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16. ABSTRACT

Carbon Monoxide and other pollutants were monitored at an intersection with U.S. Highway 50 in the South Lake Tahoe area for seventeen days during the month of February 1978. The weather patterns during the monitoring program included periods of heavy snowfall and significant windflow as well as calm clear cold days. The CO concentrations measured near the intersection were much higher than those observed at the local regional monitoring stations.

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REPORT NO. CA-TL-79-11

SOUTH LAKE TAHOE COLD WEATHER CARBON MONOXIDE AND HYDROCARBON STUDY

FINAL REPORT

MAY 1979

Caltrans
CALIFORNIA DEPARTMENT OF TRANSPORTATION

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STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF CONSTRUCTION
OFFICE OF TRANSPORTATION LABORATORY

June 1979

TL No. 657307

Mr. C. E. Forbes
Chief Engineer

Dear Sir:

I have approved and now submit for your information this final research project report titled:

SOUTH LAKE TAHOE
COLD WEATHER
CARBON MONOXIDE & HYDROCARBON
STUDY

Study made by ..... Enviro-Chemical Branch

Under the Supervision of ..... Earl Shirley, P.E.
Roy Bushey, P.E.

Principal Investigator ..... Kenneth O. Pinkerman, P.E.

Field Work Performed by ..... Orvis Box - TransLab
Robert Cramer - TransLab
Norman Baker - District 03
Jerry Antonetti - District 03

Report Prepared by ..... Kenneth O. Pinkerman

Very truly yours,

Neal Andersen

NEAL ANDERSEN
Chief, Office of Transportation Laboratory

Attachment

KOP:lb

ACKNOWLEDGEMENTS

This study was a combined effort of the Transportation Laboratory's Enviro-Chemical Branch, Air Quality Section, and District 03 Air Quality Planning Section.

The District 03 Traffic Census Section was responsible for obtaining the traffic counts and Mr. Jim Baetge of the California Tahoe Regional Planning Agency provided the time delay studies. Special acknowledgements are due to Norman Baker and Jerry Antonetti, District 03, and Orvis Box and Robert Cramer, whoe efforts made this study possible.

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INTRODUCTION

Over the past six to eight years the Enviro-Chemical Branch, Air Quality Section, has been developing and validating theoretical mathematical methods (models) to predict dispersion of vehicle pollutants. One of the more basic models (Cal%DISP) was developed to predict Carbon Monoxide (CO) dispersion from a line source (highway) under cross wind conditions. This model was calibrated with field data from an early study in New York. After gathering field data in Los Angeles from a CO bag sampling program, the model was modified and reformulated into CALINE 2. Since 1972 this model has been used by California and other states for predicting CO concentrations in the microscale area.

In the past few years, the development of recreational areas for snow skiing has placed demands on the roadways in several mountain areas. This increased traffic load during cold atmospherically stable high elevation conditions has triggered several requests to gather data which could be used to validate or modify CALINE 2 for predicting CO concentrations for future highway improvements under these conditions. There have been only scattered brief studies that have produced data for these conditions. One such monitoring program was conducted in South Lake Tahoe by Caltrans District 03 during the winter of 1975. However, it only covered one weekend. Most high elevation studies have been directed at summer conditions and photochemical smog formation.

Because of the previous experience monitoring pollutants in the South Lake Tahoe (1) area and due to the fact that atmospheric conditions in the Tahoe Basin are very conducive to high pollutant levels, TransLab looked at this area for cold weather air monitoring. The meteorological conditions in the basin, unless a storm is in progress, are very stable, especially at night. These conditions retard the dispersion of pollutants from their sources and concentrations build up. Compounding the problem is the fact that, in high altitudes and cold temperatures, vehicle engines have higher emission levels. These are attributed to richer mixtures and longer warm-up times.

