RCMA (ug/m³)	RCMA% (%)	OMH (ug/m³)	SOIL (ug/m³)	NHSO (ug/m³)	SOOT (ug/m³)	ZN (ng/m³)	PB (ng/m³)
Height =		9.0m												
PM2.5	U19	9.0	-80.0	61.0	9.63	37.3%	8.15	85.0%	4.43	0.89	2.68	0.15	3.50	2.11
PM2.5	D19	9.0	4.0	0.0	10.15	35.2%	9.26	91.0%	5.44	1.29	2.38	0.16	5.95	2.47
Height =		3.0m												
PM2.5	U13	3.0	-80.0	61.0	9.71	37.3%	7.88	81.0%	3.99	0.99	2.76	0.14	4.31	2.52
PM2.5	D13	3.0	4.0	0.0	10.94	31.5%	9.72	89.0%	5.63	1.17	2.61	0.30	12.38	4.47
PM2.5	D43	3.0	84.0	79.0	10.33	33.3%	9.52	92.0%	4.88	1.66	2.84	0.14	7.61	3.18
Height =		9.0m												
PM10	U19	9.0	-80.0	61.0	25.80	%	23.80	92.0%	8.32	12.70	2.60	0.17	7.64	3.45
PM10	D19	9.0	4.0	0.0	28.84	%	25.97	90.0%	7.57	15.49	2.71	0.20	20.78	5.61
Height =		3.0m												
PM10	U13	3.0	-80.0	61.0	25.96	%	24.19	93.0%	8.31	12.66	3.00	0.22	8.42	3.90
PM10	D13	3.0	4.0	0.0	34.65	%	31.23	90.0%	11.71	15.76	3.27	0.49	50.50	9.01
PM10	D23	3.0	60.0	51.0	35.41	%	29.18	82.0%	10.19	15.74	2.97	0.29	27.30	6.44
PM10	D43	3.0	84.0	79.0	31.01	%	27.24	88.0%	7.85	16.22	2.90	0.26	22.19	5.22
Height =		1.0m												
PM10	D11	1.0	4.0	0.0	38.52	%	53.86	140.0%	20.67	29.40	3.27	0.52	77.38	9.98

MICROSCALE PM10 MODELING AND POTENTIAL "HOT-SPOT" ANALYSIS

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Introduction

As part of a recent study by the Air Quality Group of the Crocker Nuclear Laboratory at UC Davis (Ashbaugh, et al., 1996), PM10 concentrations were measured and reported for an intersection in the city of Sacramento. This report complements that study by applying commonly used air dispersion modeling techniques to compare observed and predicted concentrations. Insight into the potential creation of PM10 "Hot-Spots" is also presented.

Intersection Configuration

The intersection study was located at Florin Road and Stockton Boulevard in the city of Sacramento and it is depicted in Figure 1.

Air Dispersion Model Inputs

The microscale air dispersion model CALINE4 (Benson, 1984) was used to predict PM10 concentrations. Actual runs were made with the CALINE4 Front-End version 1.1 (Garza, 1996). Information regarding the various inputs to the model is presented below.

Intersection Coordinates

For modeling purposes, a reference coordinate system was set up with its center coinciding with the center of the intersection. The x-axis was aligned exactly with Florin Rd. (i.e., east-west direction). Two links were used to model the intersection, one for Florin Rd and one for Stockton Blvd. Both links extended 150 m away from the center of the intersection for a total length of 300 m.

The coordinates of the link representing Stockton Blvd. were calculated as follows:

$$x_1 = 150 * \sin\theta;\ y_1 = -150 * \cos\theta;$$
$$x_2 = -150 * \sin\theta;\ y_2 = 150 * \cos\theta;$$

where θ is the angle between North and Stockton Blvd. (see Fig. 1) and was estimated to be 16 degrees. The width of each link was estimated as follows:

Florin Rd.
7 total lanes: 5 through lanes with a width of 4 m and 2 turning lanes with a width of 3 m.

