TRAFFIC AIR POLLUTION EFFECTS OF ELEVATED, DEPRESSED, AND AT-GRADE LEVEL FREEWAYS IN TEXAS

by

Michael Nikolaou
Associate Professor of Chemical Engineering
Texas Transportation Institute

Jesse L. Buffington
Research Economist
Texas Transportation Institute

Angel Herrera, Jr.
Graduate Research Assistant
Texas Transportation Institute

and

Hwang Inkeuk
Graduate Research Assistant
Texas Transportation Institute

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IMPLEMENTATION STATEMENT

The findings of this study can be used by TxDOT to improve its procedures for estimating and evaluating traffic related air pollution generated from proposed elevated, depressed, and at-grade level freeways. The study findings support the continued use of the CALINE computer estimating models with minor modification. Carbon monoxide (CO), one of the primary traffic air pollutants, was chosen to evaluate these models. CO dispersion rates measured at selected study locations were modelled by the CALINE model, which generated predicted values to be compared with actual values. This program was primarily developed to estimate at-grade air pollution levels. However, the model does have “cut” and “bridge” options, for freeway sections with over- or underpasses. The study findings can be implemented immediately to be presented at public hearings and to prepare environmental impact statements.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented within. The contents do not necessarily reflect the views or policies of the Texas Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation. It is not intended for construction, bidding, or permit purposes. The report was prepared by Michael Nikolaou, associate professor of chemical engineering, Angel Herrera and Hwang Inkeuk, graduate research assistants, and Jesse L. Buffington, research economist.

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Summary

The effects of elevated and depressed freeways on air quality were experimentally studied, as part of a broader study on the social, economic, and environmental effects of elevated and depressed freeways (Study No. 2-18D-93-1327). Carbon monoxide (CO) concentrations were measured in the vicinity of a number of elevated, depressed, and at-grade freeway sites in Dallas, Lubbock, Houston, and San Antonio. Traffic and meteorological measurements were also taken and used as inputs to standard computer models that predict CO concentration near at-grade freeways. Comparisons between model predictions and measurements suggest that no substantial air quality deterioration is evident near depressed freeways. Moreover, elevated freeways seem to result in slightly lower CO concentration levels in their vicinity, a fact supported by earlier experimental and theoretical studies conducted by other investigators.

Because of resource limitations, data were collected by one person, one site at a time. While the evidence provided by our studies is strong, we feel that a more thorough study would provide even more conclusive evidence, as follows: Data should be *simultaneously* collected on elevated, depressed, and at-grade sections of the same freeway. Provided that these freeway sections are not far apart from each other (so that traffic, landscape, and wind patterns could be the same), any differences in CO levels in the vicinity of each section of the freeway would be attributed to its configuration as elevated, depressed, or at-grade. Comparison with mathematical models would be useful but not necessary. In fact, correction factors could be developed for existing models, to account for more accurate predictions for elevated or depressed freeway sections. This kind of simultaneous collection of data at three locations of a freeway would require additional equipment (10 additional CO sensors and two additional weather stations) and personnel (two additional workers).

INTRODUCTION

STUDY PROBLEM STATEMENT

The Texas Department of Transportation (TxDOT) is continually upgrading the existing highway system in the state, especially in urban and suburban areas. These upgrades involve improving existing highways or freeways on the existing route or on a new route paralleling the old route or bypassing the central city. Such freeway improvements are made at varying grade levels, i.e., at-grade, elevated grade, and depressed grade, depending on the terrain, land use, and other factors. The choice of grade level at a particular point may be an attempt to mitigate negative noise and aesthetics impacts on a residential neighborhood. The current trend in design is toward elevated and depressed sections to gain additional lanes. The elevated sections may be either earthen or bridge in form. Many sections of each type of grade level have been built over the years since the late 1950's. Many are over 20 years old. However, quite a few sections have been built during the last 5 to 10 years, and some sections are either under construction or in the planning stages.

Even though many sections of elevated and depressed freeways have been built over the years in the state, more and more, abutting or nearby residents and businesses are raising questions about the possible negative impacts of such freeways. In recent years, stiff resistance has been given to the proposed elevated section of the Dallas North Central Expressway and more recently to the proposed elevated or depressed section of U. S. Highway 287 in Wichita Falls. Also, the elevated sections of U. S. Highway 183 now under construction in Austin have caused similar concerns.

Any highway improvement, regardless of grade level, not only impacts users but also impacts abutting and nearby property owners, businesses, and residents in some manner. Even the whole city or community is impacted in some way during and after construction. Elevated and depressed freeway designs raise particular questions concerning noise and air quality impacts, but vibration in moving vehicles and in structures adjacent to the freeway and flooding of depressed freeways are additional concerns. The recent flooding of a depressed section of IH 10 in Houston dramatized the latter problem. Soil erosion, at the point of drainage discharge, can cause a problem. Last, aesthetic qualities of elevated and depressed sections are matters that must be considered.

Impacts that result from elevated and depressed freeway improvements can be classified into three major types: (1) social, (2) economic, and (3) environmental. A partial list of the specific impacts of each of the major types is given below. The social impacts are population changes, neighborhood accessibility, neighborhood cohesion, and community services. The economic impacts are relocation and mitigation costs, business sales, land uses and proper values, tax revenues, employment and income, and user costs. The environmental impacts are aesthetics, drainage and erosion, air quality, noise and vibration, and hazardous spills.

A preliminary search of the literature reveals very few case studies that have measured many of the social, economic, and environmental impacts of depressed and elevated freeways, especially those in Texas. Therefore, the highway decision-makers have very little relevant impact data to include in environmental assessment statements as support and to present at public hearings for proposed elevated and depressed sections of existing or proposed freeway.

STUDY OBJECTIVES

The general objective of the study is to determine the social, economic, and environmental effects of elevated and depressed freeways in urban and suburban areas. The more specific objectives of the study are as follows:

- Determine the appropriate estimating procedures or models and mitigation measures to be used in this study to estimate the social, economic, and environmental effects of elevated and depressed freeways.
- Estimate the social, economic, and environmental effects of several existing, contracted, and proposed elevated, and depressed freeway sections situated in urban areas in Texas and recommend a final set of impact estimating procedures for use by TxDOT.

Specifically, the primary objectives of this project are to aid in the preparation of more accurate environmental impact statements and enable better prediction of air pollution near elevated and depressed roadways. These objectives entail the following tasks:

- Collect data, including all the required parameters suitable for use in improving model performance in the future.
- Establish the validity or refine the structure of CALINE and TXLINE impact prediction programs when dealing with elevated and depressed roadways.

SELECTION OF FREEWAY STUDY SECTIONS

At the beginning of this study, a survey was conducted of all of TxDOT's districts to locate all of elevated and depressed freeway sections at least 0.805 kilometers (one-half mile) long that were planned, under construction, or constructed during the last 10 years. (A copy of the survey form appears in Appendix A.) Also, the survey asked TxDOT to indicate the location (downtown or suburban), abutting land use, and age (less than five years or more than five years) of each qualifying freeway section. Later, the project team determined whether each freeway section was on an existing highway route or a new location. These were considered primary characteristics to be used in selecting the freeway study sections.

A total of 30 freeways (11 elevated and 19 depressed) were identified and reported by the TxDOT districts. Of those 30, 12 (six elevated and six depressed) were planned; three (one elevated and two depressed) were under construction; and 15 (four elevated and 11 depressed) were recently constructed. Each of the 30 candidate study sections was personally inspected by TTI researchers accompanied by a TxDOT district official.

With the help of TxDOT's study panel members, a total of 11 freeway section sections were selected for study. Of those selected, two (one elevated and one depressed) were planned; two (one elevated and one depressed) were under construction; and seven (three elevated and four depressed) were built. Of the seven already built, three (two elevated and one depressed) were less than four years old and four (one elevated and three depressed) were over four years old.

LOCATION AND CHARACTERISTICS OF STUDY FREEWAY SECTIONS

Table 1 shows the selected study sections and their type of grade level, location, abutting land use, and age. As can be seen, the project team attempted to have a fairly good mix of study sections representing different types of location, stages of construction, and ages and land uses for each of the study grade levels.

The 11 study sections are located in four Texas cities: one depressed section on U.S. Highway 75 in Dallas; one depressed section on the Sam Houston Tollway in Houston; and four sections in Lubbock. Two of these were located on IH 27 (one elevated and one depressed) and two are located on the planned East-West Freeway (U.S. Highways 62/82), one elevated and one depressed.

Figures 1 through 4 show the specific location of the study sections within Dallas, Houston, Lubbock, and San Antonio, respectively.

Tables 2 and 3 show other important characteristics of each study section by study grade level. Some of these characteristics were used in evaluating the different impacts considered under this study.

Table 1. Freeway Sections Selected for Study by Type of Grade Level Design and Key Characteristics

Type of Design/ Number/Status	City & Highway Type/Number	Route Location	Section Location	Abutting Land Use
Elevated Sections				
No. 11-Planned	Lubbock-U.S. 62/82	Existing	Suburban	Residential/ Commercial
No. 8-Built Under 4 Yrs	Lubbock-IH 27	New	Downtown	Commercial/ Industrial
Depressed Sections				
No. 10-Planned	Lubbock-U.S. 82	Existing	Downtown	Commercial/ Public/ Residential
No. 7-Under Construction	Dallas-U.S. 75	Existing	Downtown & Suburban	Commercial/ Residential
No. 9-Built Under 4 Yrs	Lubbock-IH 27	New	Suburban	Residential/ Commercial
No. 5-Built Under 4 Yrs	San Antonio-U.S. 281	Existing	Suburban	Vacant/ Residential/ Commercial
No. 1-Built Over 4 Yrs[1]	San Antonio-IH 35	Existing	Downtown	Residential/ Commercial
No. 6-Built Over 4 Yrs	Houston-Beltway 8	New	Suburban	Residential/ Commercial
Combination Elevated & Depressed Sections				
No. 2-Built Under 4 Yrs	San Antonio-IH 35	Existing	Downtown	Residential/ Commercial
No. 3-Built Under 4 Yrs	San Antonio-IH 10	Existing	Downtown	Residential/ Commercial
No. 4-Built Over 4 Yrs	San Antonio-IH 10/35	Existing	Downtown	Commercial/ Industrial

[1]There was no basic grade level change in this section, but it is adjacent to a new elevated/depressed section having feeder ramps that extend into this section.

Figure 1. Location of the Study Section 7 on U.S. Highway 75 (Central Expressway) near Downtown Dallas

Figure 2. Location of Study Section 6 on the Sam Houston Tollway in Southwestern Part of Houston

Figure 3. Location of Study Sections 1-5 on IH 10, 10/35, 35 and U.S. Highway 281 in San Antonio

Figure 4. Location of Study Sections 8-11 on IH 27 and U.S. Highways 62/82 (Proposed East-West Freeway) in Lubbock

Table 2. Study Freeway Sections by Age, Grade Level Before, Length, Grade Level Depth, Right-of-Way Width, Type of Mainlane Access, and ADT

STUDY NO./ TYPE OF GRADE LEVEL AFTER CONSTRUCTION	AGE AFTER (yrs)	GRADE LEVEL BEFORE	LENGTH AFTER km (mi)	GRADE LEVEL HEIGHT/DEPTH m (ft)		RIGHT-OF-WAY WIDTH m (ft)		TYPE OF ACCESS TO MAIN LANES		ADT	
				BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER
Elevated/Combination Elevated & Depressed											
No. 2 IH 35-San Antonio	1	depressed	2.01 (1.25)	-4.6 (-15)	+6.1 (+20)	64.0 (210)	70.7 (232)	full	limited	75,600	188,300
No. 3 IH 10-San Antonio	3	depressed	2.96 (1.84)	0 (0)	+6.1 (+20)	65.5 (215)	74.7 (245)	limited	limited	94,100	198,500
No. 4 IH 10/35-San Antonio	6	elevated/ depressed	2.28 (1.42)	+6.1 (+20)	+6.1 (+20)	61.0 (200)	76.2 (250)	limited	limited	79,800	186,500
No. 8 IH 27-Lubbock	3	at-grade	3.02 (1.88)	0 (0)	5.5 (+18)	38.1 (125)	121.9 (400)	full	limited	42,352	77,350
No. 10 U.S.H. 62/82-Lubbock	0	at-grade	2.32 (1.44)	0 (0)	+6.4 (+21)	53.6 (176)	97.5 (320)	full	limited	22,493	52,533
Depressed											
No. 6 Sam Houston Beltway-Houston	6	at-grade	2.09 (1.30)	0 (0)	-5.2 (-17)	91.4 (300)	91.4 (300)	full	limited	84,000	168,000
No. 7 U.S.H. 75-Dallas	0	at-grade	6.47 (4.02)	0 (0)	-6.7 (-22)	67.1 (220)	85.3 (280)	limited	limited	155,000	217,700
No. 9 IH 27-Lubbock	3	at-grade	4.84 (3.01)	0 (0)	-5.2 (-17)	38.1 (125)	121.9 (400)	full	limited	42,356	77,350
No. 11 U.S.H. 62/82-Lubbock	0	at-grade	2.56 (4.12)	0 (0)	-6.7 (-22)	53.7 (176)	102.1 (335)	full	limited	22,656	34,483
No. 1 IH 35-San Antonio	10	depressed	2.22 (1.38)	-4.6 (-15)	-4.6 (-15)	91.4 (300)	91.4 (300)	limited	limited	50,000	150,000
No. 5 U.S.H. 281-San Antonio	5	at-grade	2.85 (1.77)	0 (0)	-6.4 (-21)	91.4 (300)	91.4 (300)	full	limited	12,700	94,000

Table 3. Study Freeway Sections by Number of Structures, Crossing Streets, Mainlanes, On Ramps, and Off Ramps

STUDY NO./ TYPE OF GRADE LEVEL AFTER CONSTRUCTION	STRUCTURES (NUMBER)		CROSSING STREETS (NUMBER)		MAIN LANES (NUMBER)		ON RAMPS (NUMBER)		OFF RAMPS (NUMBER)	
	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER
Elevated/Combination Elevated & Depressed										
No. 2 IH 35-San Antonio	11	12	11	11	4	10	4	8	6	8
No. 3 IH 10-San Antonio	9	11	6	6	4	10	3	6	5	6
No. 4 IH 10/35-San Antonio	6	8	8	8	6	10	4	6	4	3
No. 8 IH 27-Lubbock	2	6	21	6	4	6	0	4	0	3
No. 10 U.S.H. 62/82-Lubbock	2	4	5	3	4	6	0	3	0	3
Depressed										
No. 6 Sam Houston Beltway-Houston	0	3	7	3	4	6	0	2	0	2
No. 7 U.S.H. 75-Dallas	13	14	13	13	4	8	16	5	16	5
No. 9 IH 27-Lubbock	0	7	11	4	4	6	0	2	0	2
No. 11 U.S.H. 62/82-Lubbock	4	21	22	15	4	6	0	8	0	8
No. 1 IH 35-San Antonio	9	9	7	7	6	6	3	3	3	3
No. 5 U.S.H. 281-San Antonio	1	2	2	2	4	6	0	3	0	3

TYPICAL CROSS-SECTIONAL DESIGN OF STUDY FREEWAY SECTIONS

Figures 5 through 9 show the typical cross-sectional designs of the study freeway sections. There are some variations in cross-sectional design through each study section, depending on the specific location. For instance, only one of the cross-sections show the on and off ramp designs or the variation in the number of main lanes or frontage road lanes throughout the study section.

GENERAL METHODOLOGY AND DATA SOURCES

The general methodology planned for this study was to conduct a "before and after" construction period comparative analysis over time, supplemented with a cross-sectional analysis of one point in time. The eight completed freeway study sections lend themselves easily to both analyses. The three others can be used to provide current before and/or construction period data to supplement these analyses. For instance, the two study sections still under construction, at the time of selection, can be used to study some of the construction effects of each grade level. The two planned study sections can be used to estimate anticipatory effects by grade level.

The "before and after" analysis can compare the elevated freeway sections with depressed freeway sections to ascertain any significant differences in various types of impact elements, i.e., air pollution, noise pollution, business activity, neighborhood cohesion, etc. The "one point in time" analysis can compare current level unit values of each impact element to determine significant differences between elevated and depressed freeway grade levels. Using either analytical approach, one can compare elevated study sections with depressed study sections and also compare these two grade levels with adjacent or nearby at-grade level sections. The at-grade sections, when available, can serve as a control or base section.

Sources of data used in the study ranged from a review of the literature to "on-site" data collection. The prior studies found in the literature, as well as data obtained from a national survey of state transportation agencies, helped determine the different methodologies used in the study.

The data obtained to estimate the effects of the different impact elements came from the literature, a national survey, the United States Census Bureau, the Texas State Comptroller and Employment Commission, TxDOT, Environmental Impact Statements (EIS) of each of the study sections, city criss-cross directories, site surveys of businesses and residents, traffic volumes and composition, air and noise levels, and drainage, erosion, and other environmental conditions.

REPORTS OF FINDINGS

Since this study involves the study of many different impact elements, the findings are presented in several reports by type of impact. The reports are as follows:

- Research Report 1327-1: Social and Economic Effects of Elevated and Depressed Freeways in Texas
- Research Report 1327-2: Land Value and Use Effects of Elevated and Depressed Freeways in Texas
- Research Report 1327-3: Noise Pollution Effects of Elevated and Depressed Freeways in Texas
- Research Report 1327-4: Air Pollution Effects of Elevated and Depressed Freeways in Texas

- Research Report 1327-5: Drainage, Erosion, Hazardous Spill, and Vibration Effects of Elevated and Depressed Freeways in Texas
- Research Report 1327-6F: Social, Economic, and Environmental Effects of Elevated and Depressed Freeways in Texas

Research Report 1327-1 contains a summary of the findings from the national survey of state transportation agencies and the Texas survey of TxDOT districts, and a description of the cities and areas of the cities where the freeway study sections are located. This report, Research Report 1327-4, contains the findings on the effects of elevated and depressed freeways on air pollution.

U. S. Highway 75 Section #7, Dallas

Sam Houston Tollway Section #6, Houston

Figure 5. Typical Cross-sectional Design of Depressed Study Sections on U. S. Highway 75 in Dallas, Texas, and Sam Houston Tollway in Houston, Texas

Elevated Section #10

Depressed Section #11

Figure 6. Typical Cross-sectional Design of the Depressed and Elevated Study Sections on the Planned East-West Freeway in Lubbock, Texas

Elevated Section #8

Depressed Section #9

Figure 7. Typical Cross-sectional Design of the Elevated and Depressed Study Sections on the IH 27 in Lubbock, Texas

IH 35 Section #1

IH 35 Section #2

IH 10 Section #3

Figure 8. Typical Cross-sectional Design of the Combination Elevated/Depressed Study Sections on IH 10 and IH 35 in San Antonio, Texas

IH 35 Section #4

U.S. Highway 281 Section #5

Figure 9. Typical Cross-sectional Design of the Depressed Study Sections on U.S. Highway 281 and IH 35 in San Antonio, Texas

BACKGROUND AND LITERATURE REVIEW

A pollutant dispersion model first requires an estimate of the source strength. Emissions models based on regional vehicle scenarios are used. Next, the pollutant's atmospheric dispersion is modeled by Gaussian dispersion or a gradient transport model. Finally, comparison to an existing database determines the model's accuracy.

THE NEED FOR POLLUTION ASSESSMENT NEAR ROADWAYS

According to the National Environmental Policy Act of 1969, environmental impact statements must be submitted before any major roadway construction project is begun. This statement is reviewed by the Federal Highway Administration (FHA), the Environmental Protection Agency (EPA), the Texas Department of Transportation (TxDOT), and the Texas Natural Resources Conservation Commission (TNRCC). This report must predict pollutant concentrations in the microscale and mesoscale regions around the roadway over 20 years for at least two options: (1) undertaking the proposed project and (2) not undertaking the proposed project.

The primary pollutants produced by internal combustion engines are carbon monoxide (CO), nitrogen oxides (NO_X), hydrocarbons (HC), lead (Pb), and particulate matter. The principle secondary pollutant of concern is ozone (O_3), which forms in the presence of sunlight and the primary pollutants. The major variables affecting downwind pollutant concentration are distance from emission source, source strength, wind speed, wind direction, atmospheric and induced turbulence, and mixing layer height.

Many mathematical models have been developed to aid in the prediction of pollutant concentrations near roadways (TXLINE 2, CALINE 3 & 4) and at intersections (TEXIN 2, IMM). Constructing a dispersion model consists of first estimating the emissions from the motor vehicles on the roadway and then applying dispersion principles, with local meteorology and topography, to predict downwind concentrations at a given receptor.

Modeling pollutant dispersion is complicated and relies on many hours of experimental data. Concentrations at different receptors upwind and downwind of the roadway are recorded along with corresponding weather conditions, traffic measurements, and roadway topography. Then, databases are used to derive empirical relations in the dispersion models when analytical solutions prove insufficient to describe actual conditions or their mathematics become too complex.

Current trends in city planning favor the construction of elevated and depressed roadways over at-grade roadways to relieve congestion in crowded areas. The most popular of the impact prediction programs (CALINE 3 & 4) are designed for use with at-grade systems—although CALINE 4 has "cut" and "bridge" options—and assume a smooth terrain surrounding the roadway. This study intends to determine the validity of using current impact prediction models when dealing with elevated and depressed roadways.

DETERMINATION OF SOURCE STRENGTH

Atmospheric dispersion models require estimation of source strength. This is easily accomplished for stationary sources, but is difficult for motor vehicles. EPA exhaust emission studies have resulted in several emission models. These are briefly described below.

AP-42

The EPA has developed standard driving sequences to represent urban emissions. The basis for existing and projected mobile source emission factors comes from Federal Test Procedures (FTP) and Surveillance Driving Sequences (SDS) data combined with assembly line and prototype model information, in use vehicle tests, tampering surveys, and technical judgment (AP-42, 1975).

Modal Analysis Model

The Automotive Exhaust Emission Modal Model was developed to estimate light-duty vehicle emissions for CO, HC, and NO_X over any specified driving sequence. The model is based on SDS emissions data for 32 various driving conditions. The SDS investigated transient and steady-state operating modes. Acceleration and deceleration modes were 32 possible combinations of the following speeds: 0, 15, 30, 45, and 60 mph. Of these speeds, 32 modes were characterized by average, constant acceleration, and speed, while 5 steady-state modes completed the sequence.

The Modal Analysis Model expands the emissions for the 32 modes into a continuous function of time. Emission rates for all possible combinations of speed and acceleration may be determined. The analyst may estimate rates for CO, HC, and NO_X, provided the speed and acceleration ranges are spanned by the model data.

Mass Balance Technique

Pollutant emission factors for a nonreactive species may be calculated using concentration profiles at a downwind receptor. This technique was first investigated with Texas Transportation Institute (TTI) Project 218 Air Quality Data.

The procedure requires numerical integration of the concentration fluxes passing a downwind receptor. The method assumes both concentration and mass flux are a function of height only along any plane parallel to the roadway. The integrated area is then used in conjunction with traffic volumes to obtain a composite vehicular emission factor.

The mass balance technique suffers two disadvantages: (1) the emission factor may only be calculated for existing roads, and (2) the analyst must have accurate air quality, traffic, and meteorological data to estimate the emission rate. This method, however, allows a valid comparison to be made between mathematical models and actual air quality data.

EPA MOBILE Models

The U.S. Environmental Protection Agency has issued a series of mobile source emission models, known as the MOBILE series. As of the time of this project, the current version of the series is MOBILE 5A. The MOBILE models (U.S. EPA, 1984; 1994) predict the emission rates of hydrocarbons (HC), carbon monoxide (CO), and nitrogen oxides (No_X) for motor vehicles. The model calculates emission factors for eight different vehicle types in low and high altitude regions. The program estimates emission data for any calendar year between 1960 and 2020. MOBILE 3 emission factors depend on ambient temperature, vehicle speed, mileage accrual rates, registration distribution, emission control tampering, and factors like trailer towing and air-conditioning usage. Calculation procedures used by MOBILE 3 are presented in EPA publication AP-42. MOBILE 5 includes most of the adjustments required by the Clean Air Act Amendments of 1990.

TEXAS-II

Lee et al. (1977) developed TEXAS-II exclusively to predict pollutant emissions as well as the amount of fuel consumed by a vehicle passing through an intersection environment. The model calculates traffic behavior at intersections and applies the information to a quantitative evaluation of emissions and fuel consumption. The model uses the following factors to determine emission data: (1) intersection size, (2) presence of special left turn lane, (3) pretimed signal control, (4) fully activated signal control, (5) all-way stop sign control, (6) traffic volumes, (7) left turns, and (8) heavy duty vehicles.

MODELING POLLUTANT DISPERSION NEAR ROADWAYS

Common dispersion models use one or more of the following approaches: (1) gradient transport approach, (2) statistical approach, (3) similarity approach, and/or (4) empirical approach. Pasquill (1974) stated that the gradient transport approach is a mathematical development of a particular physical model of mixing. The statistical approach models the turbulent flow of material near the roadway in terms of statistical properties of motion. The similarity approach formulates postulations regarding the physical parameters controlling diffusion. Dimensional analysis is then used to relate those parameters to the dispersion process. The empirical approach develops correlations between concentration and a set of measured variables such as wind speed and direction.

Nearly all roadway dispersion models use some form of the gradient transport approach, along with empirical adjustments based on experimental data. Current models usually differ in the assumptions used to solve the diffusion equations and the amount of empiricism incorporated into the calculation procedure. This review is concerned with gradient transport models only, so the reader is referred to Pasquill (1974), Sutton (1953), or Hanna, et al. (1982) for review of other dispersion schemes.