Therefore, because of the heavy winter traffic and stable atmospheric conditions, it was decided to monitor pollutants in the South Lake Tahoe area in February of 1978. A site 1/2 mile south of Stateline at the intersection of Park Avenue and Highway 50 was selected for monitoring. This site provided heavy traffic and snow cleared areas for bag sampler placement both up wind and down wind of the facility. In addition it allowed for the monitoring of pollutant concentrations at nearby receptors both inside and outside of buildings.

With one van equipped with carbon monoxide (CO), ozone (O_3), oxides of nitrogen (NO_x), and a hydrocarbon analyzer (THC) on the south corner of the intersection, seven bag samplers in surrounding locations, and one CO analyzer in the adjoining motel, the area was covered extensively.

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(1)a. Air Quality Report on the Tahoe Basin - Caltrans, Dist. 03, 1975.

b. Air Pollution Concentrations in the Tahoe Basin - Caltrans, Dist. 03, 1978.

c. Concentrations of Carbon Monoxide South Lake Tahoe/ Hwy 50, Caltrans, Dist. 03, 1977.

CONCLUSIONS

1. CO concentrations are much higher at ground level near the source under cold weather conditions and ground based inversions than indicated by the local monitoring stations.

2. Even under adverse dispersion conditions CO concentrations approach background levels 250 to 300 ft downwind.

3. Other health related pollutants (O_3, NO_2, etc.) are not found in significant concentrations during the winter season.

4. Local receptors near the intersection monitored (sidewalk and nearby commercial buildings) are exposed to CO levels above the California 6 ppm 8-hour standard on a regular basis during stable atmospheric conditions.

RECOMMENDATIONS

Further studies should be performed in the summer to analyze hydrocarbon, oxides of nitrogen, and ozone levels in the Tahoe Basin. (Some data have been provided by a District 03 study in the summer of 1978.)

DISCUSSION

Meteorology

There were considerable variations in the weather patterns. There were periods of heavy snowfall and significant windflow and also periods of calm, clear, and cold weather.

As might be expected, the concentrations of carbon monoxide were greater during the absence of weather fronts when cold stable conditions prevailed. This was amplified even more during nighttime conditions when ground based temperature inversions formed. The meteorological tower located near location 100 (see Figure 1) was equipped with temperature sensors at 5 and 20 feet above the surface. These sensors gave a continuous record of temperature and temperature difference between the two heights. This datum indicates a surface based inversion occurred normally between 2000 and 0800 hours every night (2/15/78 through 2/27/78).

The wind flow naturally varied and was influenced by the passing weather fronts. At the Park Avenue location, the winds during the stormy weekend of February 11, 1978, were usually from approximately 245° at 4 to 6 mph. During the following weekend (2/18 through 2/20), when conditions were more stable, the wind flow followed an expected diurnal pattern. During the day (0800 to 1700 hours) the winds were from a direction of 290° to 30° (west to N. East) at a speed of 4 to 6 mph. During the nighttime, the winds shifted abruptly coming from 115° to 130° (southeast) at approximately 2.5 mph.

Hourly average wind and temperature data are available for this site. They have been excluded from this report due to the volume of data.

Sampling Procedures and Analyzers

The sampling was done over a period of 17 days using a mobile van and numerous automatic bag samplers. The van was equipped with the following monitoring equipment:

1. Beckman 315 BL Non-Dispersive Infrared Analyzer for carbon monoxide (CO).

2. Thermoelectron Series 14 Chemiluminescence Analyzer for oxides of nitrogen (NO, NO_2 and NO_x).

3. Dasibi 1003AH Ultraviolet Light Absorption Analyzer for Ozone (O_3).

4. Bendix Model 8201 Gas Chromatograph Analyzer for hydrocarbons (total hydrocarbons, THC; methane CH_4; and non-methane hydrocarbons, NMHC).

5. TechEcology Wind Sensors: Wind Speed (Model 010), Wind Direction (Model 020), Signal Conditioning Translator (Model 100).

6. Data Acquisition System: Datel Magnetic Tape Data Recording System; Esterline Angus Miniservo Recorders for each data channel.