Stockton Blvd.
6 total lanes: 4 through lanes with a width of 4 m and 2 turning lanes with a width of 3 m.

In addition 3 m were added on each side of the links to account for vehicle wake effects, as recommended in the CALINE4 User's Guide (Benson, 1984). A summary of link geometry inputs is given in Table 1.

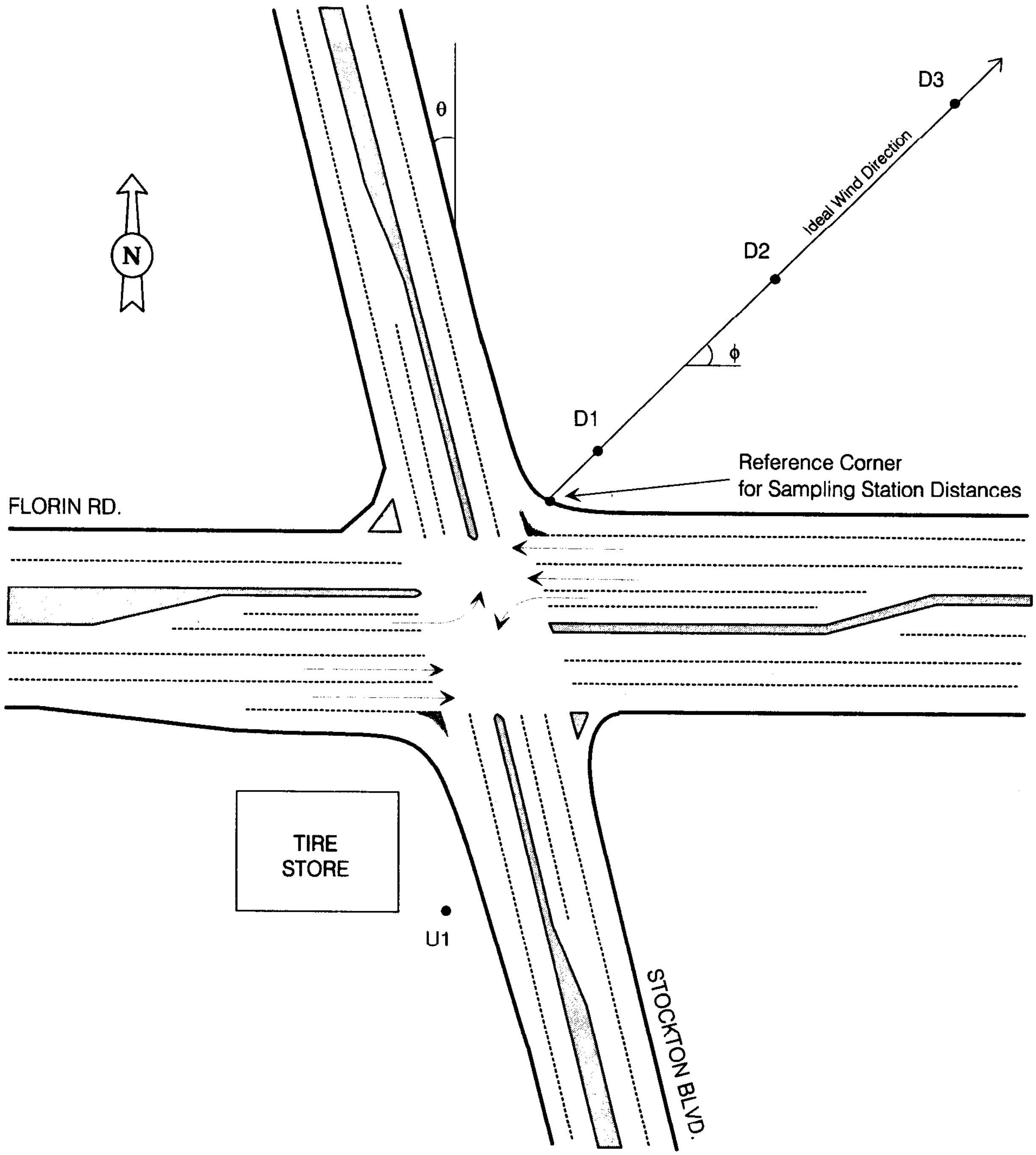

Figure 1. Schematic Diagram of Intersection at Florin Road & Stockton Boulevard.