General Atmospheric Diffusion

The basis for most gradient diffusion studies is the convective diffusion equation (Seinfeld, 1986):

$$\frac{\partial C}{\partial t} + u\frac{\partial C}{\partial x} + v\frac{\partial C}{\partial y} + w\frac{\partial C}{\partial z} = S + \frac{\partial}{\partial x}\left(K_x \frac{\partial C}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y \frac{\partial C}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_z \frac{\partial C}{\partial z}\right) \tag{1}$$

where

S = effects from all internal sources
C = concentration
t = time
x, y, z = directions in the Euclidean coordinate system
u, v, w = wind velocity components in the x, y, z directions, respectively
K_x, K_y, K_z = eddy diffusivities in the x, y, z directions, respectively.

Equation (1) may be termed a continuity equation for pollutants in the atmosphere. Treybal (1955) derives such equations from the general continuity equation.

Analytical solutions of equation (1) employ several simplifying assumptions. For example, assuming (a) time independence, (b) no net wind in the z-direction (w=0), (c) perpendicular wind (x-direction) advection dominates diffusion in the downward direction ($u\frac{\partial C}{\partial x} >> \frac{\partial}{\partial x}\left(K_x \frac{\partial C}{\partial x}\right)$), and (d) Fickian diffusion, then equation (1) becomes:

$$u\frac{\partial C}{\partial x} = S + K_y \frac{\partial^2 C}{\partial y^2} + K_z \frac{\partial^2 C}{\partial z^2} \tag{2}$$

Because eddy diffusivities K_i are not readily available, Gaussian solutions to the diffusion equation were proposed. Cramer (1959) tested the following form of the Gaussian equation using data from Calder (1949) and Barad (1971):

$$C = \frac{Q}{2\pi\sigma_y\sigma_z\bar{u}}\exp\left[-\frac{1}{2}\left(\frac{y^2}{\sigma_y^2} + \frac{z^2}{\sigma_z^2}\right)\right] \tag{3}$$

where

Q = source strength

σ_y, σ_z = standard deviations of concentration distribution in y, z directions, respectively

$\bar{u}$ = constant average wind speed.

Gifford (1976) modified a set of dispersion curves originally presented by Pasquill to predict the standard deviations as a function of downwind distance and atmospheric stability. These "Pasquill-Gifford" curves are routinely used in the estimation of σ_y, σ_z for Gaussian dispersion models.

Sutton (1953) presented an argument for modifications to the Gaussian dispersion equations based on the ground being impervious to the pollutant. This led to the variable source height solution:

$$C = \frac{Q'}{\sqrt{2\pi}\sigma_z\bar{u}}\left\{\exp\left[-\frac{1}{2}\left(\frac{z-h}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z+h}{\sigma_z}\right)^2\right]\right\} \tag{4}$$

where

Q' = line source strength per unit length

h = source height.

Most existing atmospheric models use some form of equation (4) to model pollutant dispersion. The models used in this work were CALINE 3 and 4, developed by Benson (1984) for the California Department of Transportation, and TXLINE 2, originally developed at TTI in 1980.

COLLECTION OF EXPERIMENTAL DATA BASES

Development of accurate vehicle dispersion models depends on reliable databases. Data must include (1) meteorological conditions, (2) traffic volumes, and (3) pollutant concentrations. Below is a brief description of some of the major databases available. Additional references can be found in Hlavinka (1995).

General Motors Dispersion Experiment

Performed at GM proving grounds in conjunction with EPA, this study measured the diffusion of sulfate (SF_6) tracer gas. This information has led to many correlations used in CALINE 4 and TXLINE 2 (Chock, 1977).

Texas A&M Data

Extensive CO dispersion studies were conducted by Bullin, et al. (1978; 1982; 1983) at six different sites in Texas. Four study sites were at-grade, one was depressed, and the last one was elevated. Martinez, et al. (1981) note that this data base is the only one complete enough to investigate the effects of instrument error. Additional studies conducted by Texas A&M are for use in developing intersection models.

CALTRANS Sacramento Intersection Study

The California Department of Transportation collected pollutant, traffic, and meteorological data at a Sacramento intersection during the months of February, March, and April of 1981. The surroundings consisted of single story residences, so there were no high interfering background levels of pollutants.

STUDIES ON ELEVATED AND DEPRESSED FREEWAYS

In general, there are very few experimental studies of the impact of elevated or depressed freeways on air quality.

Causey, et al. (1976) present a general study of key factors for the decision making process to build elevated or depressed freeways. They analyze the impact on environment, community, commerce, and industry for one elevated and one depressed freeway in Chicago. Their air quality data are relatively scant and rather outdated.

The economic and environmental impact of a 6 m (20 ft) raised median on a six-lane freeway (3.6 m/lane (12 ft/lane)) in Lubbock was examined by TxDOT (1973). Air quality data are outdated.

Elevated freeways were found to provide air pollution benefits in a TRRL Monograph (1980). That study cited the additional advantages of elevated freeways, such as preserved ground area, shorter period of construction, positive effect on traffic flow, and reduced noise levels.

Abdulrahman (1978) conducted a simulation study on the air quality effect of a depressed, partially covered roadway. No experimental data were collected in that study.

MATERIALS AND METHODS

STUDY PARAMETERS

Study Size

Air quality impact studies usually fit into one of three categories: Microscale, mesoscale, or macroscale. Each type has an increased study area. This study focuses on CO monitoring on a microscale regime, i.e., over linear distances up to 100 meters from the edge of the freeway section and where CO concentrations are expected to deviate more than 20% over the distance.

Temporal and Spatial Resolution

The cost of purchasing and operating an air-monitoring network depends upon the level of temporal and spatial resolution required. Good spatial resolution is obtained by sampling at numerous locations within a study area. Good temporal resolution is obtained by sampling over short periods of time. The cost to achieve both is quite high. With the available budget, this study attempts to gain "good" temporal resolution by continuous monitoring at one-minute intervals for at least three days at each study area, and acceptable spatial resolution with a minimum of five CO monitors placed in a straight line horizontal to the roadway.

Measured Variables

The following variables were recorded during the study, for comparison with existing CALINE and TXLINE model predictions:

- CO concentrations (values 2-50 ppm),
- Wind speed and direction (horizontal and vertical components),
- Temperature,
- Barometric pressure,
- Relative humidity,
- Solar radiation,
- Traffic vehicle count,
- Traffic mix (cars, trucks, buses, light- vs. heavy-duty), and
- Average vehicle speed.

Monitoring Session Length

The monitoring sessions were of adequate length and properly arranged to capture the peak pollutant concentrations for the day and week.

- Day, 8am – 6pm (10 hours). The peak levels of CO in the air usually occur three times during the day, corresponding to morning, lunch, and afternoon rush hours. Examination of the first day data at each site determined whether the proposed sampling window needed to begin earlier or later in the day. Also, the time window length of 10 hours was lengthened or shortened depending on equipment and personnel limitations.
- Week, Monday–Friday (5 days). Monitoring during the normal five-day workweek was sufficient to capture the peak pollution levels. It is generally accepted by traffic engineers that vehicle counts and mix are most representative Tuesday through Friday of the week. However, sampling could be done the entire week if personnel are available.

The individual CO monitors and the weather instruments (meteorological station) were set to record data every minute during the 10-hour session.

Microscale Air Monitoring Sites

The team considered three general categories:

- *At-grade roadway*: This roadway runs at the same level as the surrounding terrain. Most impact prediction models assume this type of roadway.
- *Elevated roadway*: This roadway sits higher than the surrounding terrain. This category includes all roadways on pylons, lengthy overpasses, and bridges.
- *Depressed roadway*: This roadway runs lower than the surrounding terrain. This includes all "cut" sections and roadways bordered by tall sound abatement walls.

CO Monitor Placement

Current mathematical models are based upon at-grade roadways. Some of these models provide options for "cut" or "bridge" sections when defining links. However, all models assume simple surrounding topography. Monitors were placed near the roadway at different distances to record CO concentrations for comparison to current model predictions. Monitor placement was based upon previous studies conducted by Bullin and co-workers (Bullin, et al., 1978; 1982; 1983). Monitors were located on masts in a straight line perpendicular to the freeway. Figures 10 through 16 show typical placements of CO monitors for depressed, elevated, and at-grade freeway sites, respectively. Data collected at each site during the first day were used to slightly adjust monitor heights if necessary.

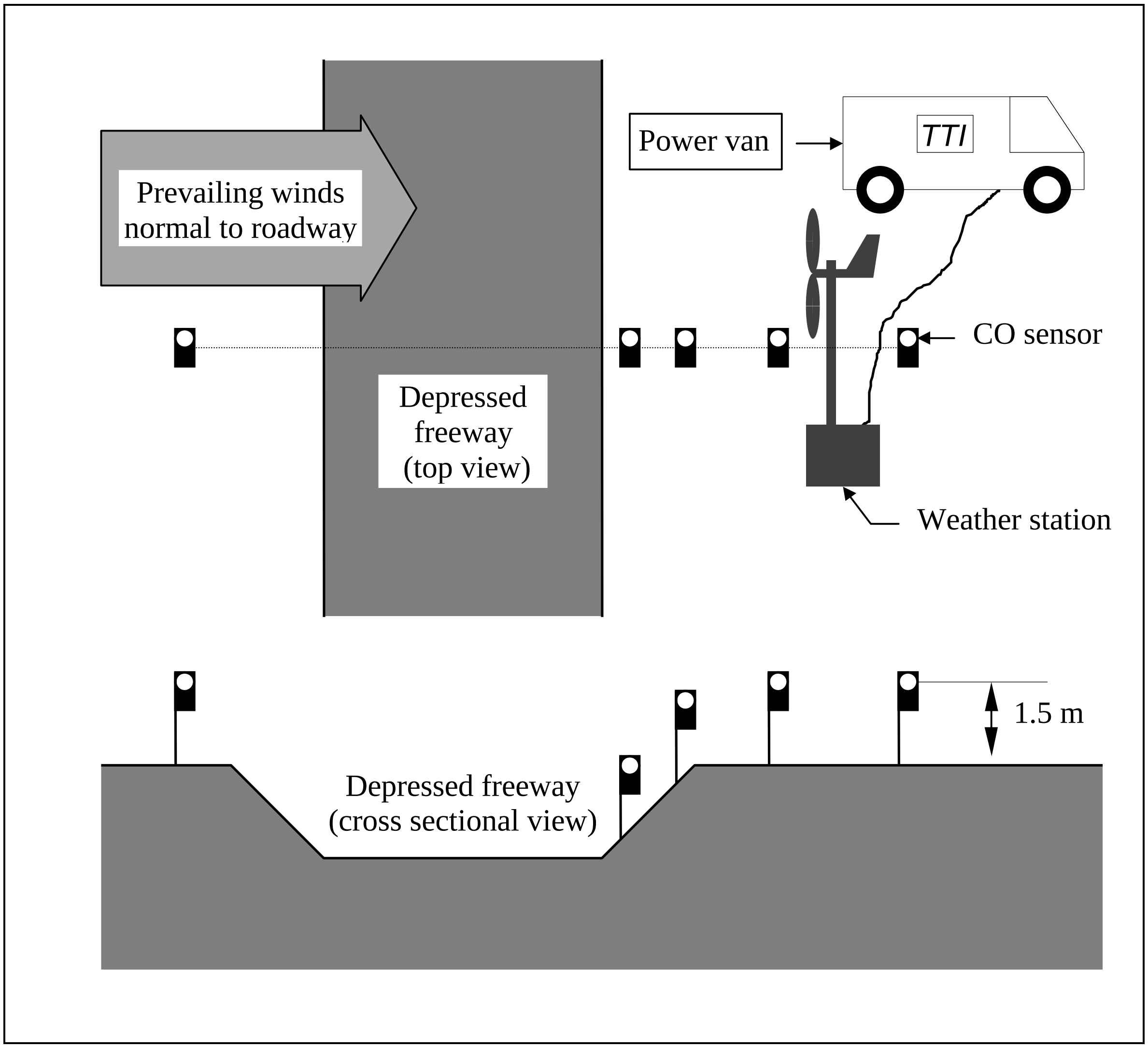

Figure 10. Typical Horizontal Placement of CO Sensors and Weather Station for a Depressed Freeway

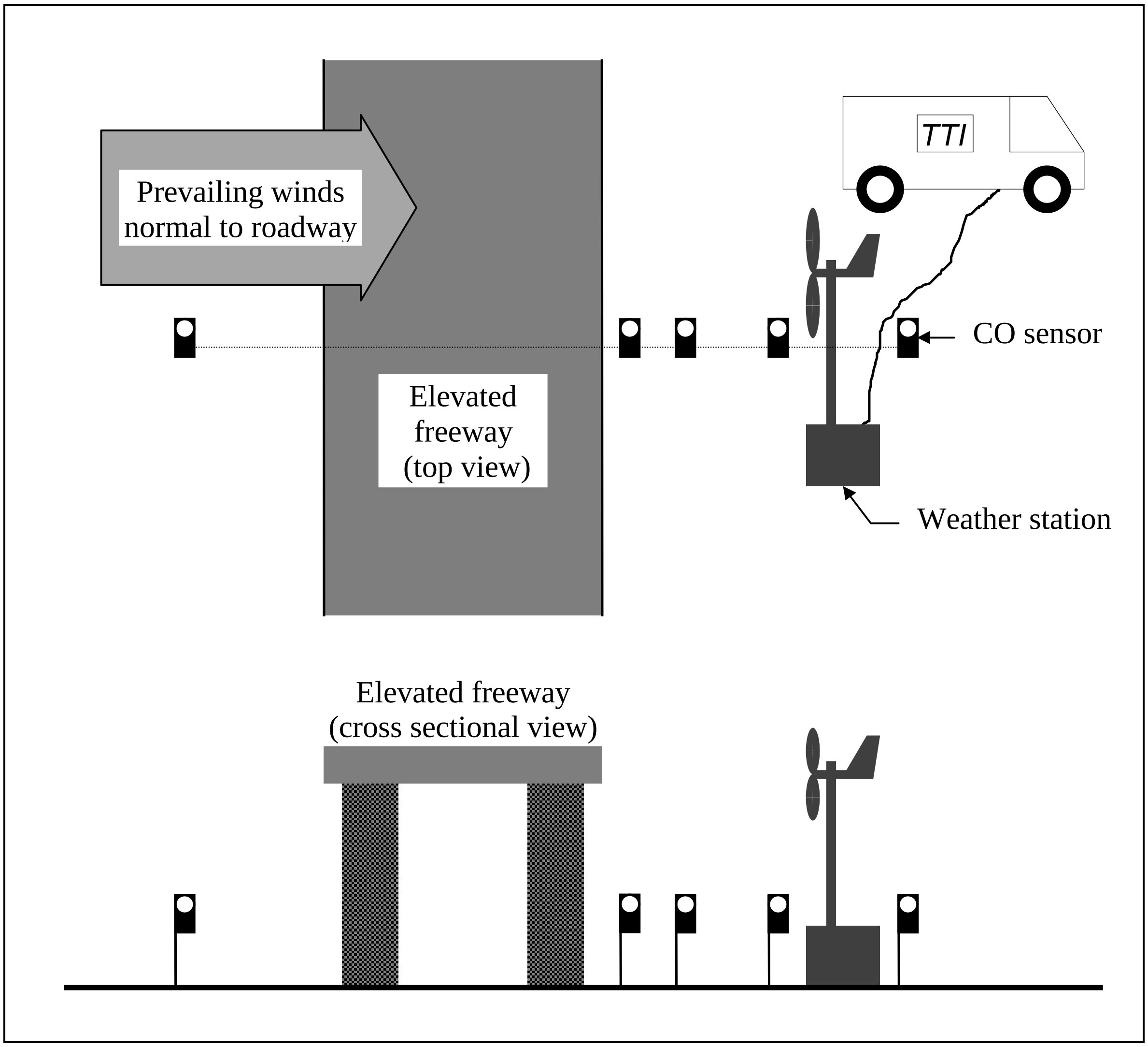

Figure 11. Typical Horizontal Placement of CO Sensors and Weather Station for an Elevated Freeway

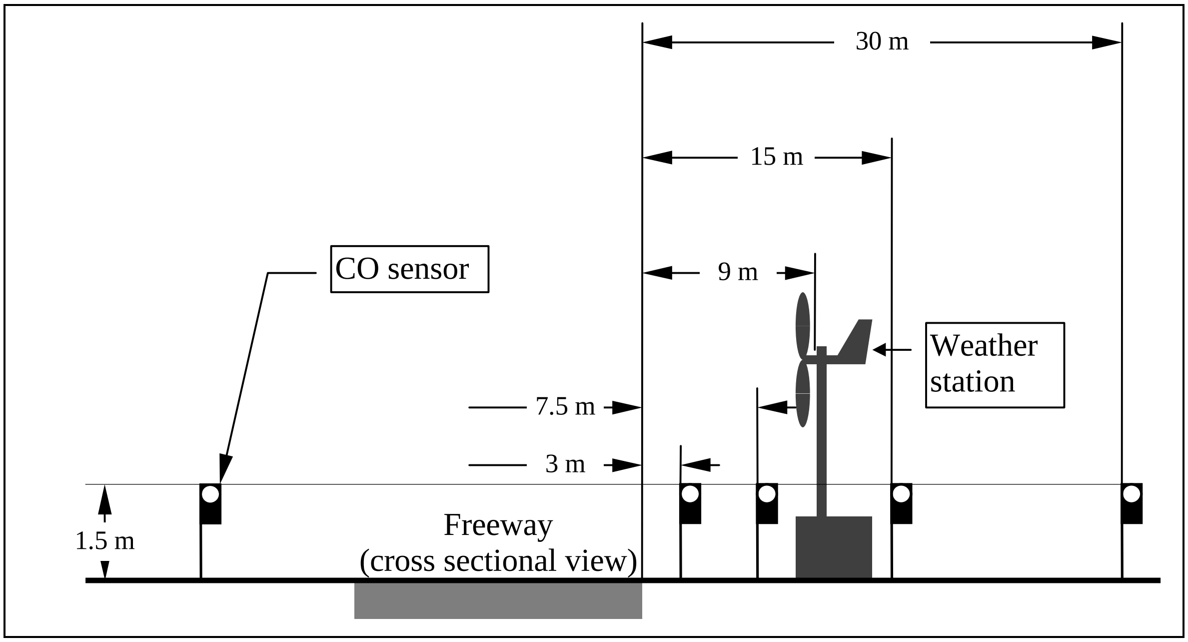

Figure 12. Typical Horizontal Placement of CO Sensors and Weather Station for an At-grade Freeway

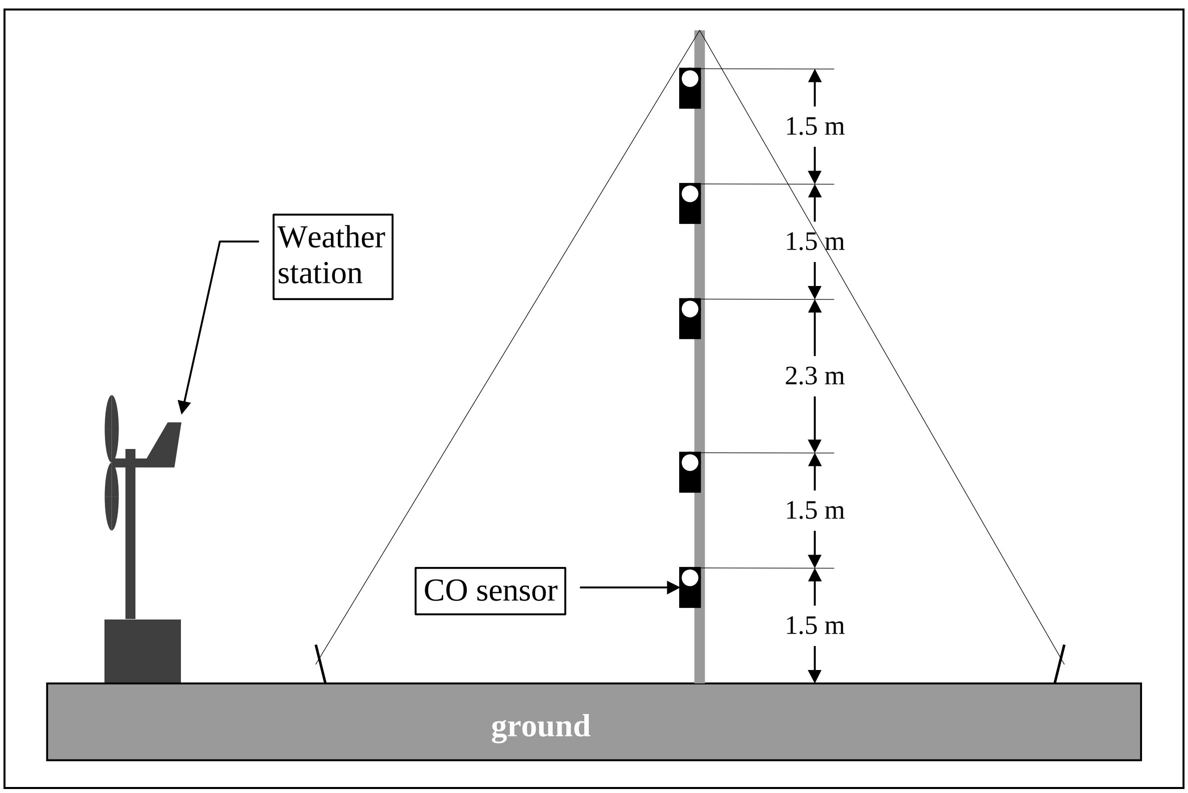

Figure 13. Typical Vertical Placement of CO Sensors and Weather Station

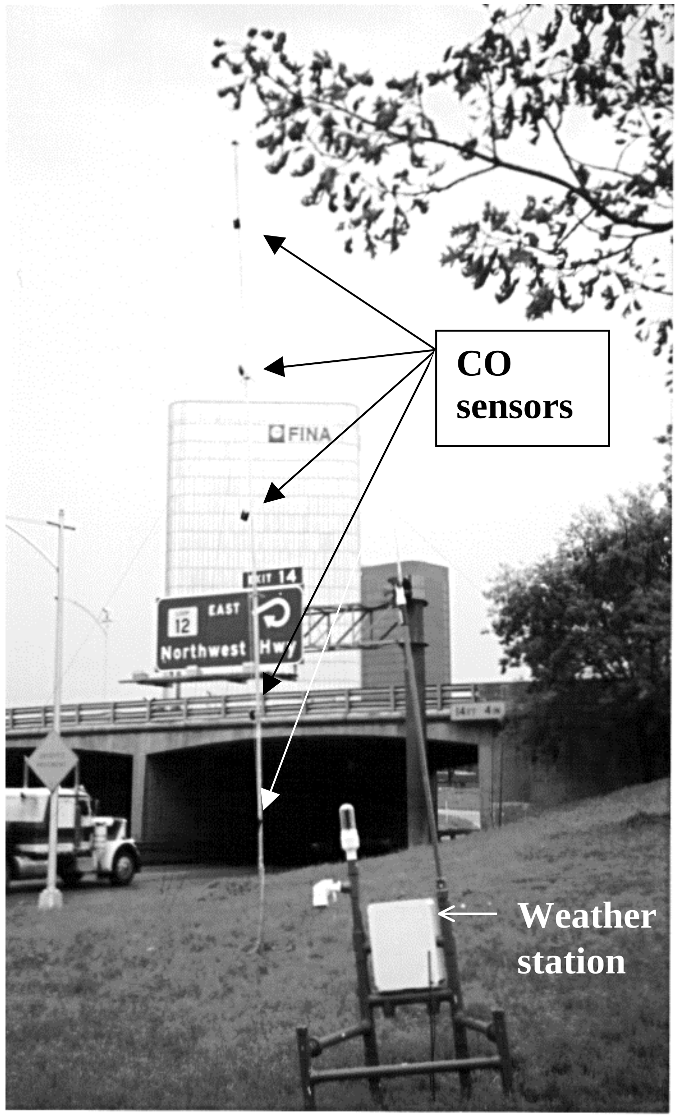

Figure 14. Vertical Placement of CO Sensors and Weather Station for a Depressed Freeway (Site: Dallas, near Intersection of Loop 12 and U.S. 75)

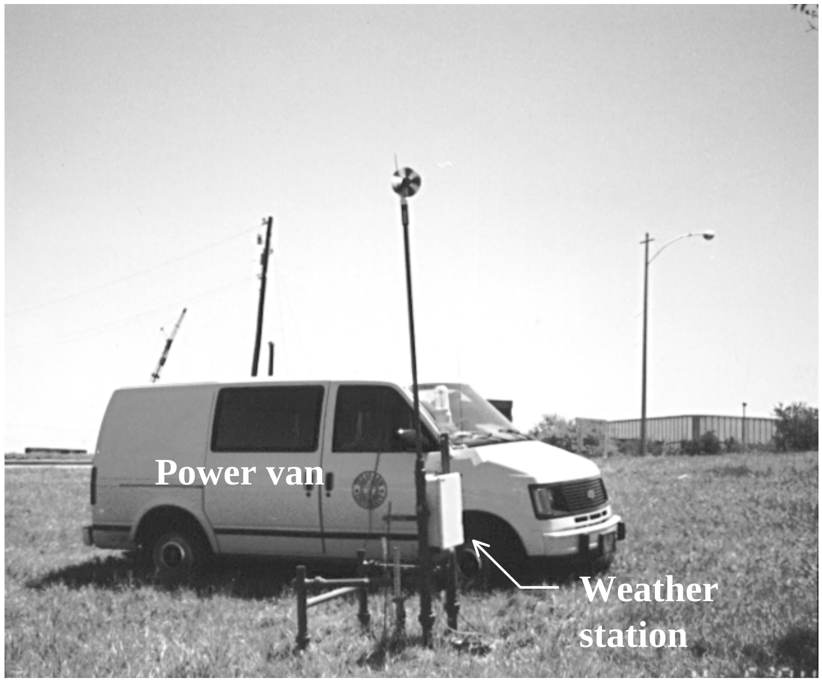

Figure 15. Power Van and Weather Station

Figure 16. Horizontally Placed CO Sensors and Weather Station for a Depressed Freeway (Site: Dallas, West of U.S. 75)

Collected Data

- *CO concentration*: The upwind CO monitor was used to determine the local background CO concentration. The downwind CO monitors, placed on the opposite side of the freeway, measured the combined CO concentration profile of the background and the freeway. The apparent CO concentration due to traffic was calculated by simple difference between downwind values and the upwind background level. The recorded data were compared to model predictions.
- *Meteorological data*: The data recorded on site were used as inputs to the mathematical model simulation.