The bag samplers were placed at various locations (Figure I) near the highway intersection to obtain CO concentration patterns. The sampler intake height was 5± feet above the ground surface. These units obtained an integrated sample over a one hour period and stored it to be retrieved and analyzed a few hours later. An additional Beckman 315BL CO analyzer was located in a motel room near the sampling location and was used for bag sample analysis.

The following table is a schedule of the sampling period, pollutants measured, and the equipment used. Figure 1 shows the sample location numbers. Figures 2 through 10 show site locations and equipment utilized to obtain and analyze samples.

Table I

Location No.	Time Period	Equipment Used	Pollutants CO	THC	RCH	CH_4	NO_x	NO	NO_2	O_3
100	2/9-2/26/78	Mobile Van	X	X	X	X	X	X	X	X
101	2/9-2/27/78	Bag Sampler	X							
102	2/9-2/27/78	Bag Sampler	X							
103	2/9-2/27/78	Bag Sampler	X							
104	2/9-2/27/78	Bag Sampler	X							
105	2/9-2/27/78	Bag Sampler	X							
106	2/9-2/27/78	Carbon Monoxide Analyzer	X							
107	2/10-2/14/78	Bag Sampler	X							
108	2/10-2/14/78	Bag Sampler	X							
*201	2/11-2/24/78	Mobile Van	X	X	X	X	X	X	X	X
*203	2/11-2/24/78	Bag Sampler	X							
*202	2/24-2/27/78	Mobile Van	X	X	X	X	X	X	X	X

*Dist. 03 monitoring in conjunction with this study

The location for monitoring was selected to meet the following criteria:

1. High elevation cold weather area.

2. High density traffic area.

3. Sampling access at varying distances from the roadway.

4. Access to typical receptor location adjacent to the highway where receptors will be exposed for extended periods of time.

Sample sites 101 through 104 were bag samplers dispersed throughout the area; site 100 was the air monitoring van. Sample site 105 was a sampler located inside the unoccupied upstairs motel room with the sample intake just outside the window. Site 106 was an analyzer inside the same room

sampling the inside air. Site 107 was a sampler inside an unoccupied downstairs motel room sampling inside air and site 108 was in the same room with the sample probe just outside of the room.

During the sampling period in February of 1978, the weather was cold and the rooms remained tightly closed. The rooms were checked during an off-peak traffic period for background carbon monoxide levels possibly influenced by the gas-fired heating systems. In both rooms the background concentrations were found to be very low (1 to 2 ppm).

It is not normally realistic to expect receptors to occupy areas as close to the road as locations 100, 102, and 103 for even a one-hour period. However, the other locations are within areas receptors could and do occupy for extended periods of time (eight hours or more).

Air Quality Measurements

Carbon Monoxide

The main purpose for this study was to examine the levels of CO concentration, therefore, most of the following discussion concerns this pollutant. A summary of these data is contained in Table II. As shown on Figure 1, the sample sites at the Park Avenue intersection were located on both sides of U.S. Highway 50. The location of the samplers was limited by snow removal activities, therefore, optimum locations could not always be utilized.

An examination of the data clearly shows the influence of meteorological conditions on the dispersion of CO emissions.

TABLE II

CARBON MONOXIDE

Site No.	Dates Sampled	Maximum 1 Hour Average Conc.	Date of Max. 8 Hour Conc.	Maximum 8 Hour Average Conc.	Mean of Maximum 8 Hour Avg. Conc. ppm	Standard Deviation of Max. 8 Hour Avg. Conc.	Highest 24 Hour Avg. Conc. ppm	Number of Violations of the Air Quality Standards	
								8 Hour (6 ppm)	1 Hour (35 ppm)
100	2/9-2/25/78	28	2/14	18	12	3.2	11	33	0
101	2/9-2/26/78	23	2/20	9	8	1.3	7	10	0
102	2/9-2/26/78	39	2/19	31	15	5.9	19	30	2
103	2/9-2/26/78	32	2/19	24	14	3.5	17	36	0
104	2/9-2/26/78	8	2/19	7	7	0.2	5	2	0
105	2/9-2/26/78	28	2/19	20	11	3.6	13	27	0
106	2/9-2/26/78	18	2/18	17	10	2.4	11	24	0
107	2/10-2/14/78	12	2/11	10	10	0	6	1	0
108	2/10-2/14/78	11	2/13	8	8	0	5.6	1	0