Table 1. Summary of Link Geometry Inputs Used for CALINE4

Link Name	Start Point (m)	End Point (m)	Height (m)	Width (m)
FLORIN	(-150, 0)	(150, 0)	0	32
STOCKTON	(41.3, -144.2)	(-41.3, 144.2)	0	28

Monitoring Station Coordinates

The monitoring station locations were described in the Crocker Nuclear Lab report in terms of a reference corner (see Fig. 1) as being 9, 50, and 88.5 m away from it. In order to calculate the exact locations based on the coordinate system used to set up the links, the coordinates of the reference corner were calculated first as follows:

$$x_c = \frac{W_2 + d_2}{(\cos\theta)} - W_1 \tan\theta \qquad \text{and} \qquad y_c = W_1$$

where W_2 is half the width of Stockton Blvd. away from the center of the intersection, W_2+d_2 is the distance from the center of Stockton Blvd. to the reference corner measured perpendicular to Stockton Blvd., θ is the angle between North and Stockton Blvd., and W_1 is half the width of Florin Road.

And the station coordinates are then given by the following expressions:

$$x_{D1} = x_c + (9\,m)\cos\phi \qquad y_{D1} = y_c + (9\,m)\sin\phi$$
$$x_{D2} = x_c + (50\,m)\cos\phi \qquad y_{D2} = y_c + (50\,m)\sin\phi$$
$$x_{D4} = x_c + (88.5\,m)\cos\phi \qquad y_{D4} = y_c + (88.5\,m)\sin\phi$$

Setting phi to 45 degrees and using the reference corner coordinates, the station coordinates are:

x_{D1} = 18.3 m; y_{D1} = 19.4 m
x_{D2} = 47.3 m; y_{D2} = 48.4 m
x_{D4} = 74.5 m; y_{D4} = 75.6 m

Other Inputs

A summary of other general inputs used to run CALINE4 is given in Table 2.

Table 2. General Inputs (not link- or time-dependent) Used for CALINE4 Runs.

Parameter	Value or Comment
Molecular Weight	Any number different from zero. Not used for PM10 calculations. Normally used to convert units to ppm.
Settling Velocity	0 cm/s
Deposition Velocity	0 cm/s
Surface Roughness	100 cm
Altitude	200 m

Comparison between Observed & Predicted Concentrations

Actual conditions (traffic volume, meteorology) corresponding to each sampling period were used to compare observed and predicted concentrations. Traffic volume was assumed to be evenly distributed in all approach and departure segments of the intersection. Therefore, link traffic volume was obtained by dividing by two the average traffic volumes given in Crocker Nuclear Lab's report (Ashbaugh, 1996). A summary of inputs by sampling period is presented in Table 3.

Observed and predicted concentrations by sampling period are presented in Table 4. A few statistical measures were calculated to judge the performance of the model including: average bias, average absolute bias and fractional bias. The performance measures are presented in Table 5 and Table 6.

Average Residual (Bias)

The average residual, or bias, is defined by the average

$$Bias = \frac{1}{N}\sum_{i=1}^{N} d_i$$

where d_i is the residual defined as the observed concentration (C_0) minus the predicted concentration (C_p) for the ith data pair. The average residual is a measure normally used to judge the accuracy of model predictions in paired observations.