EQUIPMENT

Data Acquisition System

The data was acquired from the CO sensors and weather station instruments independently. This monitoring scheme took advantage of the data-logging capabilities built into the individual CO sensors (Toxilog) and the control module of the weather station. Data were recorded at one-minute intervals by the CO sensors and the weather station. The CO data were periodically downloaded to a desktop personal computer (PC) via an optical interface. The weather data were downloaded to a diskette on portable computer in the field, and then copied to the working PC (Figures 17 and 18).

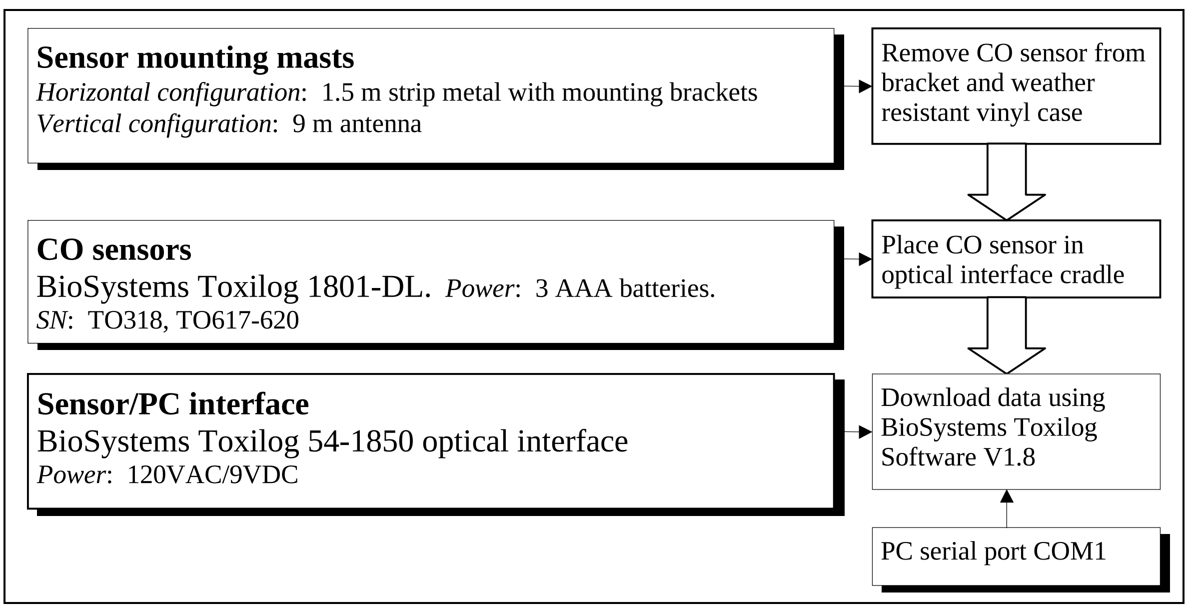

Figure 17. CO Data Transfer Procedure

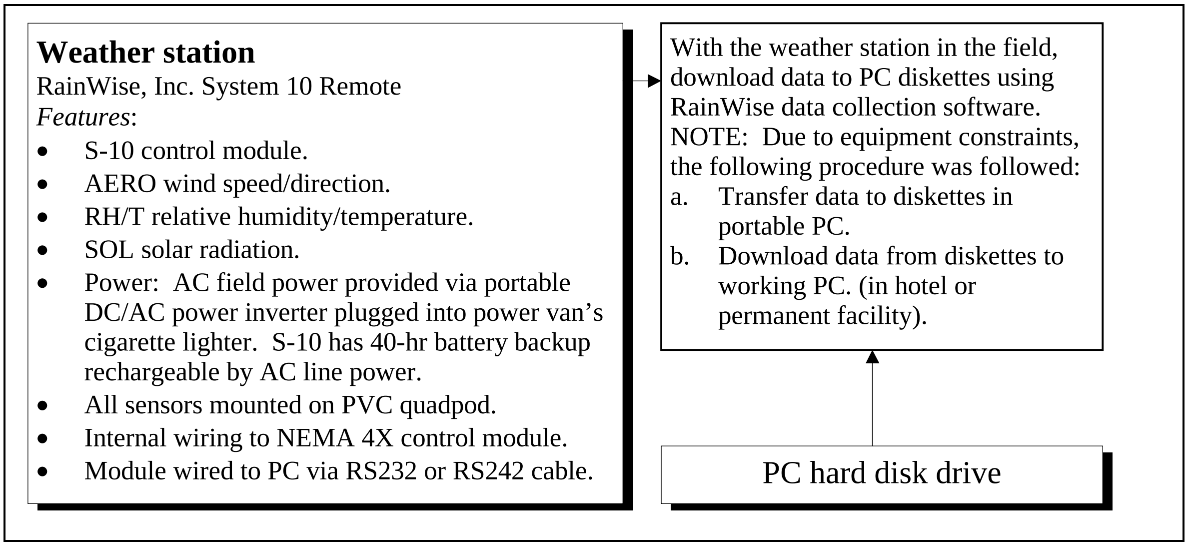

Figure 18. Meteorological Data Transfer Procedure

Air Monitoring Instruments

The atmospheric CO sensors used were Biosystems, Inc. Toxilog personal atmospheric monitors fitted with electrochemical 3E/F CO CiTicels by City Technology. The choice of electrochemical sensors was based on their combination of acceptable accuracy (0.5 ppm) and reasonable cost ($640 per sensor) in comparison to other alternatives such as infrared sensors. A major advantage of using electrochemical cells for toxic gas monitoring is that the detector output is highly specific and linear from 0 to 50 ppm (Arenas, et al., 1976). The cell functions according to the following reaction at the sensing electrode:

$$CO + H_2O \rightarrow CO_2 + 2H^+ + 2e^-$$

The sensors are passive, using diffusion across a membrane to sense the CO gas, rather than actively pumping air into the sensor. They have a range of 0 to 999 ppm, and the manufacturer lists an accuracy of 2% of signal with a resolution of 0.5 ppm. Each monitor is powered by three AAA batteries, which should be replaced about every 6 months. The monitors have the ability to log up to 50 hours of data when sampling at one-minute intervals.

Five Toxilog CO monitors were used in this project. The monitor placement near the roadway depended on the type of sampling desired (horizontal or vertical).

Meteorological Sensors

The meteorological measuring system (weather station) used was a RainWise, Inc. System 10 Remote (S-10). The system is AC powered with a battery backup. The S-10 control module is housed in a NEMA4X electronics enclosure built into the weather station supporting structure (quadpod). The quadpod is built of PVC pipe and all sensor connecting cable is prewired inside the pipe to the S-10 control module. The S-10 has 32K nonvolatile memory. The weather sensors attached to the quadpod are described below.

- AerVane: This records wind speed and wind direction. The wind speed sensor uses a balanced propeller supported in stainless steel instrument ball bearings. The propeller drives a multipole magnetic disc which generates pulses in a stationary coil. The range is

1.3 to 160 km/h (0.8 to 100 mph), and the accuracy is ±1% of the signal. Wind direction is obtained through a photo-optical disc in quadrature. The range is 360 degrees with no deadband, and the accuracy is ±1 degree.

- Temperature and relative humidity: These sensors are enclosed in white PVC housing. The temperature sensor is a calibrated diode type encapsulated in epoxy that has a range of -40°C to 132°C (-40°F to 150°F) and accuracy ± 0.5°C (1°F). The relative humidity sensor has a range of 0 to 100% and accuracy ±2% F.S.
- Solar radiation: The solar radiation sensor consists of a linear temperature sensor embedded in a 2.5 cm (one inch) diameter solid brass ball. The assembly has a flat finish and is mounted inside a sealed glass housing. The range is 167 to 1352 w/m^2 and accuracy ±67 w/m^2.

Traffic Measurements

Traffic counts were taken in different ways, depending upon personnel and equipment availability. Time-lapse videotaping was used for the Dallas study. This option was the most accurate. However, it required significant human effort to count cars on the screen. For Lubbock, San Antonio, and Houston, combinations of tube counters, traffic counters, and visual traffic counting were used by TEES and TxDOT personnel to provide traffic counts.

EXPERIMENTAL PROCEDURE

The experimental procedure for CO data collection is as follows:

1. Determine the site to be studied.
2. Record the site type (depressed, elevated, at-grade). Record the land use along both sides of the roadway (residential, business, school, park, industry), the type of terrain (flat and grassy, parking lots, tall trees, high buildings), and its possible effects on pollutant concentrations in the area (e.g., higher background concentrations from industry, disrupted wind patterns due to tall buildings and trees). Also, record the apparent weather conditions (mild and sunny, cool and foggy, drizzle vs. rain), especially if a front moves in and changes the prevailing conditions during a study.
3. On the downwind side of the roadway, erect the weather station according to the RainWise instruction manual. The weather station should be between 7.5 and 22.5 m (25 and 75 ft) of the roadway edge if possible. Note that the quadpod is not mounted, so concrete footings or flange foot extensions are not necessary.
4. Plug the weather station power cable to the power inverter connected to the field vehicle's cigarette lighter jack. As stated in the manual, make sure the power strip switch is turned ON and the panel switch is turned ON.
5. Set the TIME and DATE according to the RainWise instruction manual.
6. Place the CO sensor masts as follows:

   Horizontal sampling

   a. Using nuts and bolts, attach additional strip metal sections to those already set in concrete weight buckets. (If it is more convenient to drive the strip metal masts directly into the ground, then weight buckets may not be necessary.) Attach a CO sensor to each assembled mast, at a height of 1.5 m (5 ft) from ground level.
   b. Place the masts with the CO sensors in a straight line perpendicular to the roadway, at distances of 1.5, 3, 7.5, and 15 m (5, 10, 25, and 50 ft) downwind

from the roadway edge. Also place a mast with a CO sensor 7.5 to 15 m (25 to 50 ft) upwind of the roadway edge.

c. Turn on each CO sensor and record its serial number and distance from the roadway. Make sure the diffusion membrane is facing the roadway.

Vertical sampling

a. Drive the mast's butt plate stake into the ground, approximately 12 to 15 m (40 to 50 ft) downwind from the roadway edge. The stake tip should be left extending about 2 to 2.5 cm (¾ to 1 in) above the ground. (It should not be driven too deeply.)
b. While keeping the mast on the ground, extend the telescoping sections of the mast from top to bottom until the blue ring around each section is exposed. Make sure to tighten each section securely before proceeding to the next.
c. Attach the nylon guide lines to the three lowest sets of guide rings. The mast uses a 3 line set configuration.
d. Run the long white nylon line through the loop attached to the top guide ring. Make sure the CO sensor mounting clips are attached to the nylon line and that the knot in the cord is placed through the loop allowing the sensors to be run up and down, similarly to a flag pole. As before, four sensors are used to measure the downwind CO concentrations, while the fifth CO sensor, placed upwind from the roadway, records the background CO concentration.
e. Drive the three metal stakes into the ground 4.6 m (15 ft 2 in) from the butt plate, at a 120-degree angle from each other. Note that "curb jumpers" instead of strip metal ground stakes were used in all Dallas sites. Curb jumpers proved easier to move and restake.
f. Attach two of the three sets of the guide lines to the ground stakes or curb jumpers. One person should take hold and pull on the remaining set of guide lines, while the second person pushes the mast up into a vertical position. The final set of guide lines is then secured. Attach the post level to the mast. WARNING: WHEN ERECTING THE ANTENNA, BE SURE TO AVOID CONTACT WITH POWER LINES. IN ADDITION, PLACE THE MAST FAR ENOUGH FROM THE ROADWAY TO PREVENT OBSTRUCTION OF TRAFFIC OR ACCIDENTS IN CASE IT FALLS.
g. While one person holds on to the mast, the other should adjust the turn buckles, so that the lines are taunt and the mast is vertical. It may be necessary to move and restake one set of guide lines. If so, one person should hold the mast in a vertical position until the lines are restaked.
h. The sensors may now be attached to the clips on the nylon cord extending up the flagpole. Start each sensor as it is attached and record its serial number and height on the mast.

7. Collect data for the prescribed amount of time. Note that the field vehicle is allowed to idle during the day to provide power to the weather station. During this time, take photographs and prepare drawings of the sample site.
8. After completing data collection for the day, turn off and collect downwind CO sensors. Store masts in field vehicle. Even if the threat of vandalism or theft is not evident, only the masts may be left in place for the next day's data collection.

9. Connect the portable computer's RS-232 cable (and power supply, if necessary) to the weather station. Follow the RainWise instruction manual procedures for downloading data to diskette. The data on diskette may be copied to the working PC later.
10. Clear weather station RAM, switch station OFF. Disassemble the weather station and store it in the field vehicle. If the threat of vandalism or theft is not evident, the weather station may be left in the field, provided it is chained down to the ground stakes.
11. Turn off and collect upwind CO sensor. Disassemble mast and store in field vehicle.
12. Download individual CO sensor data to the PC hard drive, or diskettes, using the optical interface and the Toxilog software according to the Toxilog instruction manual. Note that if the Toxilog has a downloading error before the transfer is complete, return to the main menu and run the "Configure Instrument" option. This won't affect the stored data. Attempt to download the data again. Sometimes the download command must be used more than once before the data is transferred.
13. After all CO data has been archived and transferred to text files, clear the Toxilog memory.
14. If necessary, recalibrate the zero and span of the CO sensors, as recommended in the Toxilog instruction manual. Span gas (50 ppm CO) is available in a small cylinder. Be sure to keep a record of the conditions under which the sensors were recalibrated. Make sure all sensors are zeroed under the same conditions.
15. Repeat procedure for each day of data collection.

SITES STUDIED

Dallas Area

The team collected eight days of CO data on U.S. 75. Figures 19 through 24 show sketches of the exact locations. Traffic data were recorded by videocamera operated by TTI personnel.

Day 1 (3/29/94) -

Site: Intersection of Lemmon Ave. and U.S. 75, across from City Place Tower; elevated.

CO sampling: Vertical.

Weather: Sunny and mild with south wind.

Area: Open and grassy.

Day 2 (3/30/94) -

Site: East side of U.S. 75 on access road, one block north of Hall St. and one block south of Lemmon Ave.; at-grade.

CO sampling: Vertical.

Weather: Sunny and mild with north wind.

Area: Open and grassy with nearest buildings located about a block away in all directions.

Day 3 (3/31/94) -

Site: Same site as day one.

CO sampling: Horizontal.

Weather: Sunny and warm with south wind.

Day 4 (4/4/94) -

Site: On west side of U.S. 75 on the access road three blocks down from Lovers Ln.; at-grade.

CO sampling: Horizontal.

Weather: Overcast with high south winds.

Days 5, 6 (4/5/94, 4/6/94) -

Site: Depressed freeway sites inside northwest and northeast clover leaves where Loop 12 intersects U.S. 75, respectively.

CO sampling: Vertical.

Weather: Southeast wind shifted to northeast after two hours of rain, on 4/5/94. 4/6/94 was cold and sunny with high northwest winds.

Days 7, 8 (4/7/94, 4/8/94) -

Site: West side of U.S. 75 in sloping cut on southern side of Park Ln. as it crosses over U.S. 75; depressed.

CO sampling: Horizontal.

Weather: Cool and sunny with southeast wind.