As the temperature inversion persists, the dispersion of CO is restricted more and more. For example, the dates of 2/18-2/20 demonstrated this type of condition and resulted in the highest levels measured. From the data it is apparent that CO remains near the ground surface and builds up in concentration around the source. Also, the CO values vary greatly with distance and height from the source under cold stable meteorological conditions.

CO levels in the motel rooms adjacent to the roadway were compared to the levels just outside the window. As expected, changes in the inside levels lagged changes in outside values, but levels inside the rooms did exceed the 6 ppm 8-hour (California high elevation) carbon monoxide standard as shown in Figure 2. These conditions would continue for 12-18 hours during the night and early morning.

In contrast, a nearby (500+ east of the test site) monitoring station, with a 30± ft high sampling mast, had hourly averages that were very low (0 to 4 ppm). This shows, for these atmospheric conditions, that the problem of violations of the carbon monoxide standard are not regional but are confined to the microscale area.

Non-Methane Hydrocarbons

At the only location were NMHC was monitored (Site 100), the standard 0.24 ppm) was exceeded every day except one between 0600 and 0900. The mean of the 0600 to 0900 values is 0.47 ppm with a minimum of 0.10 ppm. This contrasts with values previously obtained where Christmas Valley never exceeded the standard and Tahoe City exceeded only 3 days during the sampling period (1). The exceedances during the winter are not important, however, since photochemical pollutants are at a minimum.

Nitrogen Dioxide

The maximum values for NO_2 were well below the Air Quality Standard (0.25 ppm for one hour) during the time period covered in this study.

Available Data

A complete air pollutant and meteorological data file is available at the California Transportation Laboratory.

Traffic Data

Traffic counts were taken at several locations on a continuous basis during the study period and time delay studies were conducted on various transportation links. The following table is a summary of the time delay study.

Table III

Date	Time	Location	Distance (miles)	Average Speed (mph)
2/11/78	1500	Tahoe Keys to Jct. 89(Meyers)	5.4	33
2/11/78	1500	Jct. 89(Meyers) to Kingsbury/ Rte. 50	26.6	23
2/11/78	1600	Kingsbury to the Wye	16.7	20
2/11/78	1800	Wye to Kingsbury	5.6	16
2/11/78	1800	Kingsbury to Tahoe Keys	5.1	23
2/17/78	1900	Echo Summit to Kingsbury	14.2	30
2/17/78	2000	I-80/Rte. 89 to Tahoe City	13.6	48
2/18/78	1500	Tahoe Keys to Pioneer Trail @ Stateline	4	12
2/18/78	1800	Tahoe Keys to Barneys	4.6	10
2/18/78	1700	Squaw Valley/89 to Tahoe City	5.1	7
2/19/78	1400	Tahoe Keys to Kingsbury	5.1	13
2/29/78	1400	Tahoe Keys to Jct. 89(Meyers)	5.4	5
2/29/78	1500	Jct. 89(Meyers) to Ski Run	8.6	31

Analyzing the data indicates the greatest volumes occurred during the Washington's Birthday weekend. As including all the counts would be voluminous, an effort is made to summarize and look at the peak conditions. The following table contains peak hour and average daily traffic volumes for that weekend.