Absolute Average Residual (AAR)

The absolute average residual (or bias) is defined as:

$$AAR = \frac{1}{N}\sum_{i=1}^{N} |d_i|$$

and it is often used to judge the accuracy of model predictions in paired observations. Unlike the average residual, the AAR is not affected by offsetting effects of over- and underpredictions.

Fractional Bias (FB)

The fractional bias is defined as

$$FB = 2\left[\frac{\overline{C}_o - \overline{C}_p}{\overline{C}_o + \overline{C}_p}\right]$$

The fractional bias is a relation between averages and it does not provide any information about the goodness of the association in time or space. The fractional bias is often used to judge the capability of a model to match the highest observed concentrations. A fractional bias greater than 0.67 indicates that the average of the predicted values underestimated the average of the observed values by at least factor of two. Similarly, a fractional bias less than -0.67 indicates that the average of the predicted values overestimated the average of observed values by at least a factor of two.

Results show that the best match was obtained for monitors D11, D13 and D23. More importantly, the results clearly show that the worst match occurred for the monitor D1 at a height of 9 m, which might suggest that such monitor was influenced by an elevated source upwind.

Table 3. Summary of Meteorological Data, Background Concentration and Emission Factors by Sampling Period.

Period No.	Start Date	Start Time	End Time	Total Time (hr)	Avg Traffic (vph)	Avg WS (m/s)	Stability	Avg WD (deg)	Sigma Theta (deg)	Bkgnd ($\mu g/m^3$)	Avg EF (mg/VKT)	Avg EF (g/VMT)
1	8/23/95	12:00	16:00	4	3,838	2.53	B	234.9	15.8	32.4	109	0.1754
2	8/23/95	16:00	19:00	3	4,517	3.53	C-D	237.3	8.0	38.5	263	0.4232
3	8/23/95	19:00	06:00	11	1,536	2.44	E-F	200.4	25.0	21.6	189	0.3041
4	8/24/95	06:00	10:01	4	2,417	2.66	C-D	200.7	23.0	28.4	261	0.4199
5	8/24/95	11:43	16:00	4	3,897	2.98	B	237.7	12.0	36.9	198	0.3186
6	8/24/95	16:00	20:55	5	3,973	3.06	C-D	225.7	10.6	32.1	186	0.2993
7	8/24/95	20:55	05:56	9	1,064	2.20	E-F	182.7	13.8	26.3	184	0.2961
8	8/25/95	05:56	10:01	4	2,221	2.39	C-D	219.8	17.5	26.2	389	0.6259
9	8/25/95	11:07	15:58	5	4,093	2.80	B	232.0	12.8	29.7	150	0.2414
10	8/25/95	15:58	21:00	5	4,479	2.96	C-D	220.2	16.7	27.3	141	0.2269
11	8/25/95	21:00	05:56	9	1,294	2.47	E-F	189.3	8.3	19.6	127	0.2043
12	8/26/95	05:56	10:00	4	1,463	1.63	B-C	208.4	29.8	22.1	164	0.2639
13	8/26/95	11:01	16:06	5	3,694	1.71	B	280.6	52.8	25.2		
14	8/26/95	16:06	19:00	3	3,699	2.07	C-D	237.0	18.6	25.9	84	0.1352

Notes:

1. *WS=wind speed; WD=Wind Direction; EF=Emission Factor*
2. *Sampling period number 13 was not used because the wind direction variations were inappropriate for the analysis (see Ashbaugh, et al., 1996)*
3. *Stability class was estimated based on time of day (day/night), wind speed and, strength of incoming solar radiation. The higher stability (i.e., more stable one) was used for those periods where the estimated stability had a range.*

Table 4. Comparison Between Observed and Predicted PM10 Concentrations by Sampling Period.