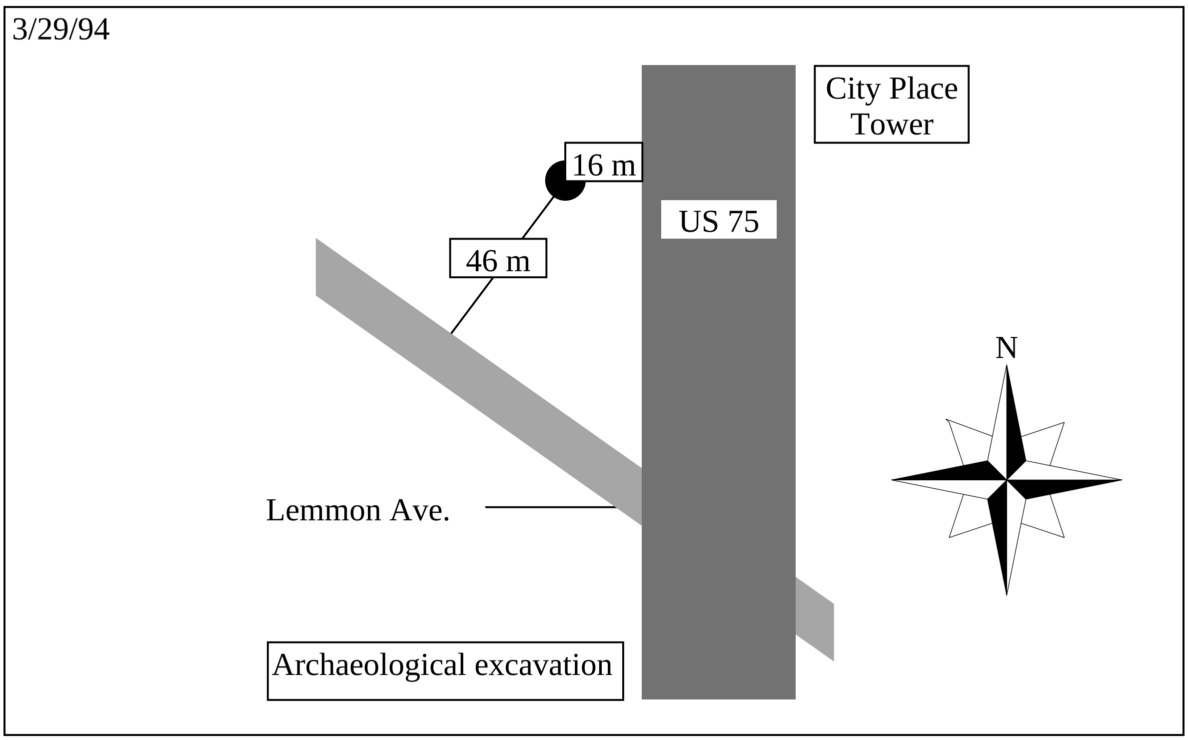

Figure 19. Elevated Site, Dallas

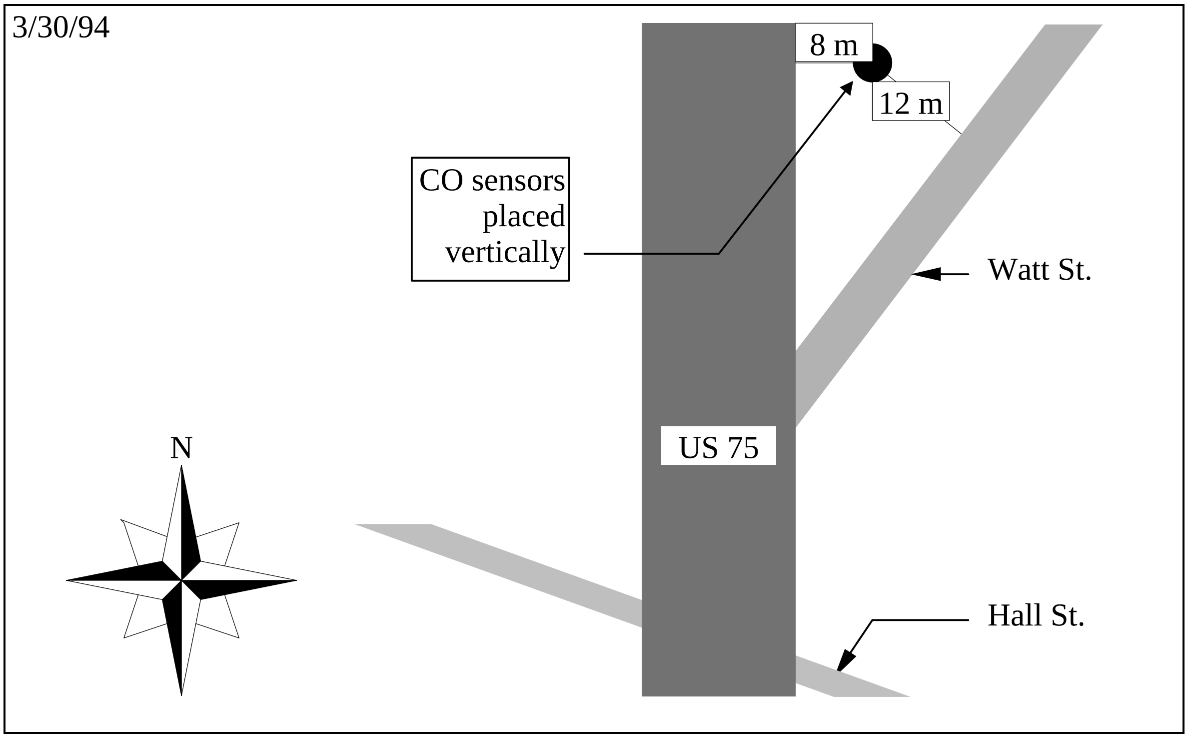

Figure 20. At-grade Site, Dallas

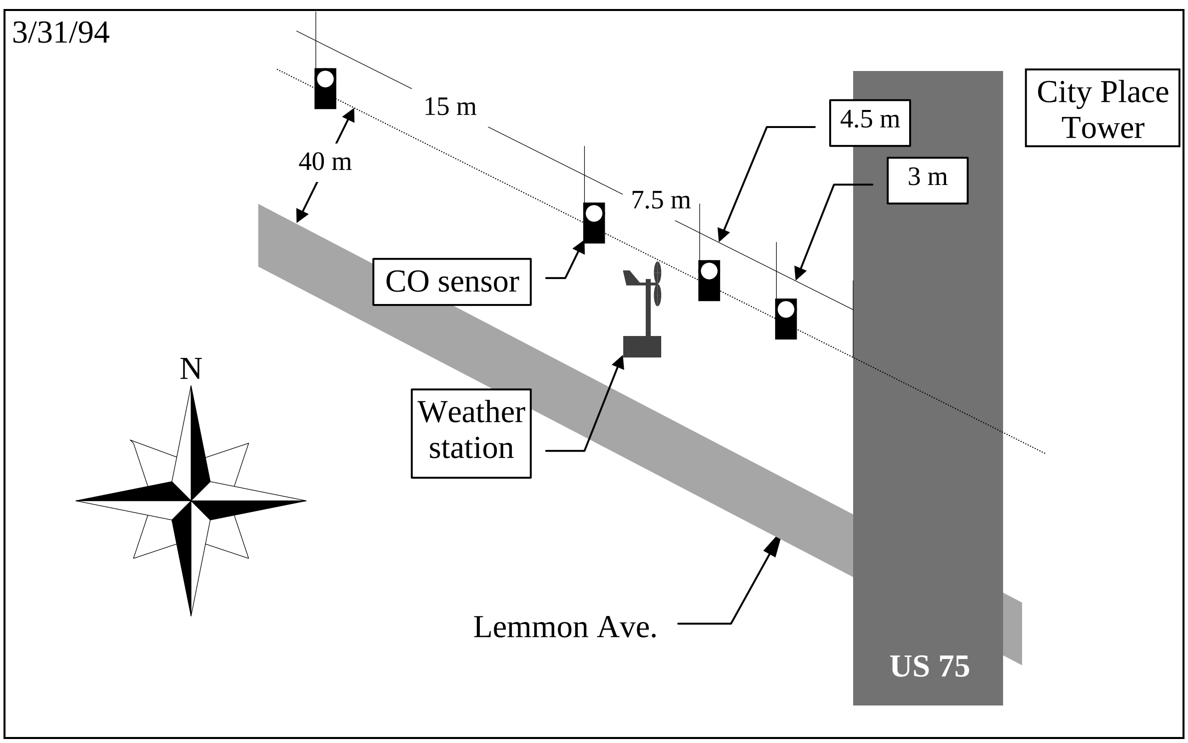

Figure 21. Elevated Site, Dallas

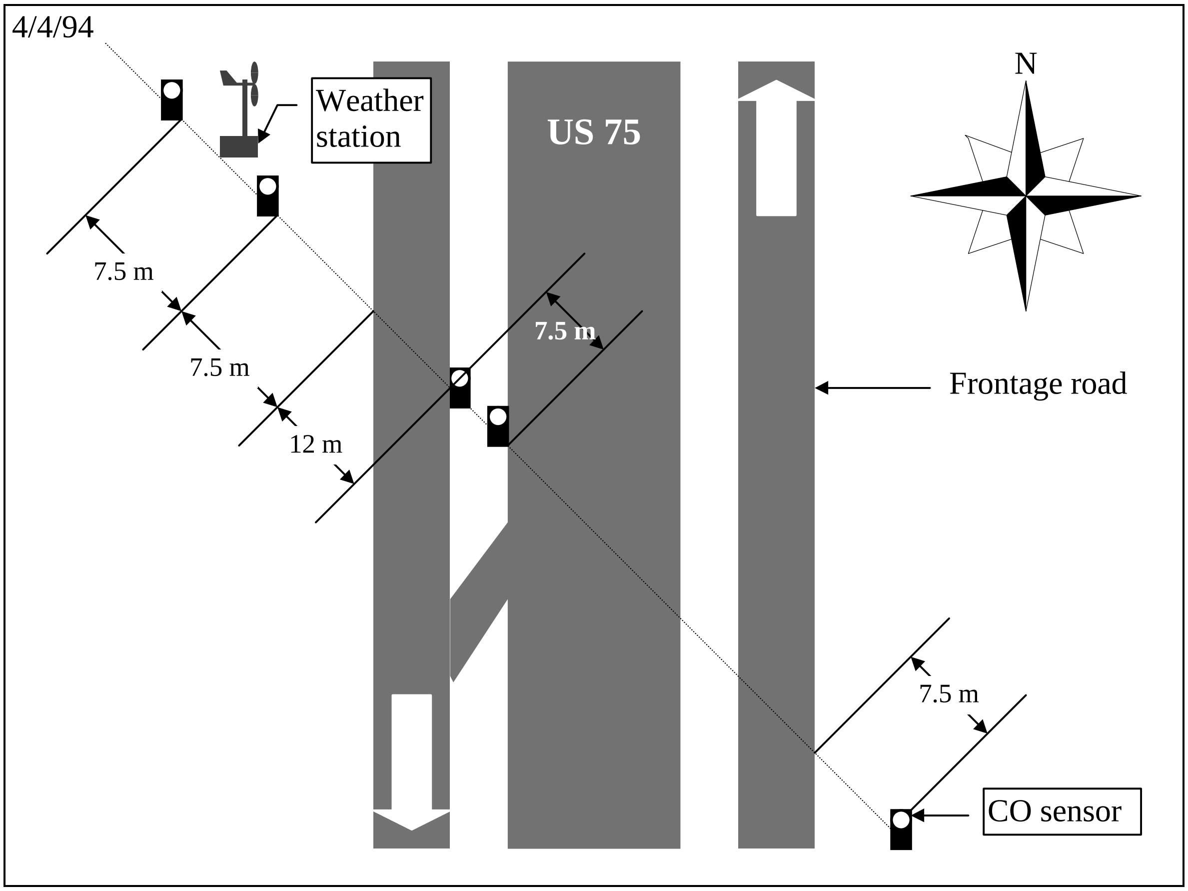

Figure 22. At-grade Site, Dallas

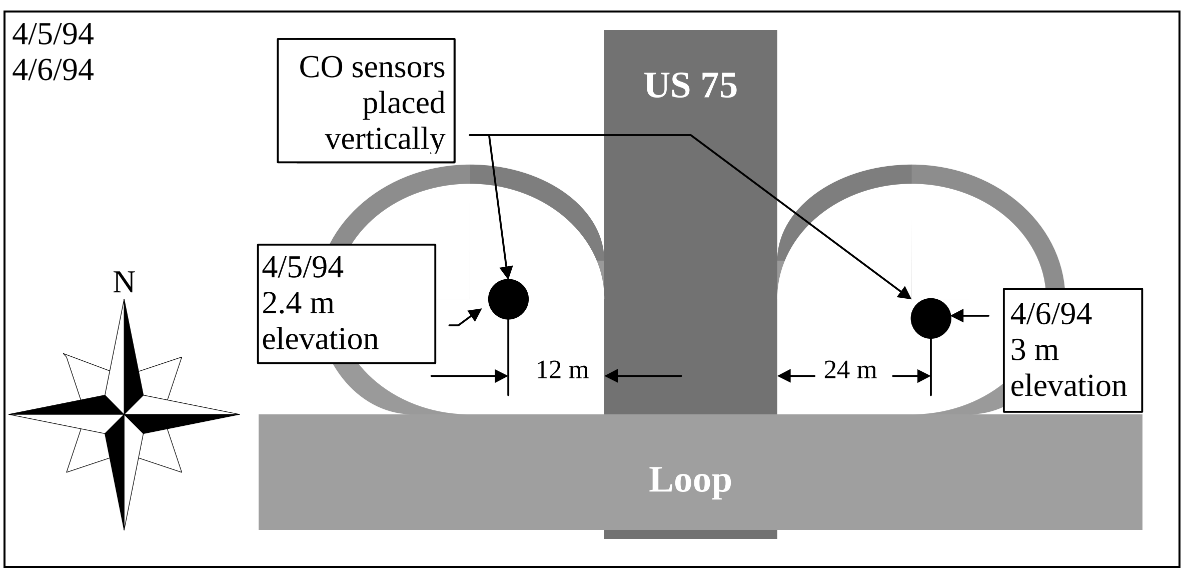

Figure 23. Depressed Site, Dallas

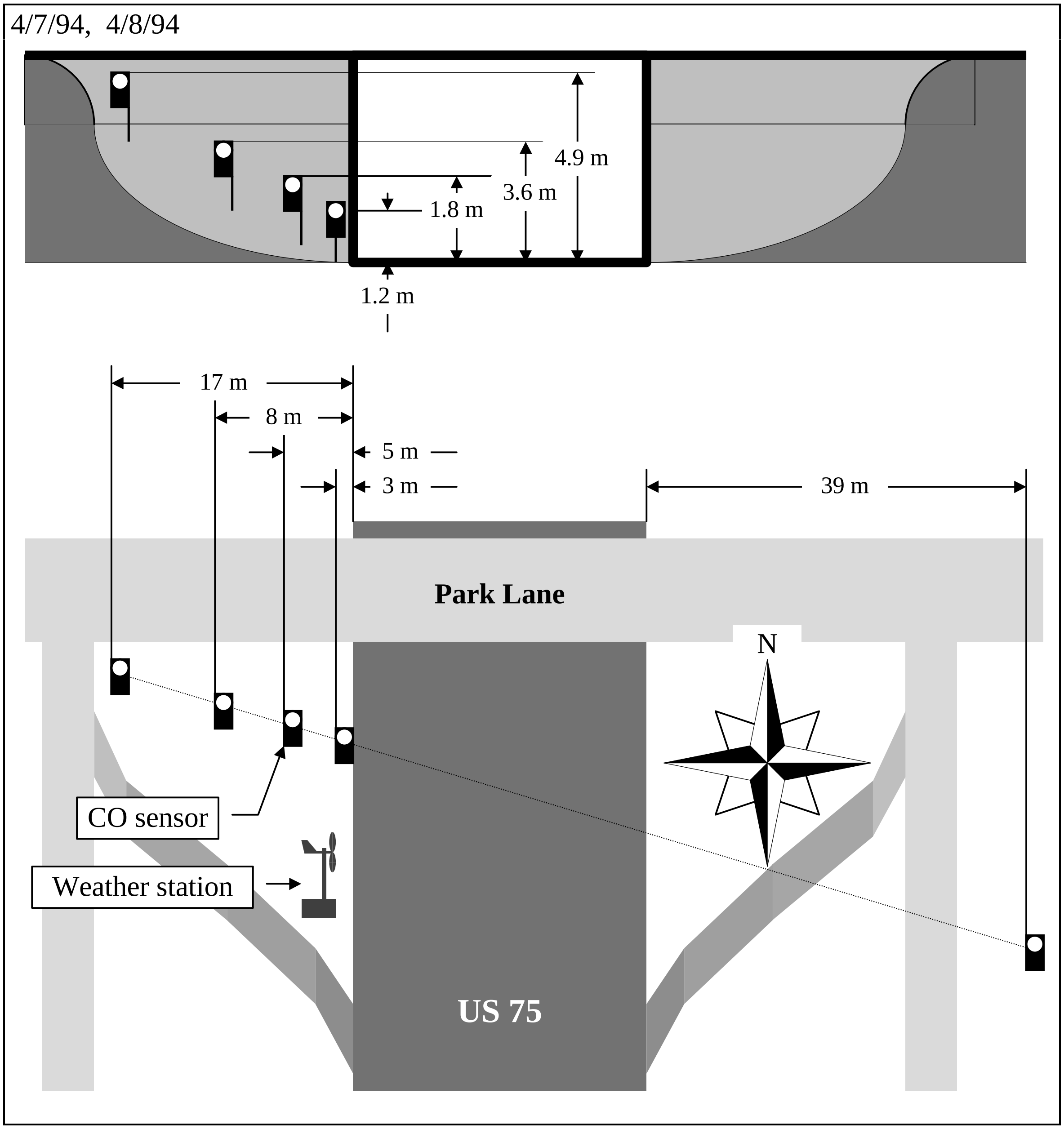

Figure 24. Depressed Site, Dallas

Lubbock Area

The team collected eight days of CO data on IH 27 in Lubbock. A brief description of the freeway type and conditions are given below. Sketches of the sites are given in Figures 25 to 28. Traffic data were provided by TTI personnel.

Day 1 (7/13/94) -
Site: IH 27 (48th St. area), depressed.
CO sampling: Horizontal.
Weather: Partly cloudy with south wind.
Area: Open and grassy.

Day 2 (7/14/94) -
Site: IH 27 (42nd St. area), depressed.
CO sampling: Horizontal.
Weather: Partly cloudy and mild with south wind.
Area: Open and grassy.

Day 3 (7/15/94) -
Site: IH 27 (51st St. area), depressed.
CO sampling: Vertical.
Weather: Partly cloudy with south wind.
Area: Open and grassy.

Day 4 (7/16/94) -
Site: IH 27 (Q Ave. area), depressed.
CO sampling: Vertical.
Weather: Sunny with south wind.
Area: Open and grassy.

Day 5 (7/18/94) -
Site: IH 27 (32nd St. area), elevated.
CO sampling: Horizontal.
Weather: Sunny with south wind.
Area: Open and grassy.

Day 6 (7/19/94) -
Site: IH 27 (32nd St. area), elevated.
CO sampling: Horizontal.
Weather: Sunny with south wind.
Area: Open and grassy.

Day 7 (7/20/94) -
Site: IH 27 (32nd St. area), elevated (same as day 5).
CO sampling: Vertical.
Weather: Sunny with south and southwest winds.
Area: Open and grassy.

Day 8 (7/21/94) -
Site: IH 27 (32nd St. area), elevated.
CO sampling: Vertical.
Weather: Sunny with south wind.
Area: Open and grassy.

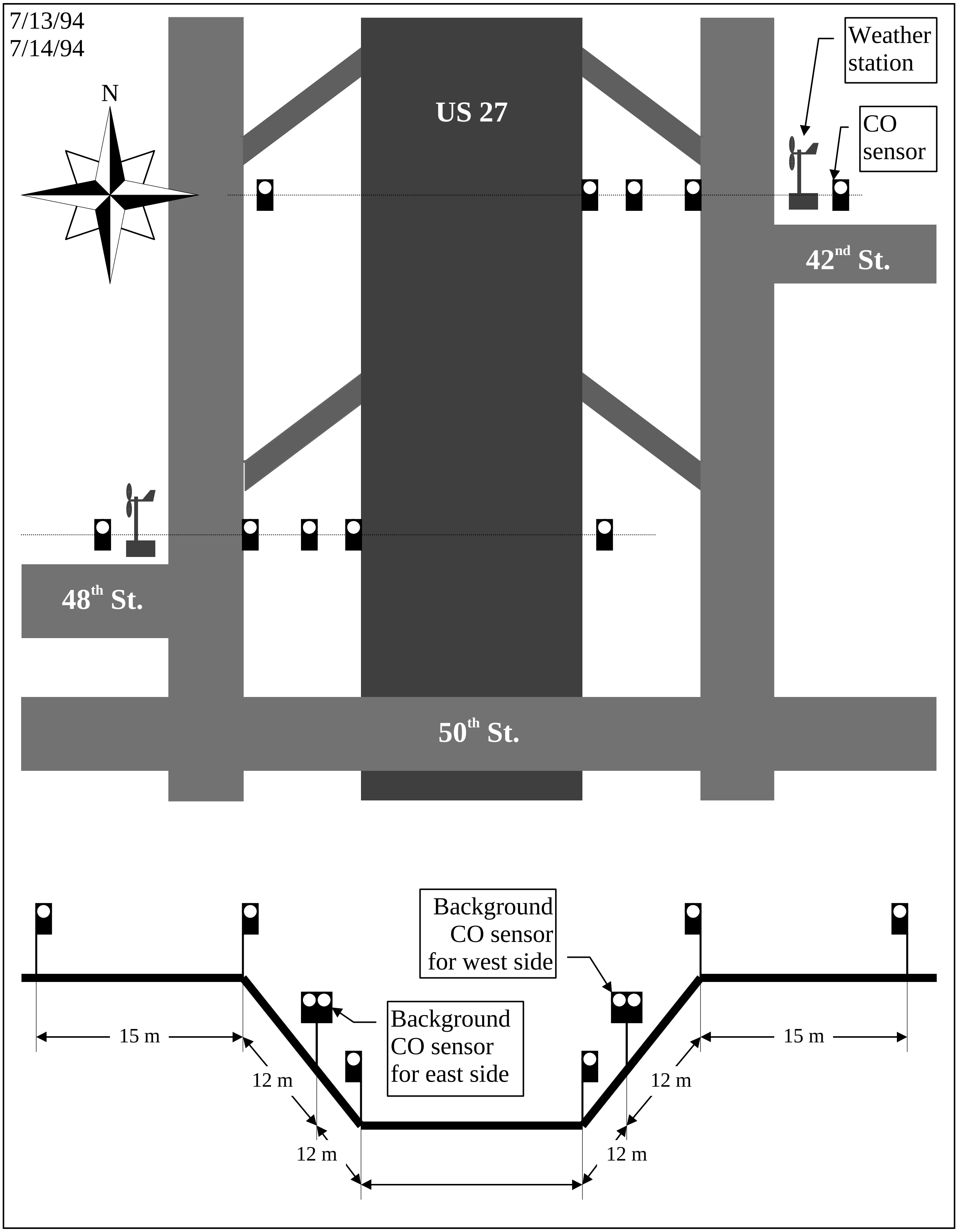

Figure 25. Depressed Site, Lubbock

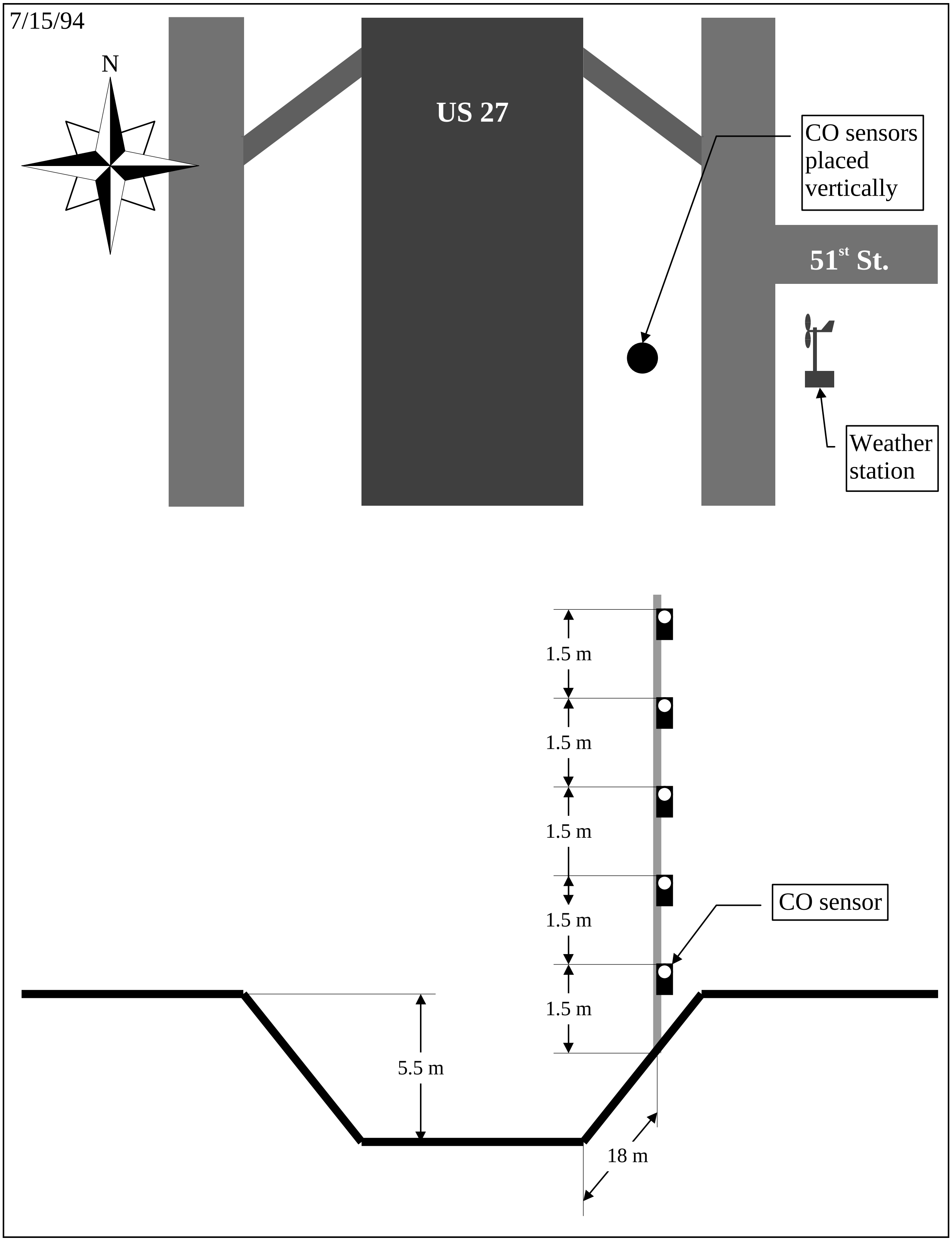

Figure 26. Depressed Site, Lubbock

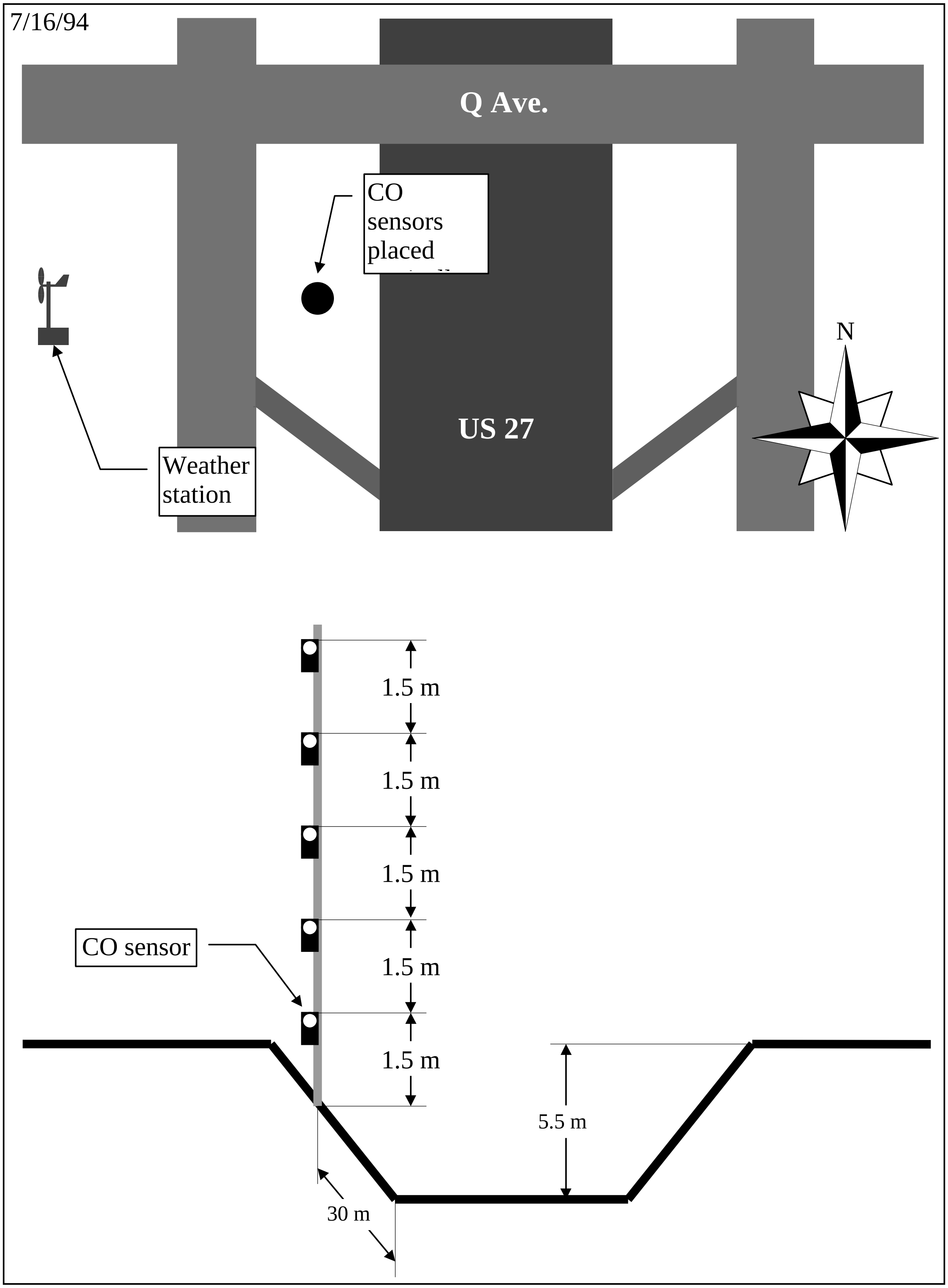

Figure 27. Depressed Site, Lubbock

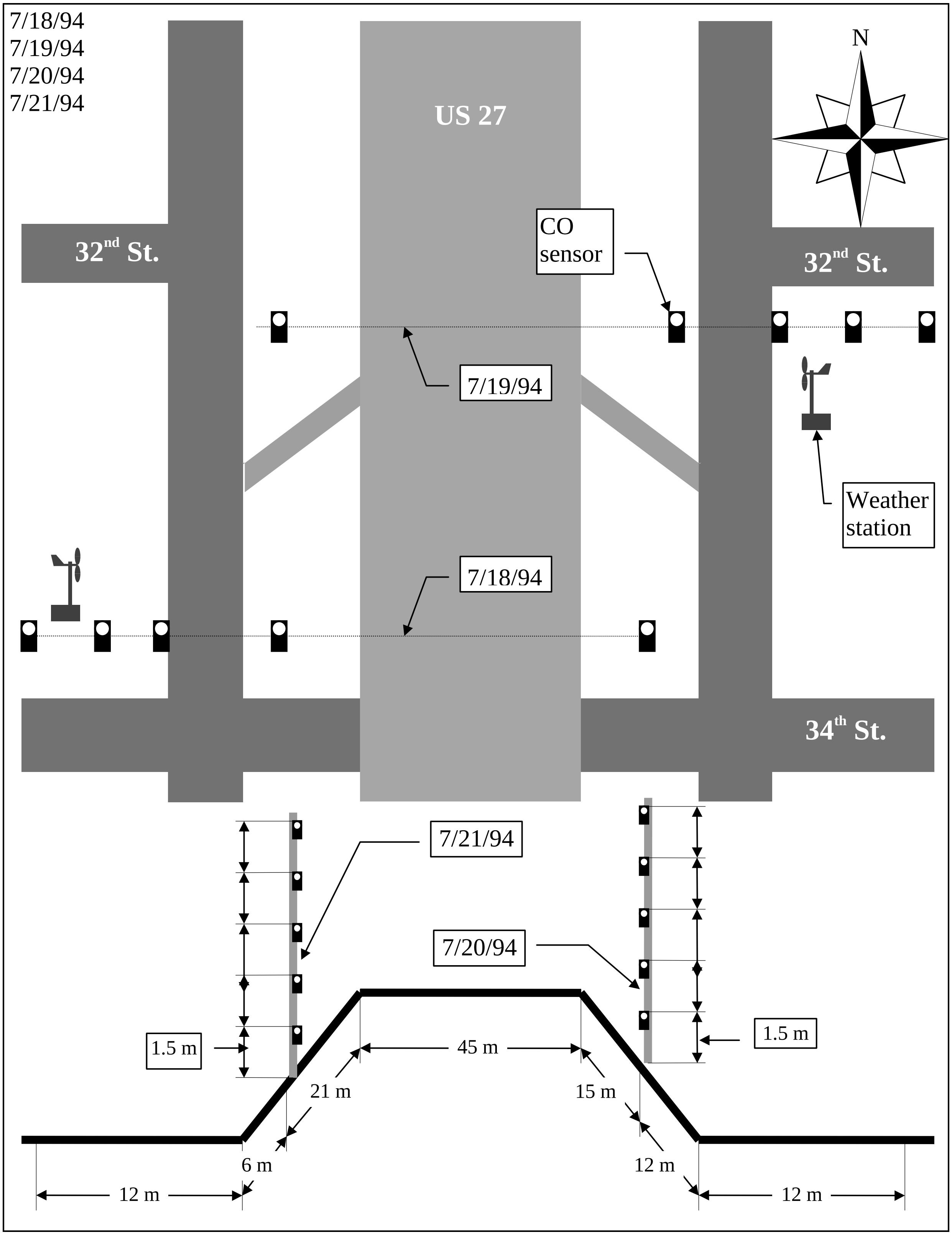

Figure 28. Elevated Site, Lubbock

Houston Area

The team collected CO data on three different locations of Sam Houston Tollway, for 10 days. Heavy rain and flooding in the Houston area caused equipment failure, thus interrupting CO data collection in October 1994. After the equipment was repaired, the team collected additional CO data in spring 1995. Schematics of the data collection sites are shown in Figures 29 through 31. Traffic data were provided by TTI. Additional details are provided in Appendix B.

Day 1 (10/10/94) - Site: At-grade.
Day 2 (10/11/94) - Site: Elevated.
Day 3 (10/12/94) - Site: Depressed.
Day 4 (10/13/94) - Site: At-grade.
Day 5 (10/14/94) - Site: Elevated (Data corrupted due to equipment failure).
Day 6 (2/7/95) - Site: Depressed.
Day 7 (2/8/95) - Site: At-grade.
Day 8 (2/9/95) - Site: Elevated.
Day 9 (2/13/95) - Site: Depressed.
Day 10 (2/14/95) - Site: At-grade.

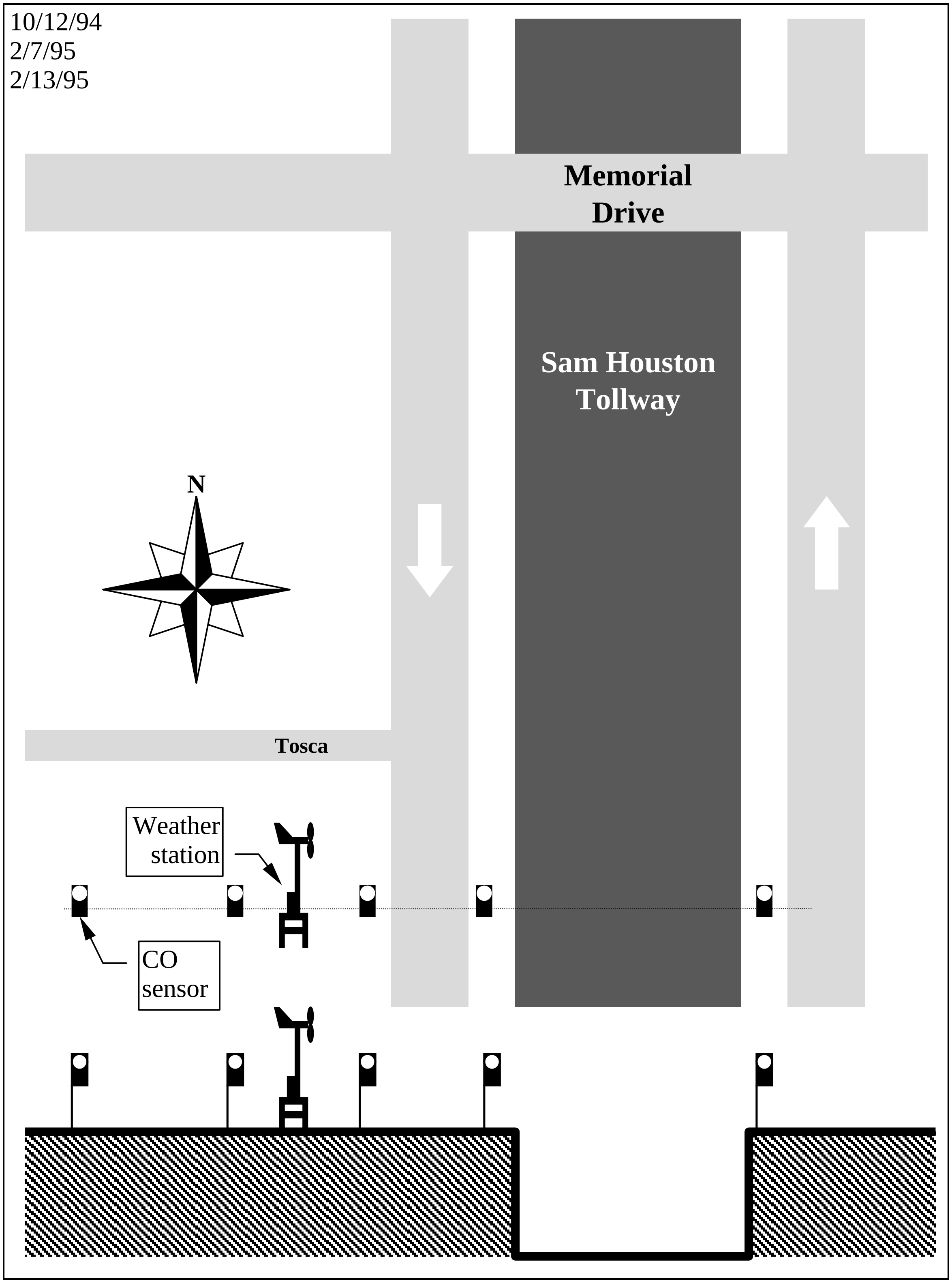

Figure 29. Depressed Site, Houston

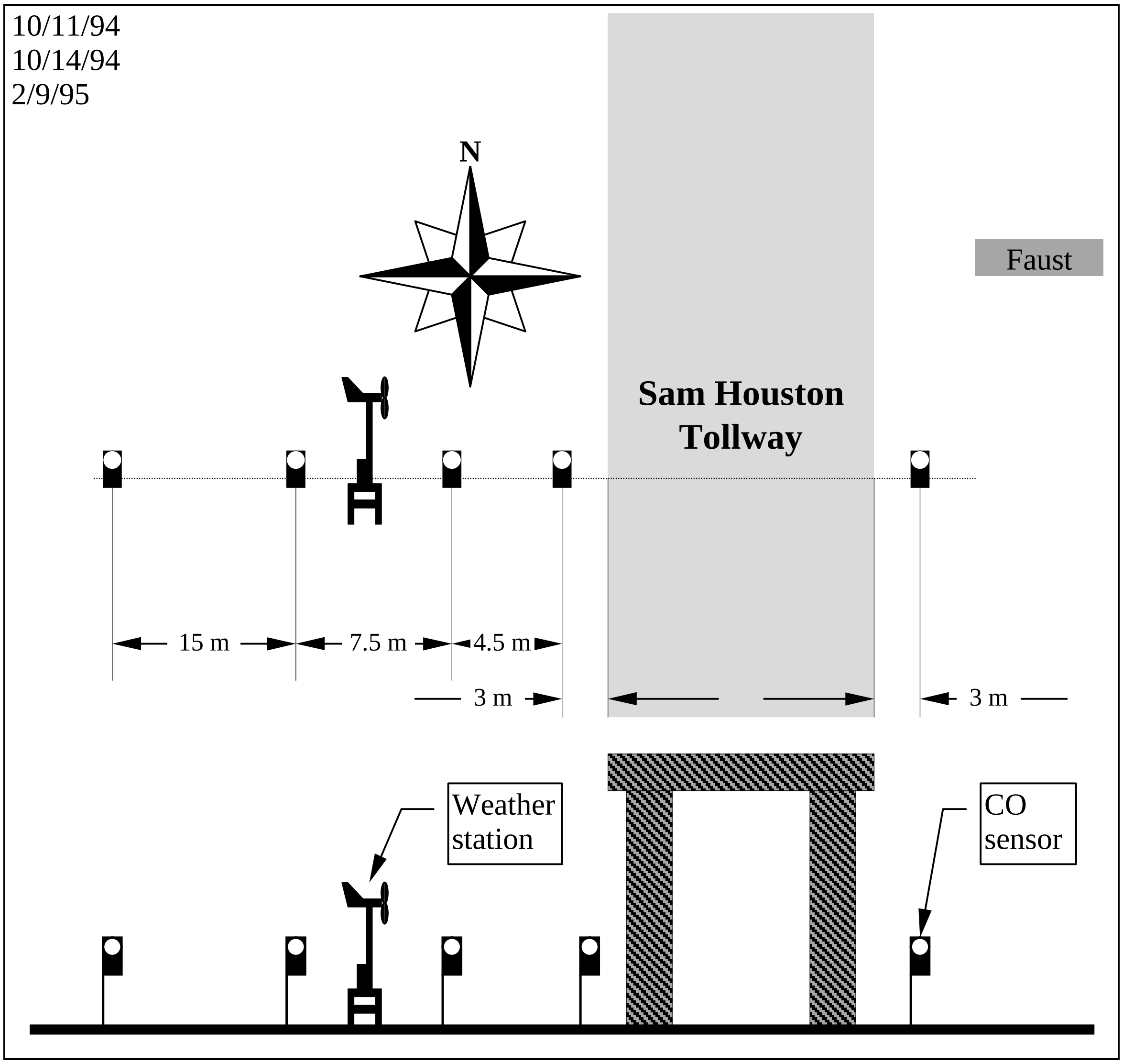

Figure 30. Elevated Site, Houston

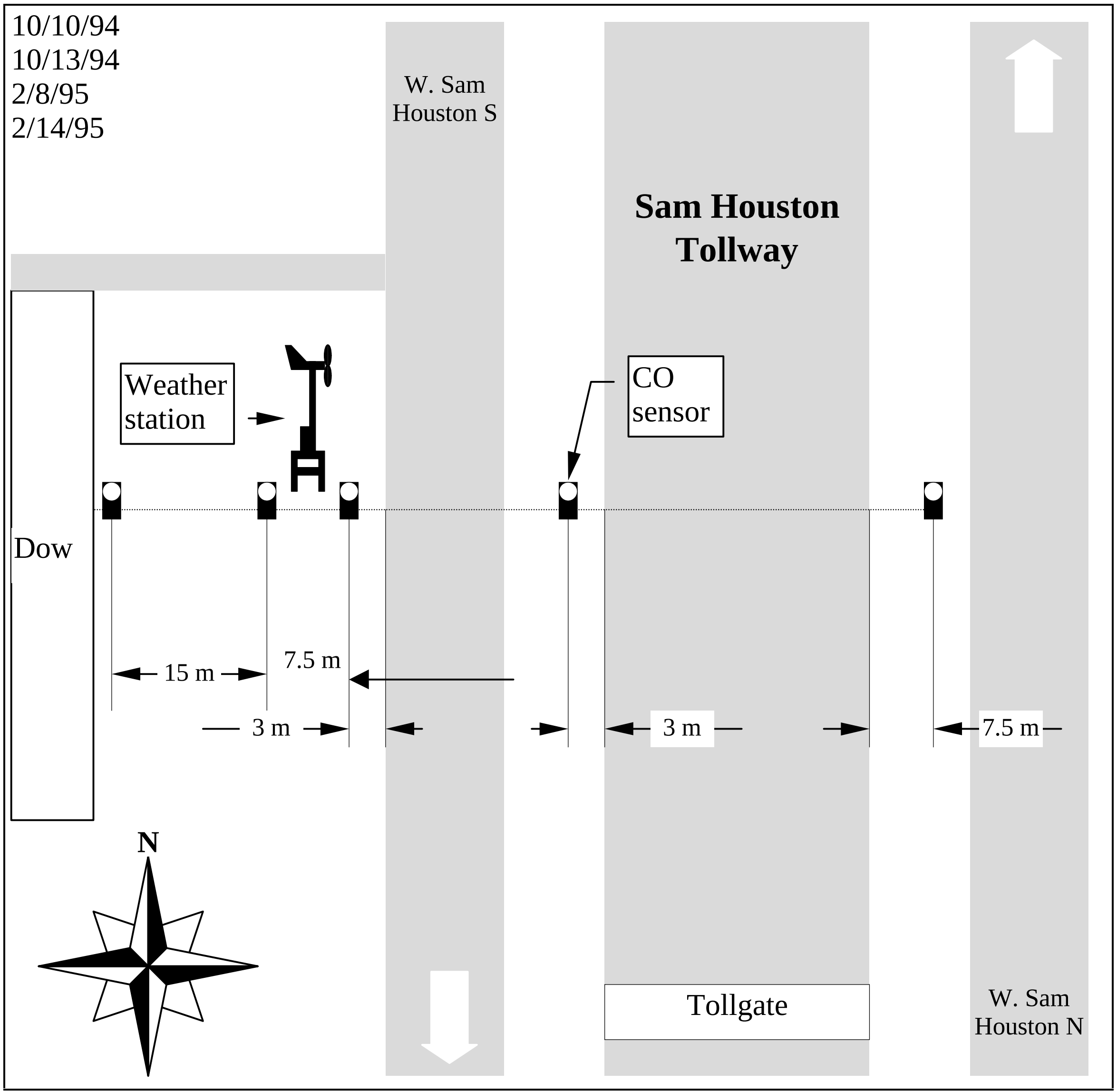

Figure 31. At-grade Site, Houston

San Antonio Area

The team collected nine days of CO data in three different locations of highway 281 in the San Antonio area. Due to personnel limitations, the team did not collect any data in the downtown area, close to I-35. Schematics of the data collection sites are shown in Figures 32 through 34. Traffic data were provided by TTI. The data collection sites were as follows:

Day 1 (3/10/95) - Site: Depressed.
Day 2 (3/13/95) - Site: Elevated.
Day 3 (3/14/95) - Site: At-grade.
Day 4 (3/16/95) - Site: Depressed.
Day 5 (3/17/95) - Site: Elevated.
Day 6 (3/20/95) - Site: At-grade.
Day 7 (3/21/95) - Site: Depressed.
Day 8 (3/22/95) - Site: At-grade.
Day 9 (3/23/95) - Site: Elevated.

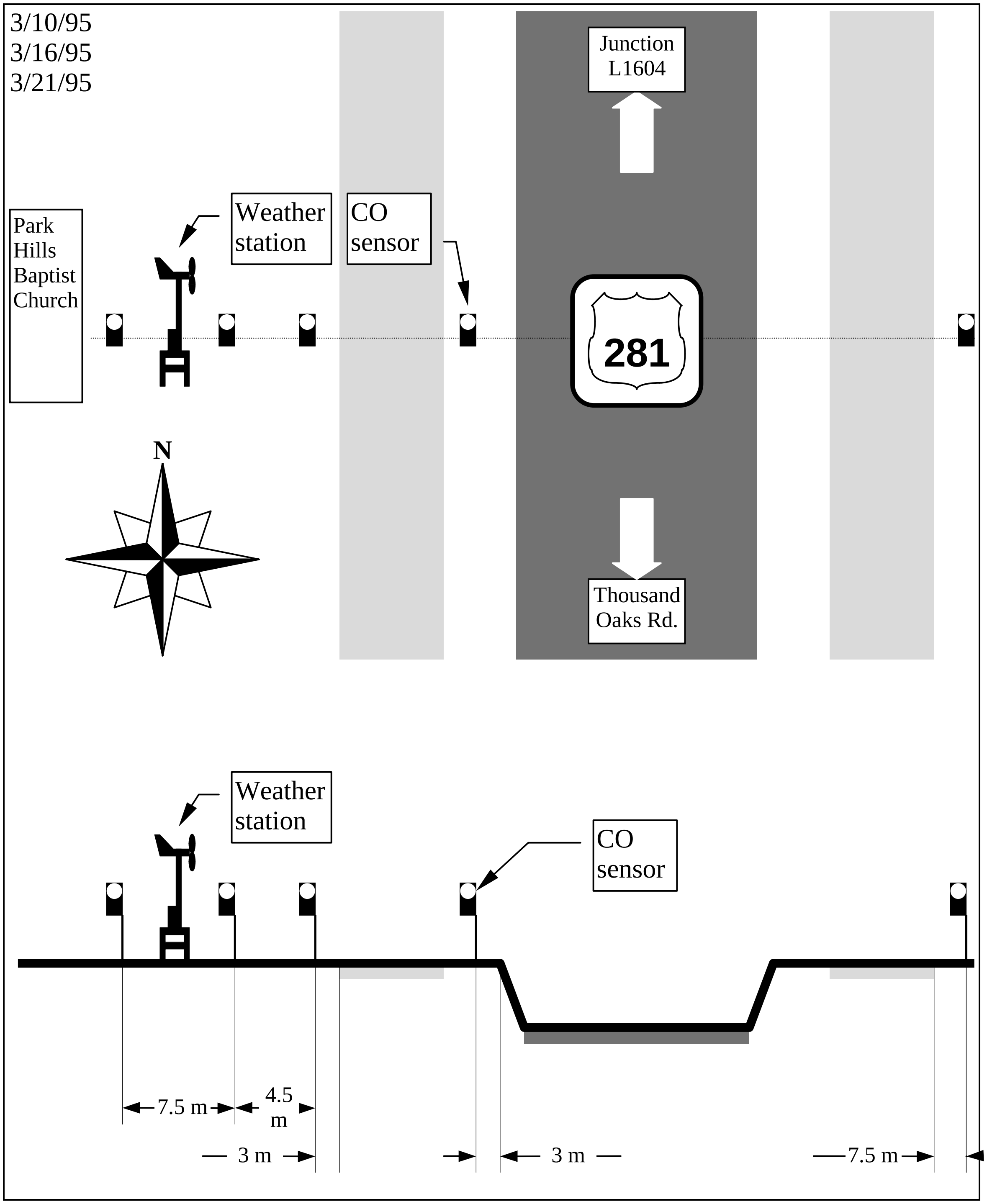

Figure 32. Depressed Site, San Antonio

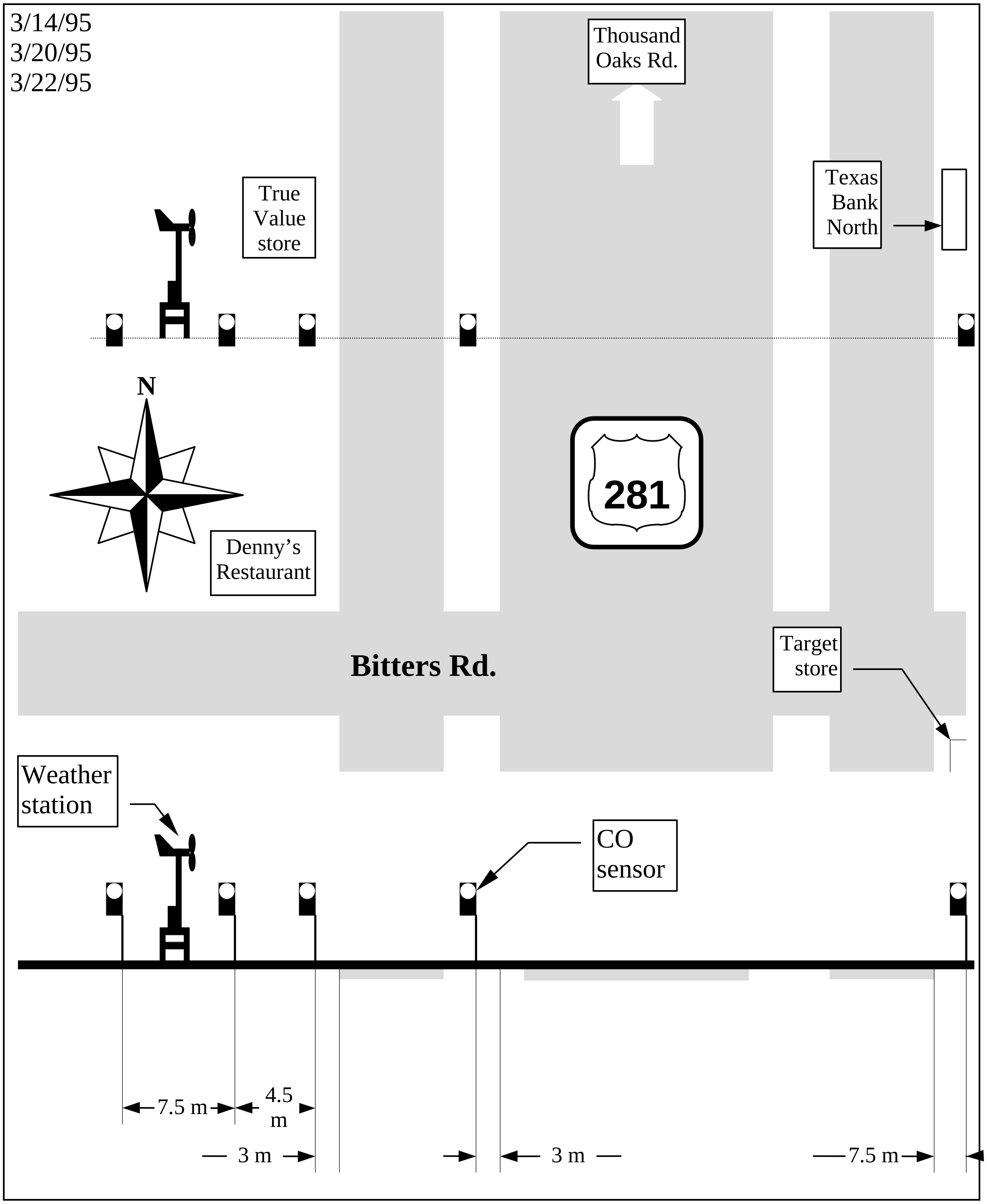

Figure 33. At-grade Site, San Antonio

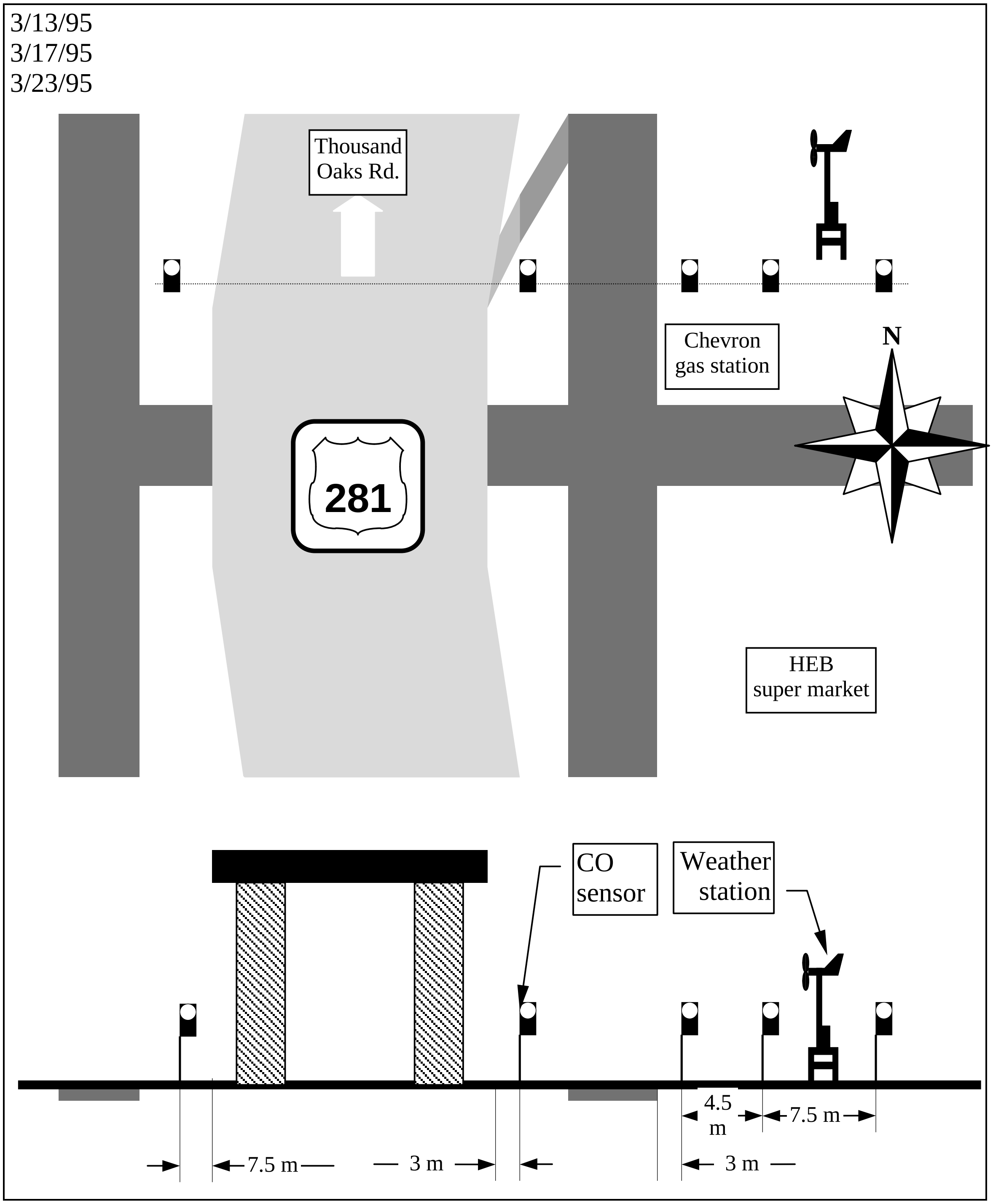

Figure 34. Elevated Site, San Antonio

ANALYSIS

DATA PROCESSING

To analyze the data, the team followed a similar procedure for all sites. That procedure can be summarized as follows:

1. The first step in editing the data is the correction of any incorrect characters written to the text files. The Toxilog text files are usually trouble-free and can be converted to spreadsheet format rather quickly. The weather text files usually have some errors in them. The most common of these is a missing portion of the date or time stamp. Also, spacing between data entries is sometimes incorrect. These are easily corrected using any of the various file editors, including spreadsheets.
2. The next step is to load the data onto spreadsheets. Excel can do this easily using the "Parse data" option. The team found it easiest to store all the CO and weather data for a day's sampling on a single spreadsheet.
3. Synchronize the data by editing out any points that do not have values for all five sensors and corresponding weather data. Also, the STEL and TWA values are not needed and can be dropped from the spreadsheet.
4. The CO contribution from the highway is calculated by taking the difference between the downwind readings and the upwind background reading. The original raw values should be retained with the calculated values on the spreadsheet.
5. The wind speed and solar radiation can be used to assign Pasquill stability classes (Pasquill, 1974). These stability classes are needed to run the CALINE and TXLINE impact prediction models.

DATA REDUCTION

Data are eliminated on the basis of wind direction. When the wind direction is less than 90 degrees from the perpendicular to the roadway, corresponding data points are eliminated. All data where wind is not blowing over roadway is also eliminated. Note that data with wind blowing parallel to the roadway is retained.