Period	Start	Start	End	Observed Concentrations (μg/m3)					Predicted Concentrations (μg/m3)				
No.	Date	Time	Time	D1 (1 m)	D1 (3 m)	D1 (9 m)	D2 (3 m)	D4 (3 m)	D1 (1 m)	D1 (3 m)	D1 (9 m)	D2 (3 m)	D4 (3 m)
1	8/23/95	12:00	16:00	16.7	4.7	24.6	27.2	4.3	14.4	9.9	1.0	5.7	3.8
2	8/23/95	16:00	19:00	17.5	29.6	17.8	10.7	0.8	33.3	20.6	1.3	14.5	10.6
3	8/23/95	19:00	06:00	7.6	8.1	7.3	7.0	1.7	10.4	6.8	0.8	4.6	3.4
4	8/24/95	06:00	10:01	18.7	22.2	3.6	12.8	8.3	20.6	13.3	1.6	8.6	6.0
5	8/24/95	11:43	16:00	24.4	12.3	18.2	-4.9	2.0	23.7	15.8	1.6	9.4	6.2
6	8/24/95	16:00	20:55	17.5	11.6	10.1	6.2	1.4	22.4	13.8	0.5	9.7	7.2
7	8/24/95	20:55	05:56	7.5	7.0	5.0	3.2	0.6	8.2	5.8	1.3	3.0	1.9
8	8/25/95	05:56	10:01	26.9	16.3	4.9	1.1	6.4	30.7	20.3	1.3	13.9	10.2
9	8/25/95	11:07	15:58	14.2		6.4	2.5	1.8	19.4		1.0	7.8	5.3
10	8/25/95	15:58	21:00	12.7		0.5	3.1	0.2	19.1		0.6	8.4	6.1
11	8/25/95	21:00	05:56	7.4	1.8	4.2	4.5	2.7	6.3	4.3	0.7	2.8	1.7
12	8/26/95	05:56	10:00	14.5	4.7	3.9	2.7	5.2	10.6	7.8	1.2	4.7	3.3
13	8/26/95	11:01	16:06										
14	8/26/95	16:06	19:00	12.6	8.7	2.9	9.5	5.1	13.0	9.3	1.2	5.5	3.9
Average:				15.2	11.5	8.4	6.6	3.1	17.9	11.6	1.1	7.6	5.4

Table 5. Statistical Performance Measures by Sampling Period.

Period	Start	Start	End	Bias (μg/m3)					Absolute Bias (μg/m3)				
No.	Date	Time	Time	D1 (1 m)	D1 (3 m)	D1 (9 m)	D2 (3 m)	D4 (3 m)	D1 (1 m)	D1 (3 m)	D1 (9 m)	D2 (3 m)	D4 (3 m)
1	8/23/95	12:00	16:00	2.3	-5.2	23.6	21.5	0.5	2.3	5.2	23.6	21.5	0.5
2	8/23/95	16:00	19:00	-15.8	9.0	16.5	-3.8	-9.8	15.8	9.0	16.5	3.8	9.8
3	8/23/95	19:00	06:00	-2.8	1.3	6.5	2.4	-1.7	2.8	1.3	6.5	2.4	1.7
4	8/24/95	06:00	10:01	-1.9	8.9	2.0	4.2	2.3	1.9	8.9	2.0	4.2	2.3
5	8/24/95	11:43	16:00	0.7	-3.5	16.6	-14.3	-4.2	0.7	3.5	16.6	14.3	4.2
6	8/24/95	16:00	20:55	-4.9	-2.2	9.6	-3.5	-5.8	4.9	2.2	9.6	3.5	5.8
7	8/24/95	20:55	05:56	-0.7	1.2	3.7	0.2	-1.3	0.7	1.2	3.7	0.2	1.3
8	8/25/95	05:56	10:01	-3.8	-4.0	3.6	-12.8	-3.8	3.8	4.0	3.6	12.8	3.8
9	8/25/95	11:07	15:58	-5.2		5.4	-5.3	-3.5	5.2		5.4	5.3	3.5
10	8/25/95	15:58	21:00	-6.4		-0.1	-5.3	-5.9	6.4		0.1	5.3	5.9
11	8/25/95	21:00	05:56	1.1	-2.5	3.5	1.7	1.0	1.1	2.5	3.5	1.7	1.0
12	8/26/95	05:56	10:00	3.9	-3.1	2.7	-2.0	1.9	3.9	3.1	2.7	2.0	1.9
13	8/26/95	11:01	16:06										
14	8/26/95	16:06	19:00	-0.4	-0.6	1.7	4.0	1.2	0.4	0.6	1.7	4.0	1.2
Average:				-2.6	-0.1	7.3	-1.0	-2.2	3.8	3.8	7.3	6.2	3.3