CO IMPACT PREDICTION MODEL RESULTS

The team obtained copies of the current (1995) impact prediction models used by TxDOT (CALINE and TXLINE). These copies were installed on the working PC hard drive and diskette at TTI. The input variables that were used are listed below:

- receptor (CO sensor) location,
- recorded wind speed,
- wind direction,
- assigned stability class, and
- traffic count.

A default traffic mix, assigned by the program, was used. Comparisons between model predictions and actual CO measurements are shown in Appendix B.

CONCLUSIONS AND RECOMMENDATIONS

The main conclusion of the preceding analysis is that, on the basis of our data and analysis, there is no evidence of increased CO levels in the vicinity of elevated or depressed freeways, in comparison to at-grade level freeways. In fact, elevated freeways appear to result in slightly lower CO levels than usual. This results is in agreement with what would be expected from elevated freeways, given the possibilities they offer for increased turbulent dispersion of pollutants.

While the evidence provided by our studies is strong, we feel that a more thorough study would provide even more conclusive evidence, as follows: Data should be *simultaneously* collected on elevated, depressed, and at-grade sections of the same freeway. Provided that these freeway sections are not far apart from each other (so that traffic, landscape, and wind patterns could be the same), any differences in CO levels in the vicinity of each section of the freeway would be attributed to its configuration as elevated, depressed, or at-grade. Comparison with mathematical models would be useful but not necessary. In fact, correction factors could be developed for existing models, to account for more accurate predictions for elevated or depressed freeway sections.

This kind of simultaneous collection of data at three locations of a freeway would require additional equipment (10 additional CO sensors and two additional weather stations) and personnel (two additional workers).

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APPENDIX A

COPIES OF THE FORMS USED IN THE INITIAL SURVEY CONDUCTED BY TXDOT TO DETERMINE POSSIBLE SITES

Recent Construction

Estimate the number of **recently constructed** (within the past 10 years) elevated and depressed freeway sections in your District [City].

☐ Number of elevated sections.

☐ Number of depressed sections.

Note: Please list only sections that would be viable for study, that is, sections that involve at least two over/underpasses, or are at least 1/4 mile long.

Give the location and check the descriptive characteristics for each section.

Section Location (Hwy/Fwy Name or Number)*	Elevated	Depressed	Downtown	Suburban	Residential	Commercial	Age of Facility <5yrs	6-10yrs	Facility Length (Miles)	Land Use Map Available	Aerial Map Available

*Please attach map with section identified.

Under Construction

Estimate the number of elevated and depressed freeway sections in your District [City] that are currently **under construction**.

☐ Number of elevated sections.

☐ Number of depressed sections.

Note: Please list only sections that would be viable for study, that is, sections that involve at least two over/underpasses, or are at least 1/4 mile long.

Give the location and check the descriptive characteristics for each section.

Section Location (Hwy/Fwy Name or Number)*	Elevated	Depressed	Downtown	Suburban	Residential	Commercial	Construction Start Date	Facility Length (Miles)	Land Use Map Available	Aerial Map Available

*Please attach map with section identified.

Planned Construction

Estimate the number of **planned** elevated and depressed freeway sections in your District [City].

☐ Number of elevated sections.

☐ Number of depressed sections.

Note: Please list only sections that would be viable for study, that is, sections that involve at least two over/underpasses, or are at least 1/4 mile long.

Give the location and check the descriptive characteristics for each section.

Section Location (Hwy/Frwy Name or Number)*	Elevated	Depressed	Downtown	Suburban	Residential	Commercial	Construction Start Date	Facility Length (Miles)	Land Use Map Available	Aerial Map Available

*Please attach map with section identified.

APPENDIX B

SAMPLE DATA AND COMPARISON BETWEEN CO MEASUREMENTS AND MODEL PREDICTIONS

Figure B1. Map of Dallas Sites

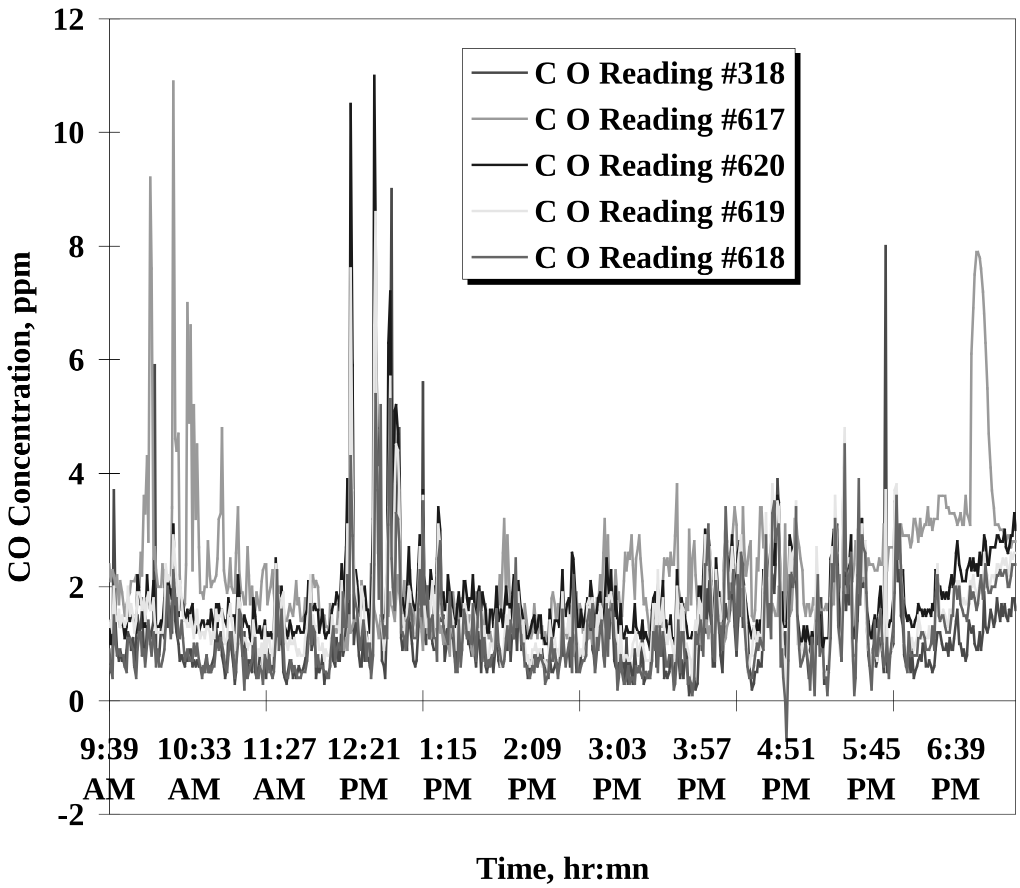

Figure B2. Example of CO Sensor Readings: Dallas, Day 2. Peaks can be noticed during the morning, noon, and afternoon rush hours

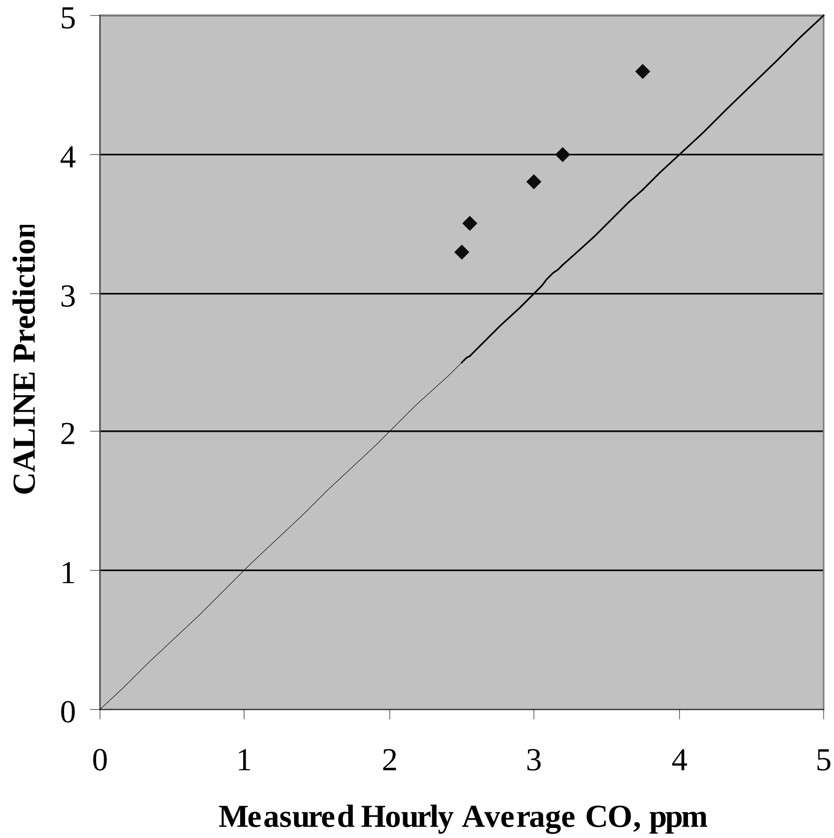

Figure B3. Dallas, Day 2: At-grade Section

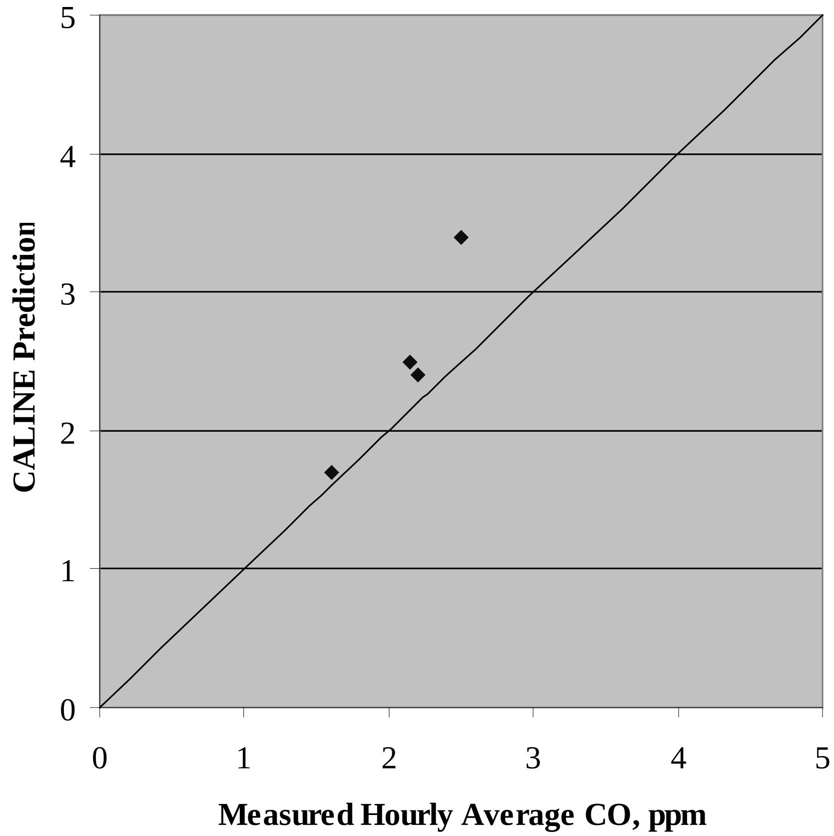

Figure B4. Dallas, Day 3: Elevated Section

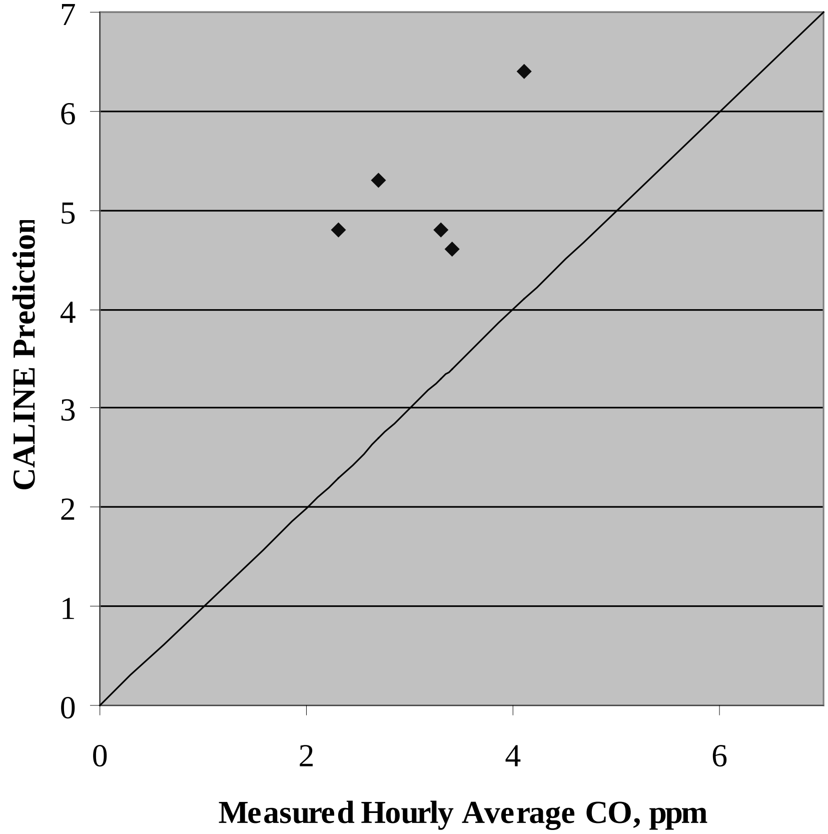

Figure B5. Dallas, Day 5: Depressed Section

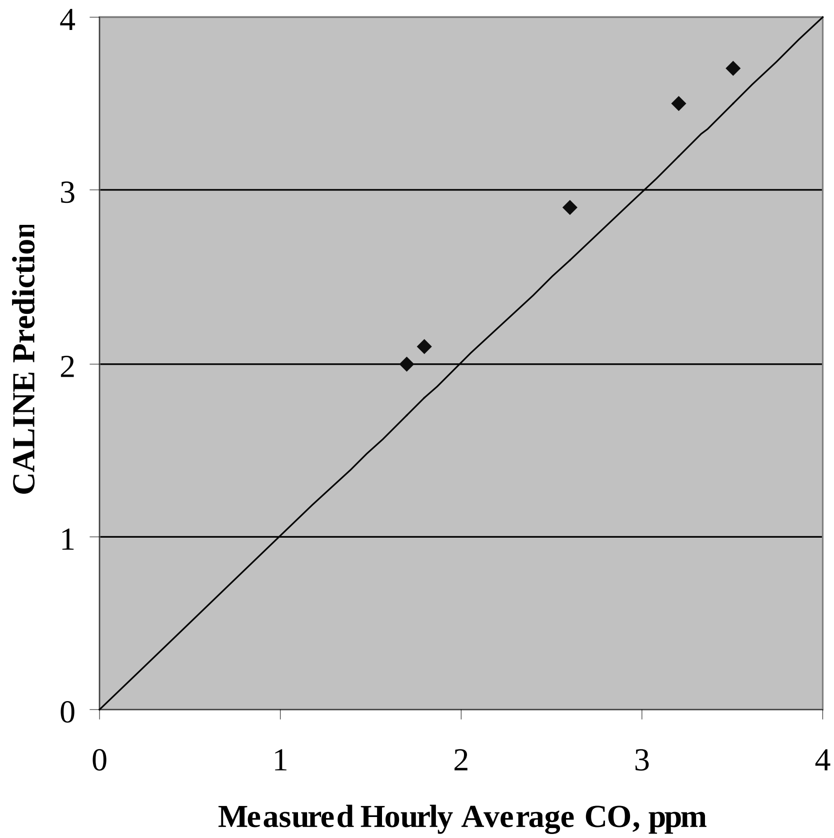

Figure B6. Dallas, Day 6: Depressed Site

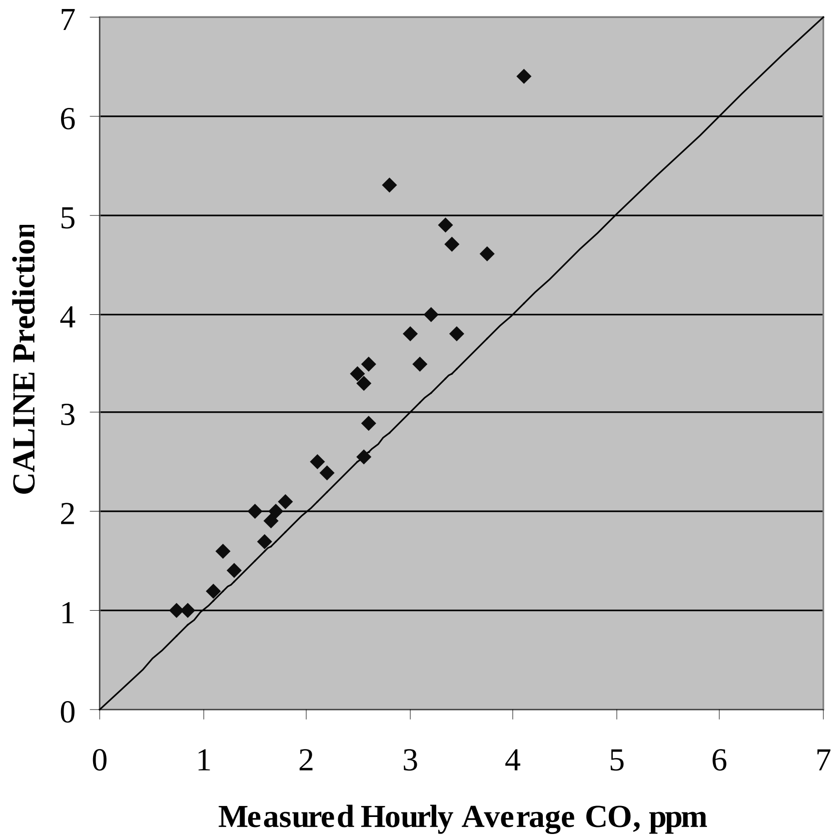

Figure B7. Dallas, 8 Days, 4 Locations (At-grade, Elevated, and Depressed)