Table 6. Fractional Bias by Monitor.

Monitor	Fractional Bias (FB)
D1 (1 m)	-0.16
D1 (3 m)	-0.01
D1 (9 m)	1.54
D2 (3 m)	-0.14
D4 (3 m)	-0.53

Estimating Percentage of Under/Over-Prediction

The average amount of overprediction by the model compared to the observed concentrations was calculated based on concentration averages close to (or equal to) a 24-hr average. Using a 24-hr average to calculate the level of overprediction is more appropriate than using the average of the sampling period because one is ultimately interested in comparing it to the 24-hr PM10 standard. Therefore, in order to estimate the average overprediction, 24-hr averages had to be calculated first. A running 24-hr average was calculated using the observed concentrations at monitor D1 at a height of 1 m, starting with sampling period 1 and ending with period 12. The results are shown in Table 7.

Table 7. Approx. 24-hr Avg. PM10 Concentration in (μg/m^3) Based On Observed Values at Monitor D1 at 1-m height.

Averaging Period	From Period	To Period	Avg. Traffic Volume (vph)	PM10 Conc. Without Background	PM10 Conc. With Background
22	1	4	2521	12.62	39.73
22	2	5	2532	14.02	41.95
24	3	6	2584	14.31	41.78
22	4	7	2486	14.88	44.81
22	5	8	2451	16.37	45.90
23	6	9	2556	14.50	42.79
23	7	10	2666	13.46	40.70
23	8	11	2756	13.42	38.04
23	9	12	2624	11.27	35.17
Average			2575	13.87	41.21

A similar procedure of calculating 24-hr running averages was followed using the CALINE4-predicted concentrations for the same monitor at the same height over the same period. The results, including the average overprediction, are shown in Table 8.

Estimating PM10 concentrations for unfavorable wind direction

At a particular site, the highest concentrations of PM10 are likely to occur under unfavorable meteorological conditions. In this study, PM10 concentrations were calculated using CALINE4 under the most unfavorable wind direction during a 24-hr period, keeping all other meteorological variables (wind speed, stability, sigma theta) at their measured level. Use of the most unfavorable wind directions may not represent the worst possible condition but should, nonetheless, provide a "rough" estimate of how unfavorable meteorology would affect PM10 concentrations. Results for the aforementioned scenario are shown in Table 10. Predicted PM10 concentrations were corrected to account for the estimated average overprediction. The procedure for determining the average overprediction was explained in the previous section of this report.

Potential Existence of Hot-Spots at Other Intersections

PM10 concentration levels at any given site, used for comparison to the PM10 standard to determine whether there is an exceedance, are calculated as the sum of two concentrations: the background and the site contribution. Exceedances are largely dependent on the background concentration level. Some insight is provided in this section regarding the site (or project) contribution to the total PM10 concentration for intersections having different traffic volumes.

Concentrations of PM10 decrease with distance from the source. Results are presented for receptors located at varying distances from the intersection. Figure 2 shows the contribution of an intersection to the 24-hr avg. PM10 concentration as a function of the 24-hr avg. traffic volume.

Table 8. Approx. 24-hr Avg. PM10 Concentration in ($\mu g/m^3$) Based on Predicted Values at Monitor D1 at 1-m Height.

Averaging Period	From Period	To Period	PM10 Conc. Without Background	Overpred. (%)	PM10 Conc. With Background
22	1	4	16.10	27.6	43.21
22	2	5	17.80	26.9	45.72
24	3	6	16.82	17.5	44.29
22	4	7	16.50	10.9	46.43
22	5	8	18.34	12.0	47.86
23	6	9	17.63	21.6	45.92
23	7	10	16.92	25.7	44.16
23	8	11	16.17	20.5	40.79
23	9	12	12.68	12.5	36.58
Average				19.5	

Table 9. Approx. 24-hr Avg. PM10 Concentration in ($\mu g/m^3$) for the "Most Unfavorable" Wind Direction Based on Predicted Values at Monitor D1 at 1-m Height.

Averaging Period	From Period	To Period	PM10 Conc. Without Background	Corrected PM10 Conc. Without Background
22	1	4	17.15	14.35
22	2	5	19.00	15.90
24	3	6	17.87	14.95
22	4	7	17.88	14.96
22	5	8	20.13	16.85
23	6	9	19.37	16.21
23	7	10	18.33	15.34
23	8	11	17.67	14.78
23	9	12	13.72	11.48
Average=				14.98

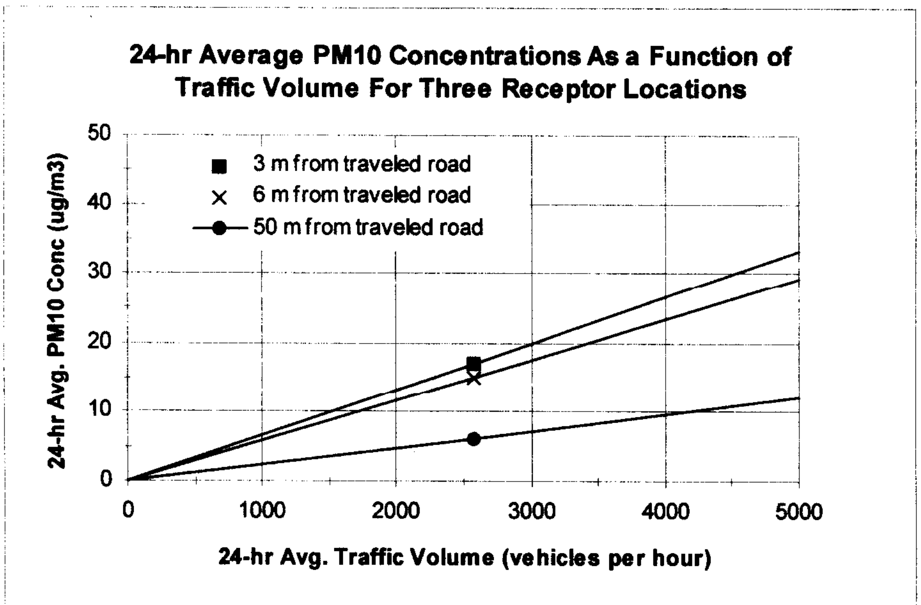

Figure 2. 24-hr Average PM10 Concentrations As a Function of Traffic Volume.

Caution is advised in the use and interpretation of the results provided above. Namely the following considerations should be kept in mind:

- Concentration levels were assumed to be directly proportional to traffic volume and the plots were prepared using only two points including the one at (0,0).

- Strictly, the results are only valid for intersections having similar traffic volume distributions in time (e.g., peak and off-peak activity) as those observed at the Florin Rd. & Stockton Blvd. intersection.

- Strictly, the results are only valid for sites exhibiting similar meteorological conditions as those observed at the Florin Rd. & Stockton Blvd. intersection.

- The results represent a condition of most unfavorable wind direction for a 24-hr period; such condition may or may not be representative of the worst-case meteorological condition at the site.

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