Figure B8. Map of Lubbock Sites

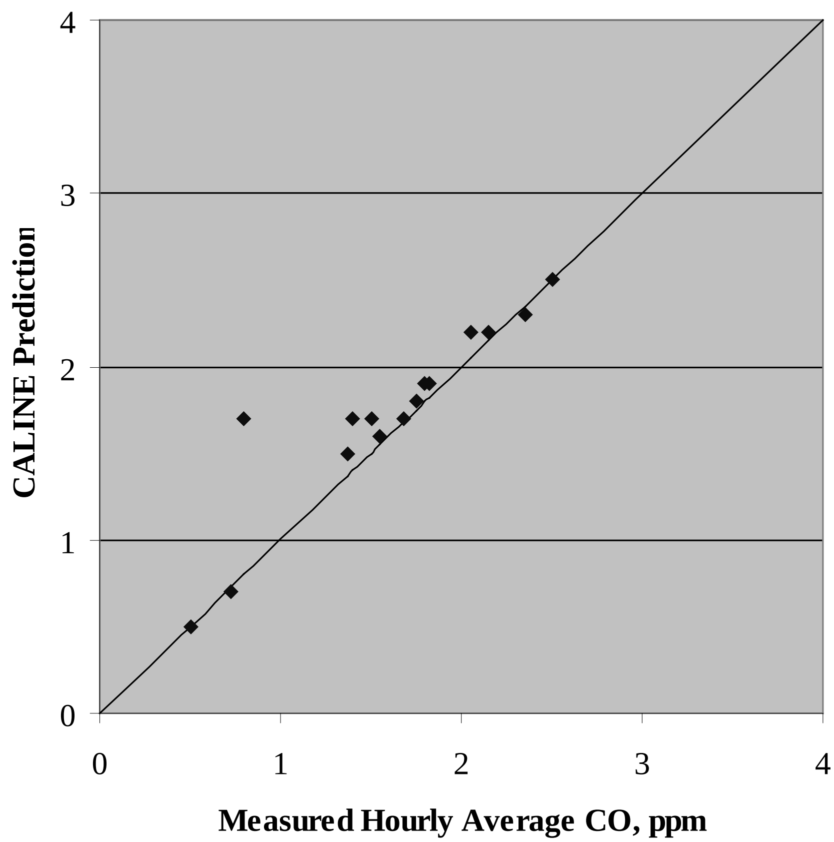

Figure B9. Lubbock, Day 1: Depressed Site

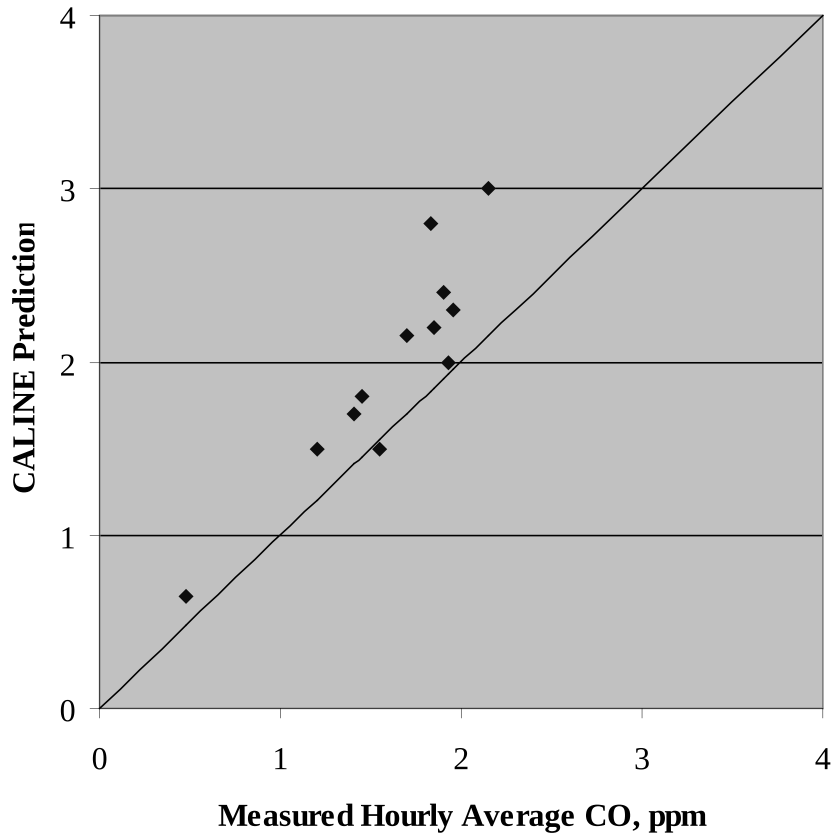

Figure B10. Lubbock, Day 2: Depressed Site

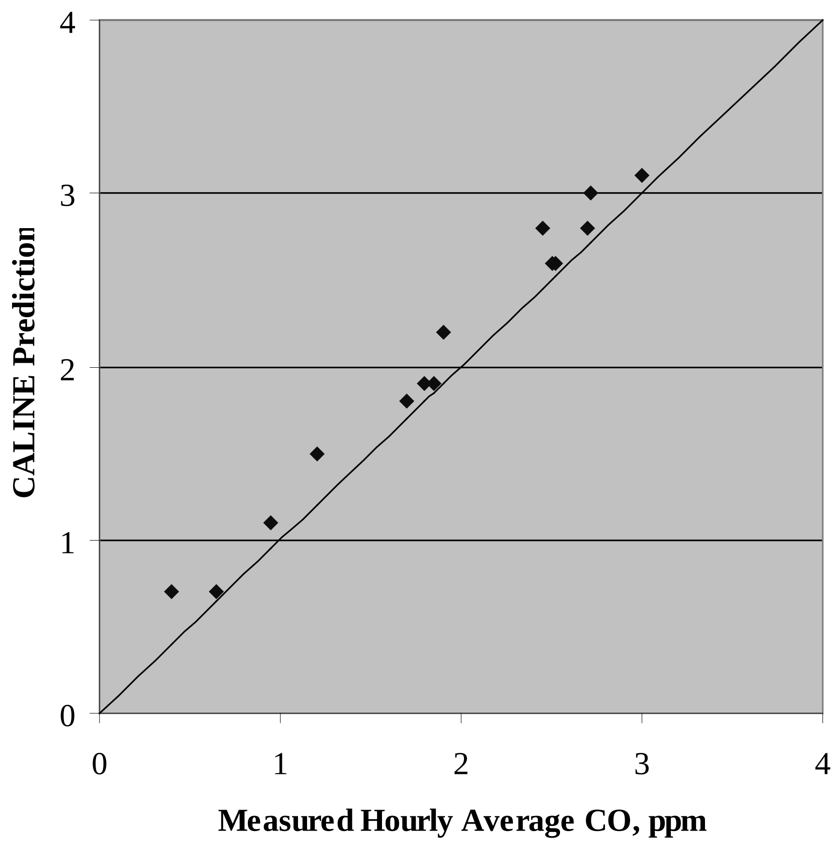

Figure B11. Lubbock, Day 3: Depressed Site

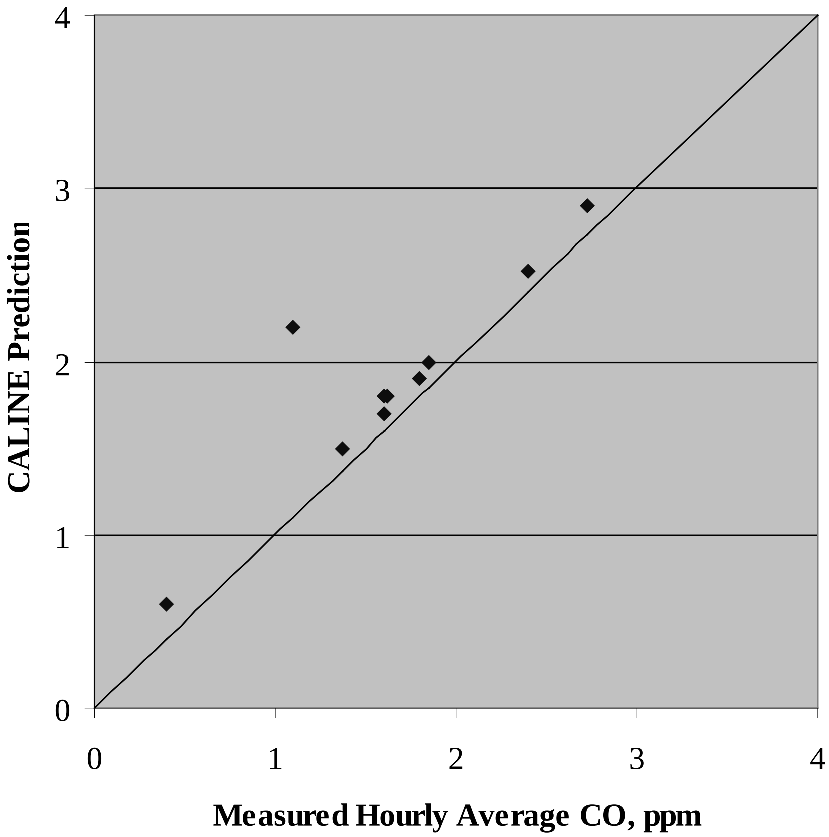

Figure B12. Lubbock, Day 4: Depressed Site

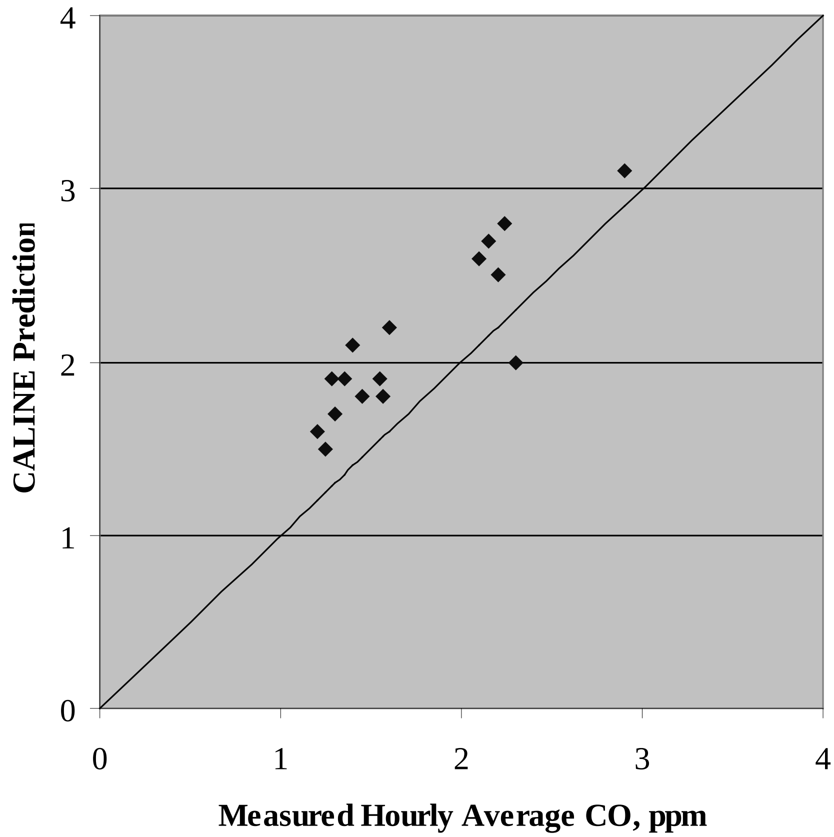

Figure B13. Lubbock, Day 5: Elevated Site

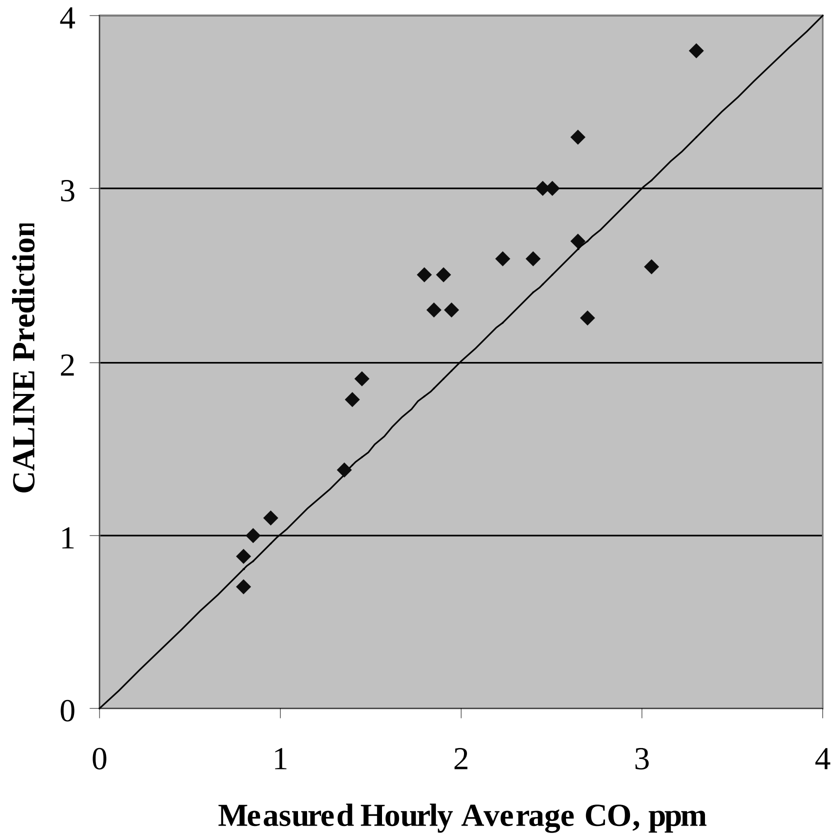

Figure B14. Lubbock, Day 6: Elevated Site

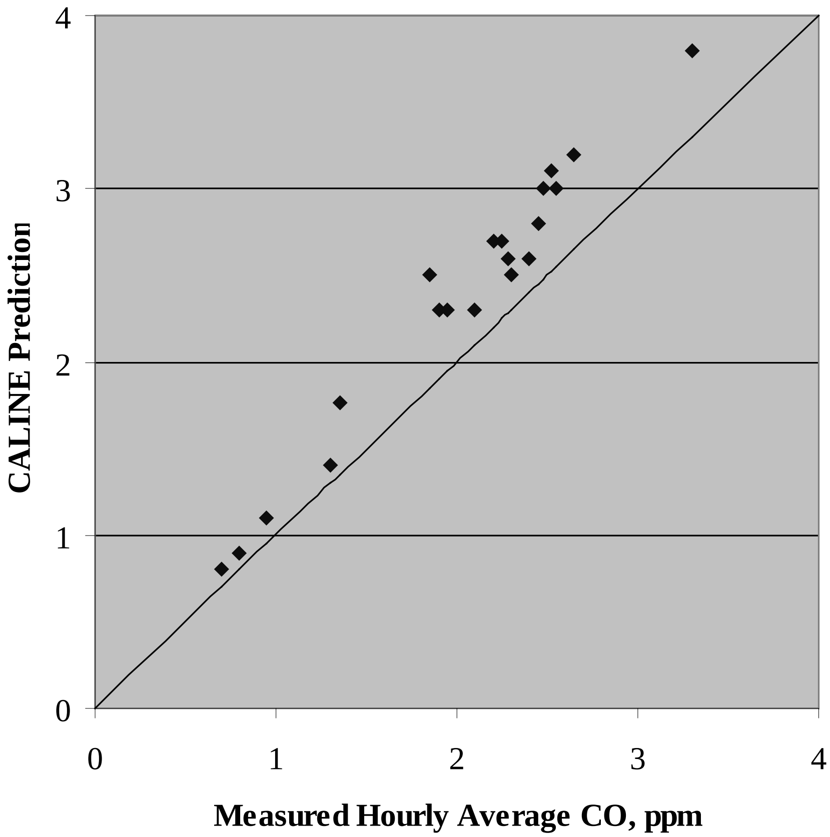

Figure B15. Lubbock, Day 7: Elevated Site

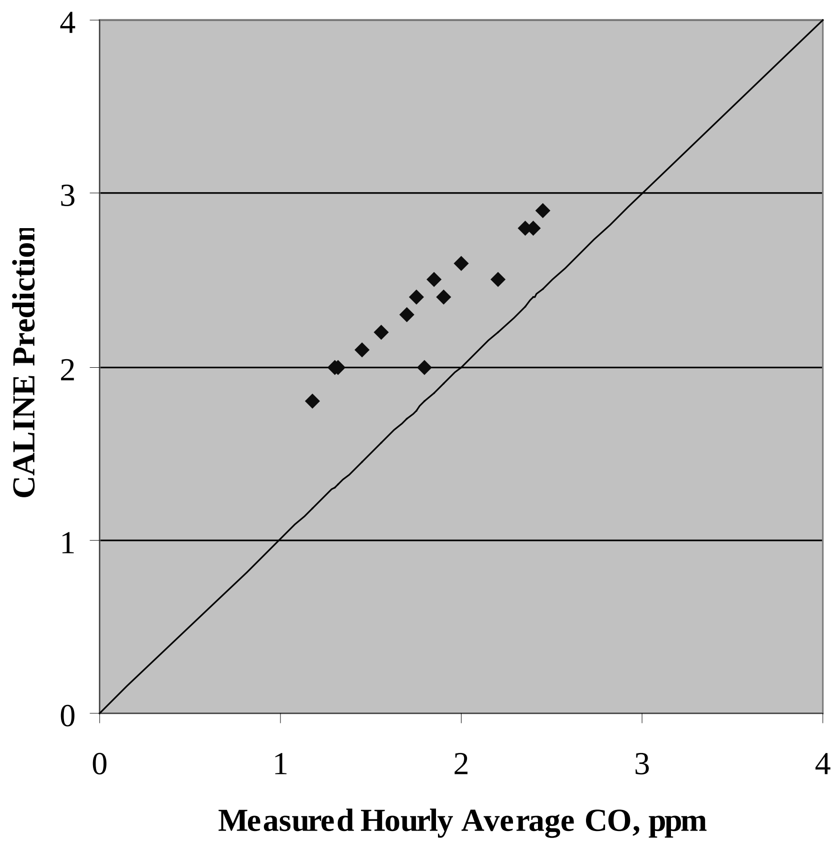

Figure B16. Lubbock, Day 8: Elevated Site

Figure B17. Map of Houston Sites

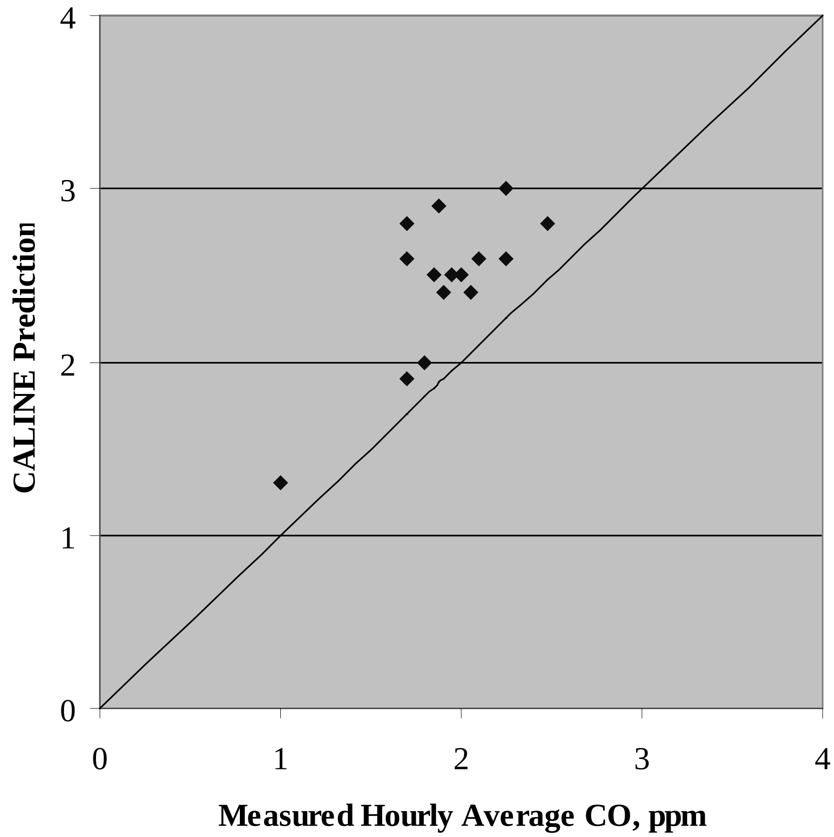

Figure B18. Houston, Day 1: At-grade Site

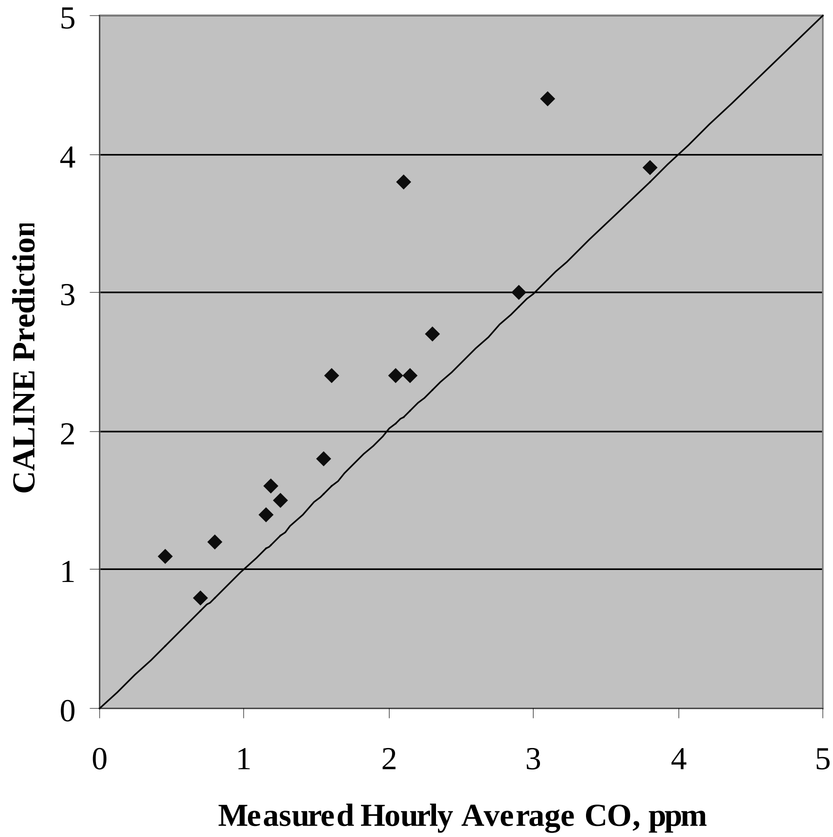

Figure B19. Houston, Day 2: Elevated Site

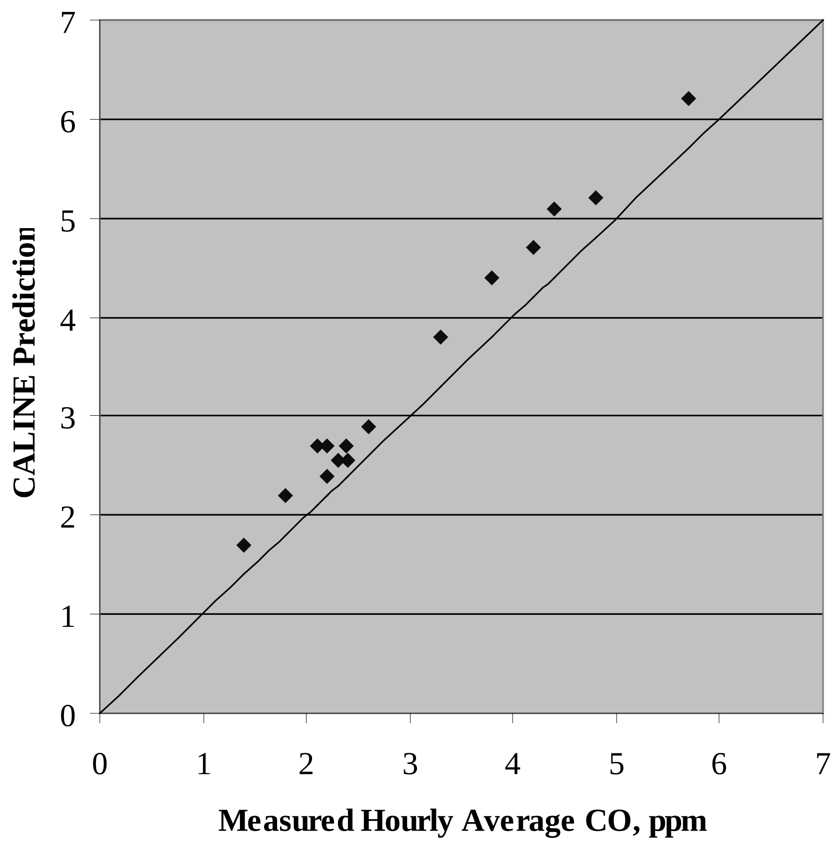

Figure B20. Houston, Day 3: Depressed Site

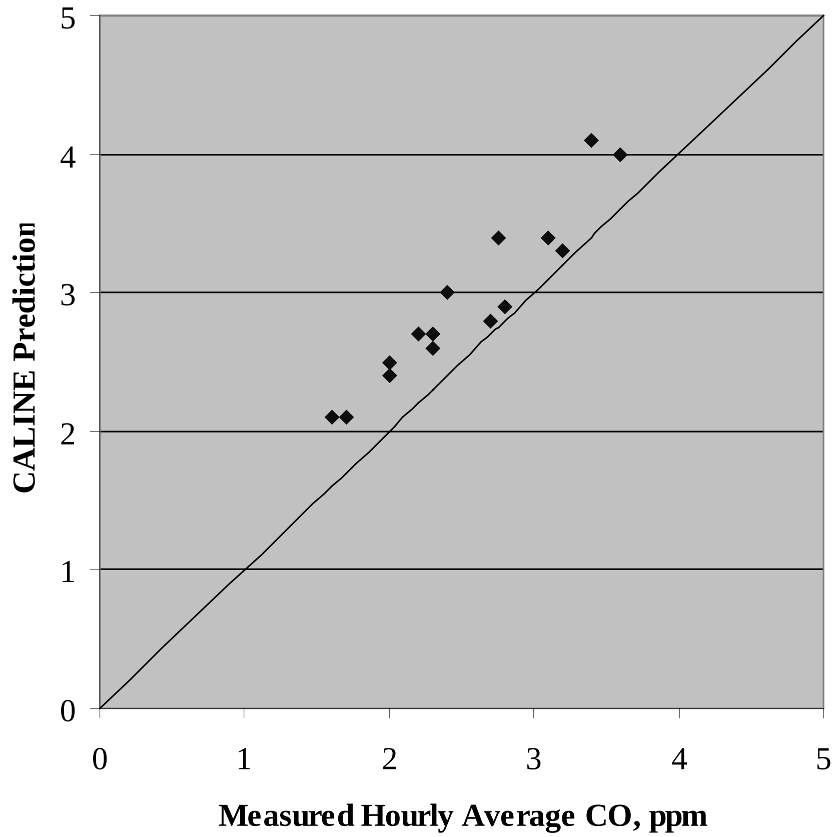

Figure B21. Houston, Day 4: At-grade Site

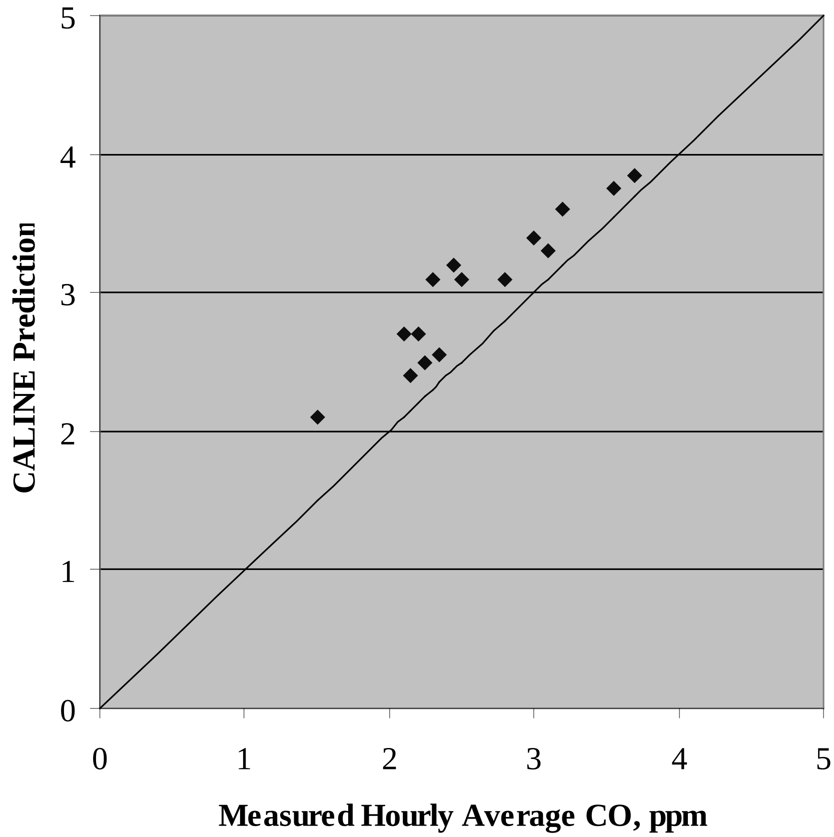

Figure B22. Houston, Day 6: Depressed Site

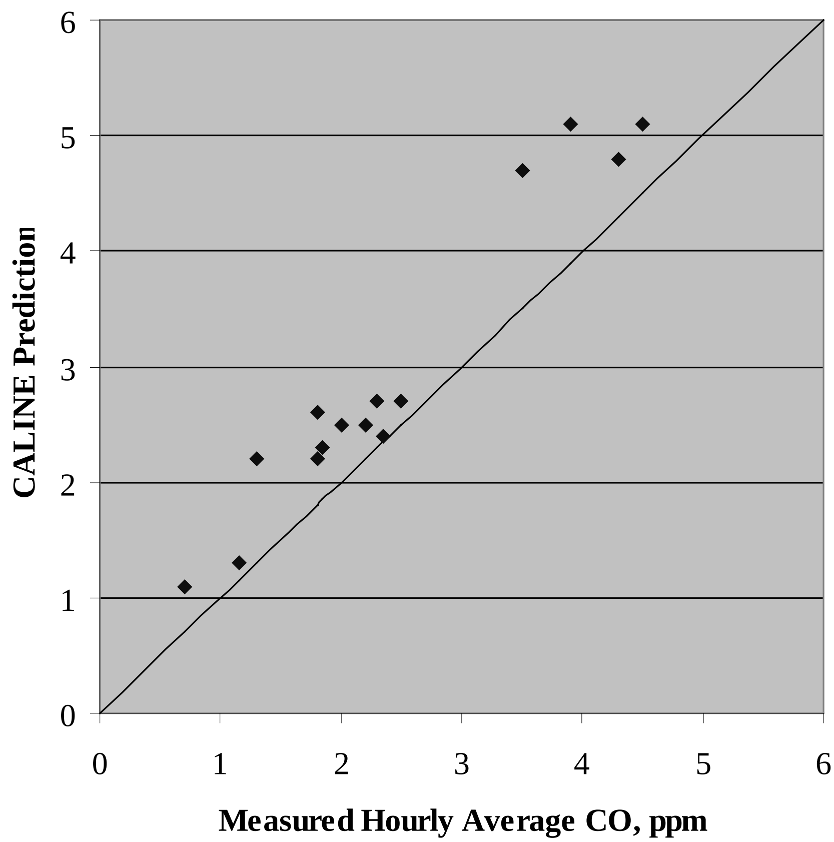

Figure B23. Houston, Day 7: At-grade Site

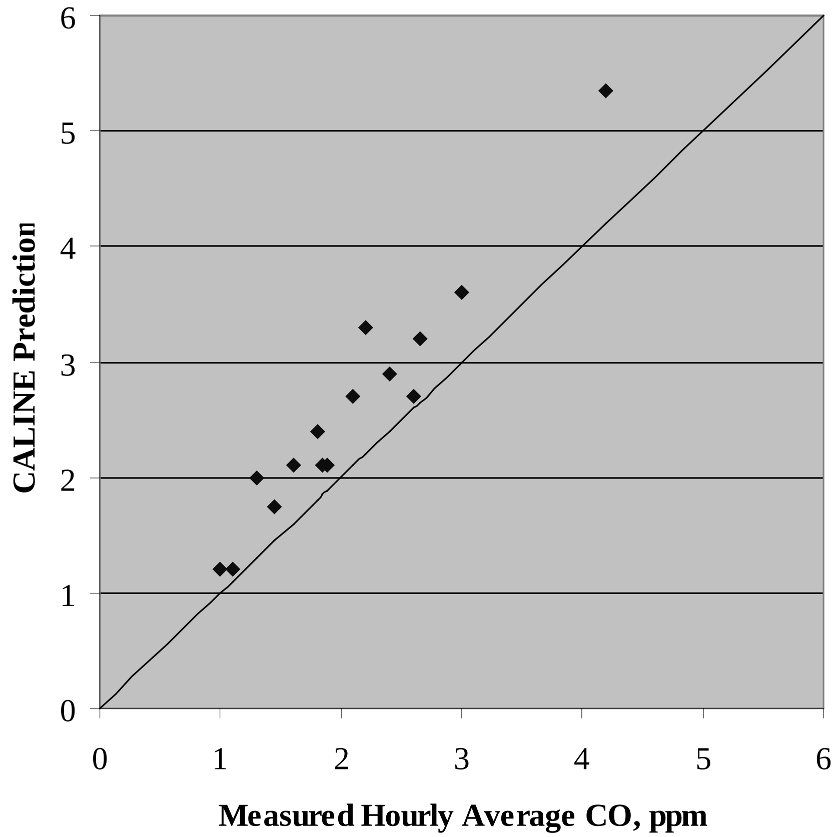

Figure B24. Houston, Day 8: Elevated Site

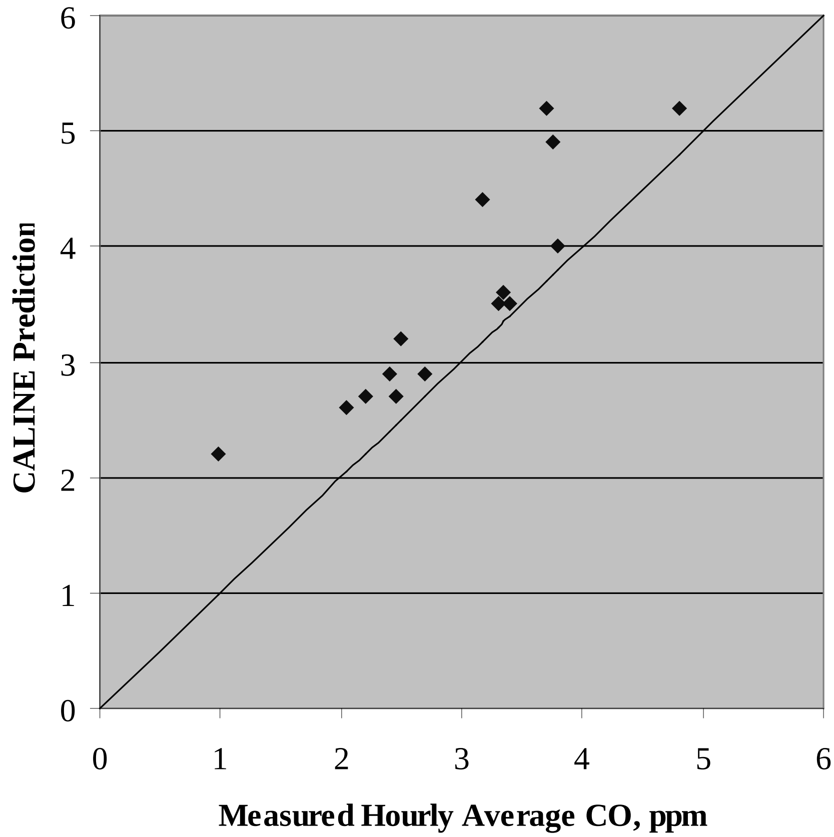

Figure B25. Houston, Day 9: Depressed Site

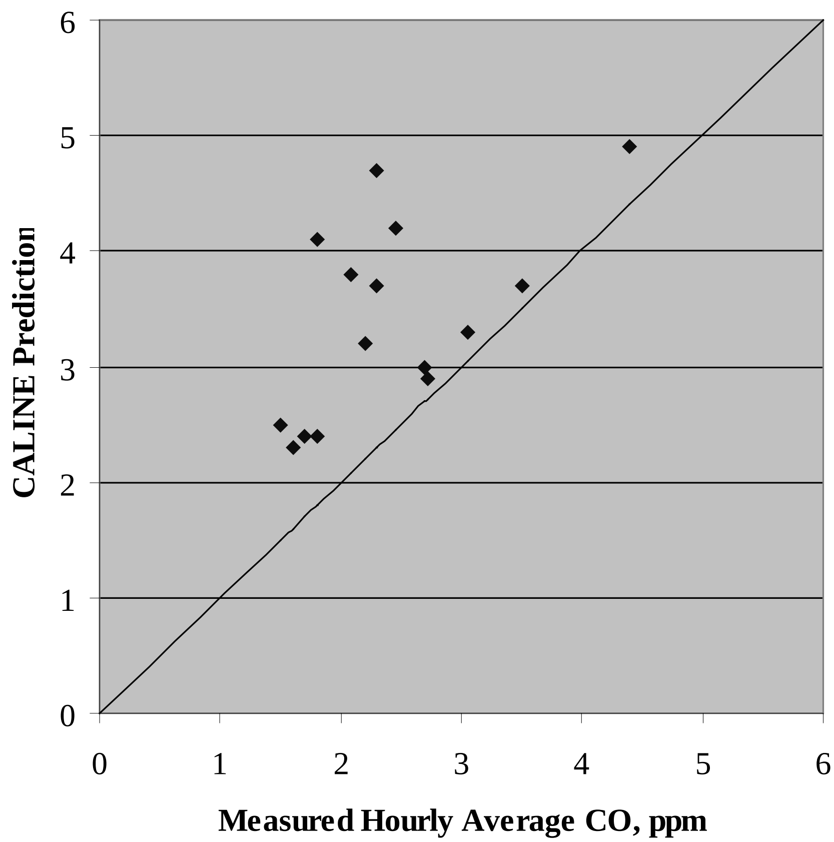

Figure B26. Houston, Day 10: At-grade Site

Figure B27. Map of San Antonio Sites

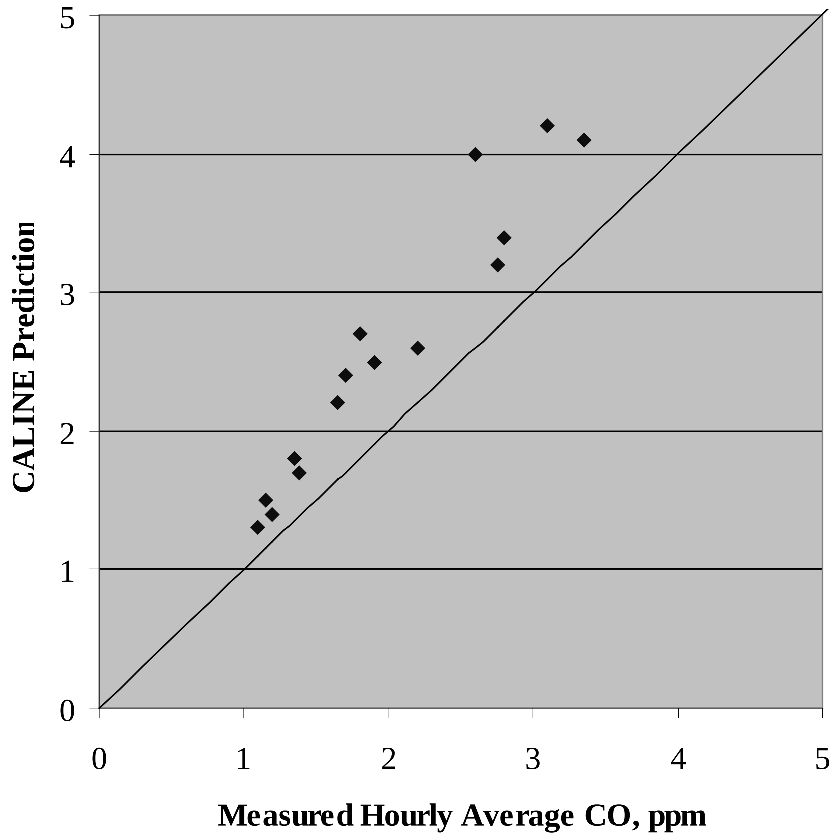

Figure B28. San Antonio, Day 1: Depressed Site

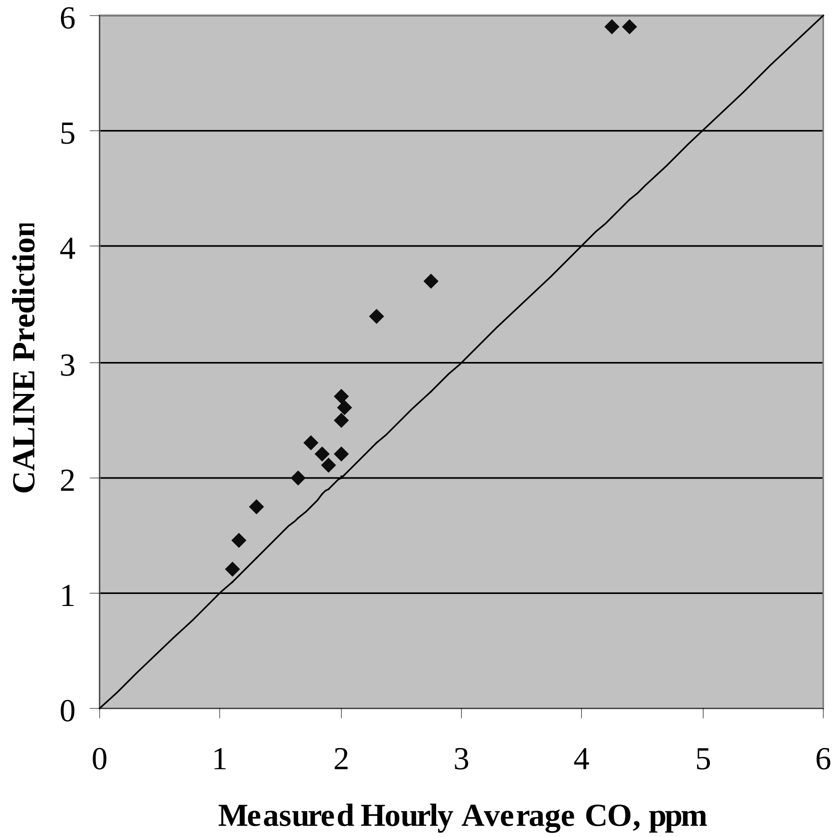

Figure B29. San Antonio, Day 2: Elevated Site

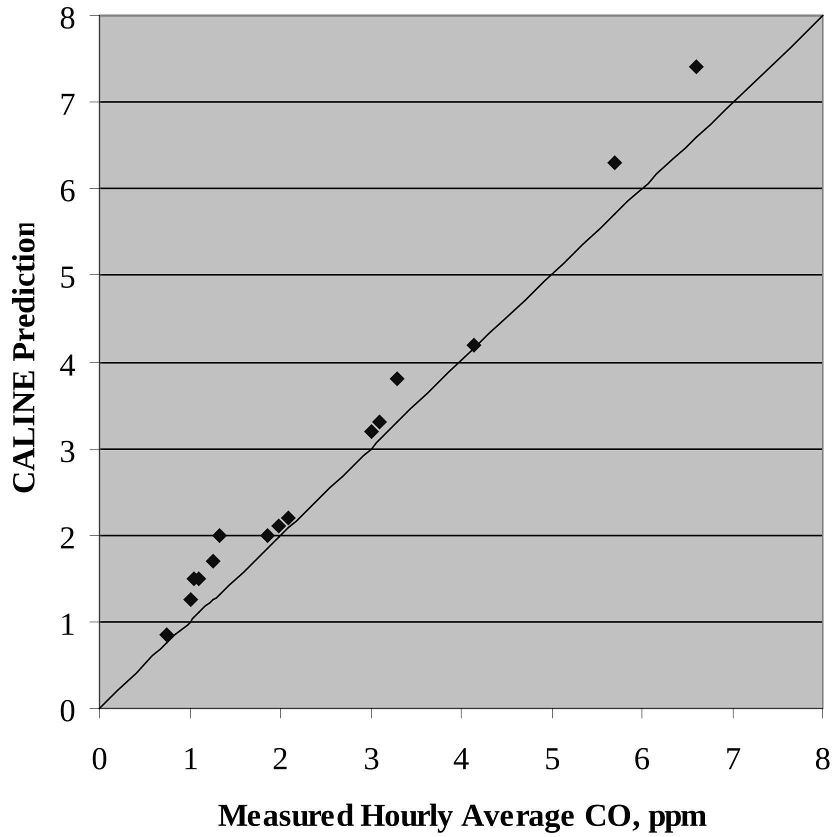

Figure B30. San Antonio, Day 3: At-grade Site

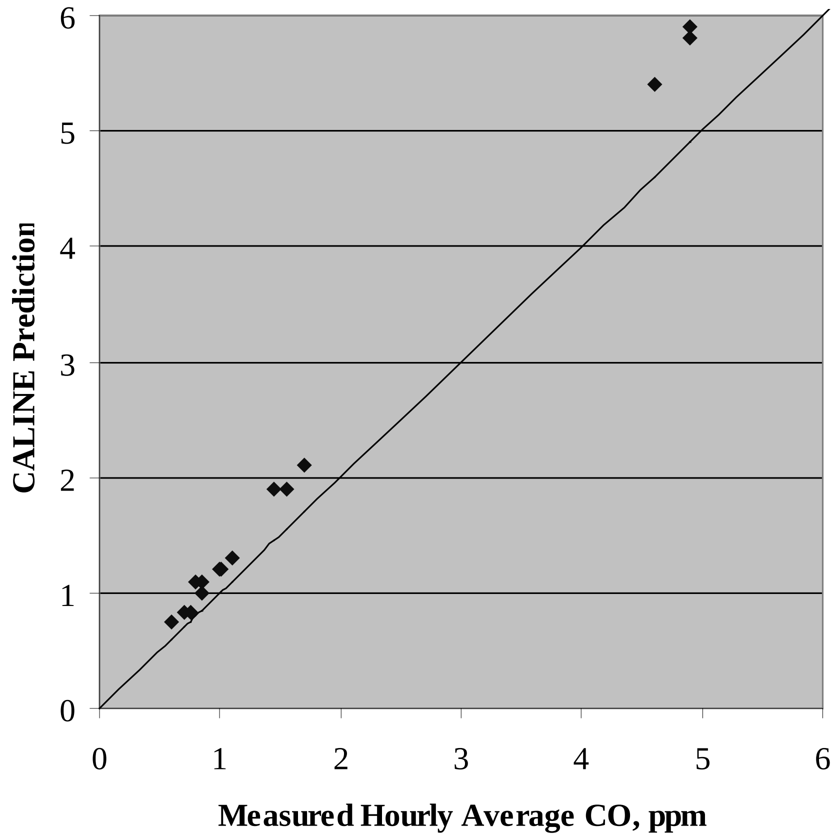

Figure B31. San Antonio, Day 4: Depressed Site

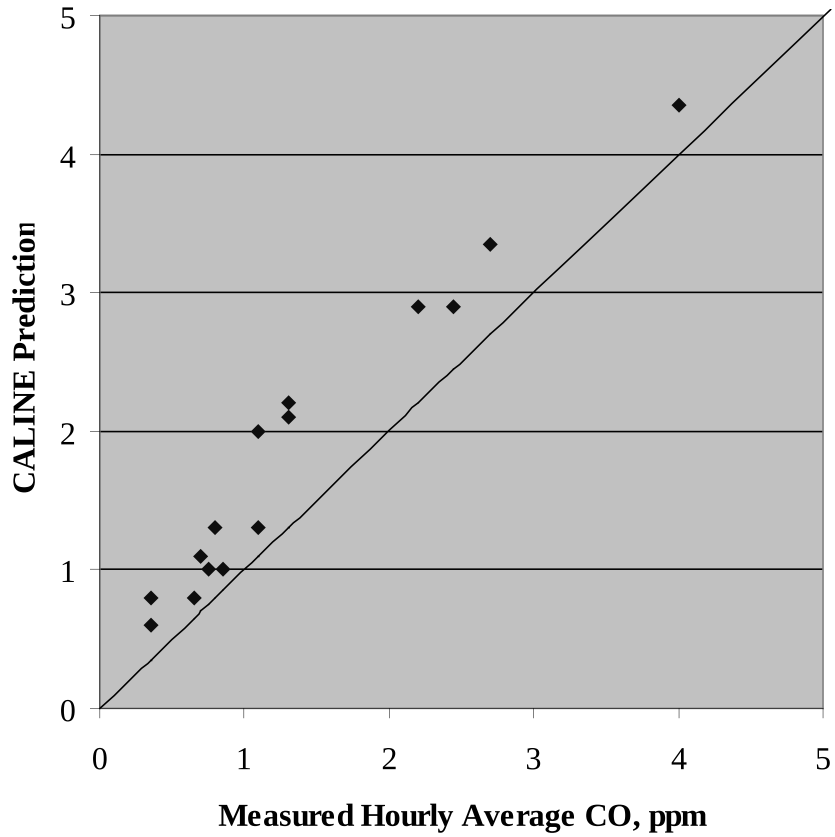

Figure B32. San Antonio, Day 5: Elevated Site

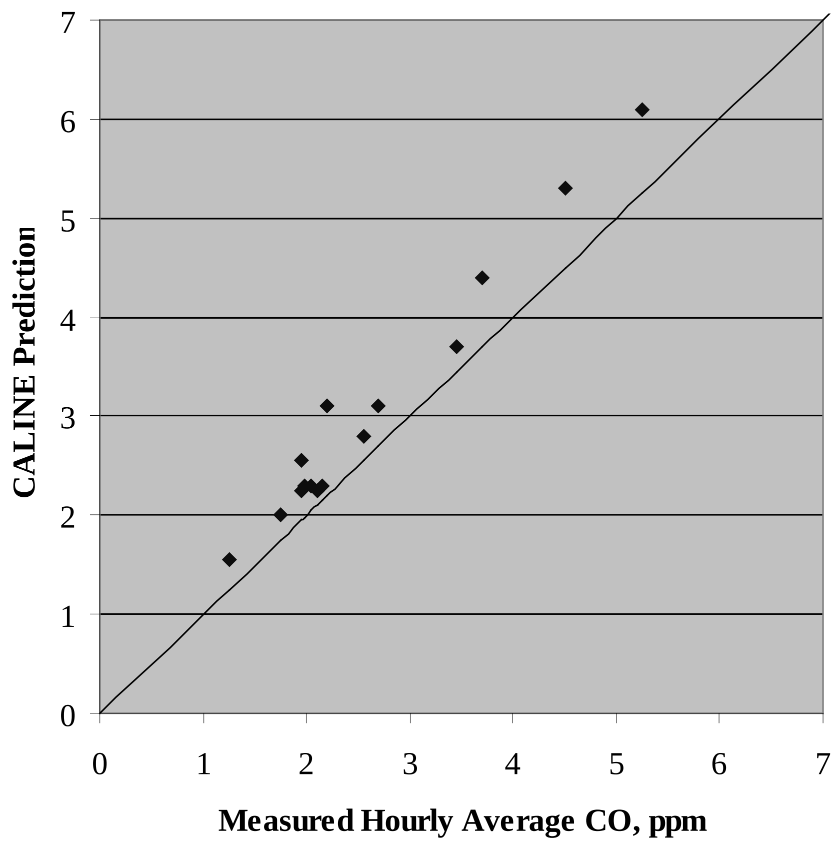

Figure B33. San Antonio, Day 6: At-grade Site

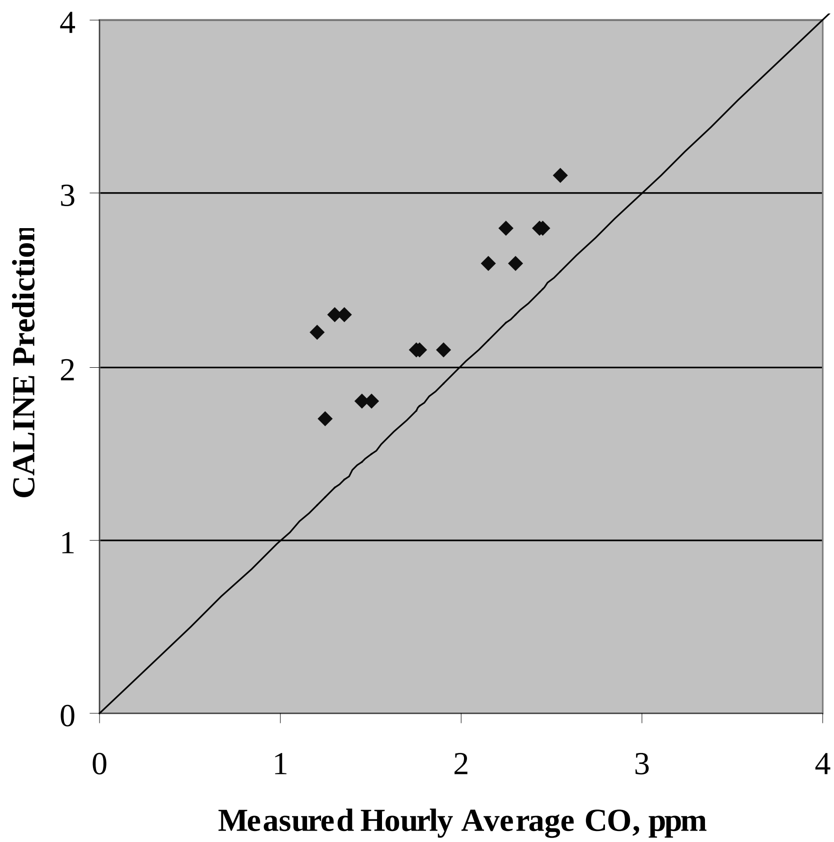

Figure B34. San Antonio, Day 7: Depressed Site

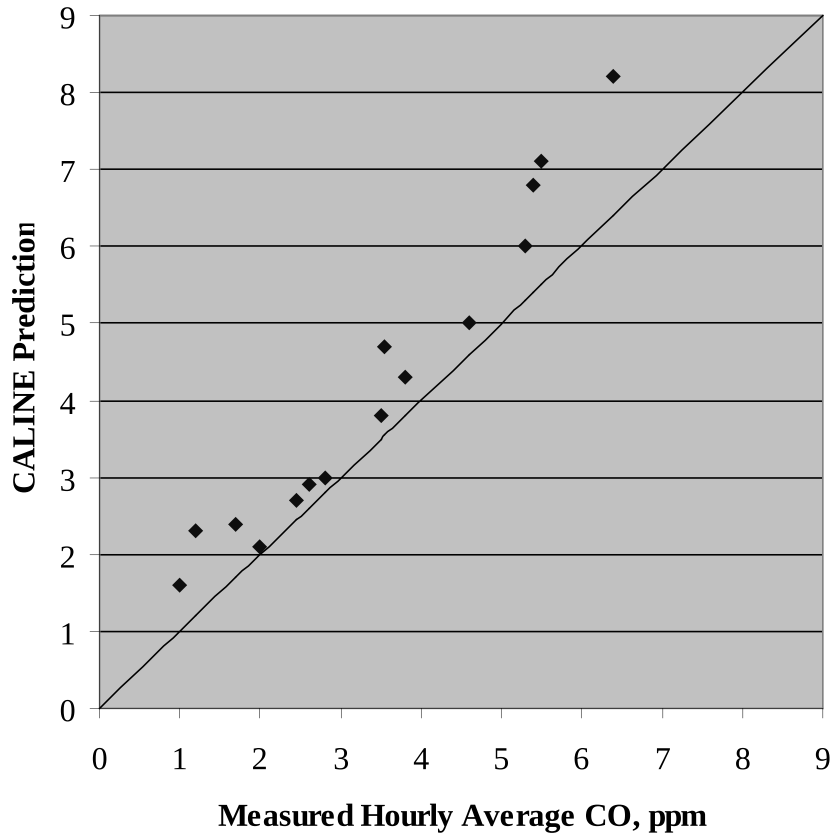

Figure B35. San Antonio, Day 8: At-grade Site

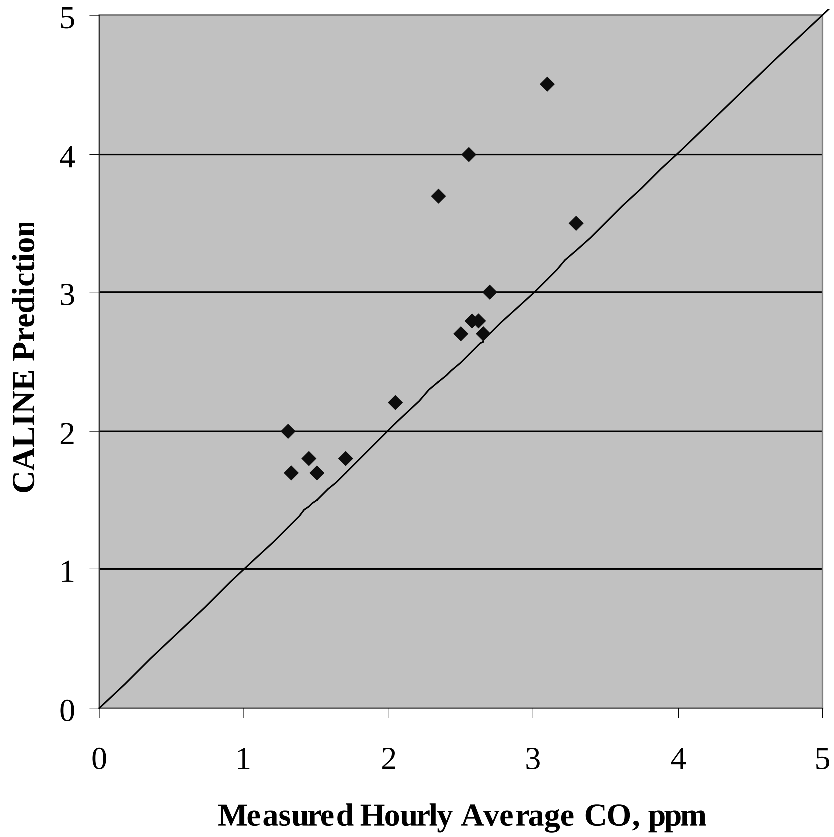

Figure B36. San Antonio, Day 9: Elevated Site