Table IV

Date	Location	Peak Hour Volumes	Time	Average Daily Traffic
2/17/78	Tahoe City Maint. Station	1330	1600 & 1700	14,310
2/18/78	" " " "	1440	0800 & 0900	17,670
2/19/78	" " " "	1480	0800 & 0900	18,360
2/20/78	" " " "	1430	0800 & 0900	17,260
2/17/78	Rte. 89 @ Squaw Valley	1009	1600 & 1700	10,487
2/18/78	" " " "	1257	1700 & 1800	12,433
2/19/78	" " " "	1494	1700 & 1800	13,076
2/20/78	" " " "	1496	1600 & 1700	14,406
2/17/78	Rte. 89 @ Truckee River Br.	1070	1700 & 1800	12,890
2/18/78	" " " "	1390	1600 & 1700	17,710
2/19/78	" " " "	1500	1700 & 1700	18,100
2/20/78	" " " "	1380	1600 & 1700	15,740
2/17/78	Rte. 50 @ Upper Truckee River Bridge	3520	1600 & 1700	43,560
2/18/78	" " " "	3560	1600 & 1700	47,780
2/19/78	" " " "	3480	1200 & 1300	45,870
2/20/78	" " " "	3250	1100 & 1200	41,040
2/17/78	Rte. 28 @ Cal Neva Drive	1250	1700 & 1800	15,860
2/18/78	" " " "	1580	1700 & 1800	21,900
2/19/78	" " " "	1940	1700 & 1800	23,950
2/20/78	" " " "	1430	1300 & 1400	18,340
2/17/78	Rte. 50 west of Park Ave.	2911	1600 & 1700	--
2/19/78	" " " "	2720	1400 & 1500	46,831
2/19/78	" " " "	2842	1400 & 1500	49,510
2/20/78	" " " "	2844	1200 & 1300	41,131

The data show there are large variation in volumes throughout the basin. The largest volumes were near the Stateline area on Route 50.

Modeling

The California Air Resources Board's Modeling Section analyzed the dispersion of carbon monoxide downwind from the Park Avenue and Highway 50 intersection using mathematical models. Three models were considered for this analysis, two Gaussian, (EPA's HIWAY and Caltrans' CALINE2) and one numerical (ARB's CARS).

The adverse day chosen for model studies was February 19, 1979, as meteorological data demonstrated that a ground based inversion existed from 1700-0200 hours with a related "F" stability class. The input data for traffic (from Caltrans & CTRPA), the emission factors from ARB's EMFAC 5 model (corrected for low to high attitude), and the percent of hot and cold starts were entered into the three models and predictions of CO for the downwind locations were generated. These models predict levels generated by nearby traffic and therefore require the addition of ambient levels for comparison to actual monitored data.

The ambient levels were taken from readings at Sites 100 and 104. These two sites were located in the Raley's parking lot approximately 25 and 100 feet upwind of the intersection.

Table V shows the comparison of all three models for the "F" stability class. Because the Gaussian models characterize atmospheric turbulence in an empirical manner, they have limited applications for intersections, especially if the winds are nearly parallel to the roadway alignment. For this reason the CARS model was chosen for comparison because of its fundamental treatment of the wind shear and its ability to characterize atmospheric turbulence (ARB Lake Tahoe Nonattainment Plan (Appendix) April 18, 1979).

TABLE V

COMPARISON OF CO PREDICTIONS AT
U.S. HY 50 AND PARK AVENUE FOR

February 19, 1978

1700-1800 Hours

EPA HIWAY MODEL

Stability Class F

	Site		
	101	102	103
Ambient	13	13	8
Model	54.1	87.1	62.9
Total	67.1	100.1	70.9
Measured	12	39	22
Ratio	5.59	2.56	3.22

CALINE 2

Stability Class F

	Site		
	101	102	103
Ambient	13	13	8
Model	11.6	18.9	55.2
Total	24.6	31.9	63.2
Measured	12	39	22
Ratio	2.05	0.82	2.87

CARS

Stability Class F

	Site		
	101	102	103
Ambient	13	13	8
Model	8	25	25
Total	21	38	33
Measured	12	39	22
Ratio	1.75	0.75	1.50

Future modifications to the CALINE2 model should improve its ability to predict CO concentrations at intersections. Further research and study is planned for this application.

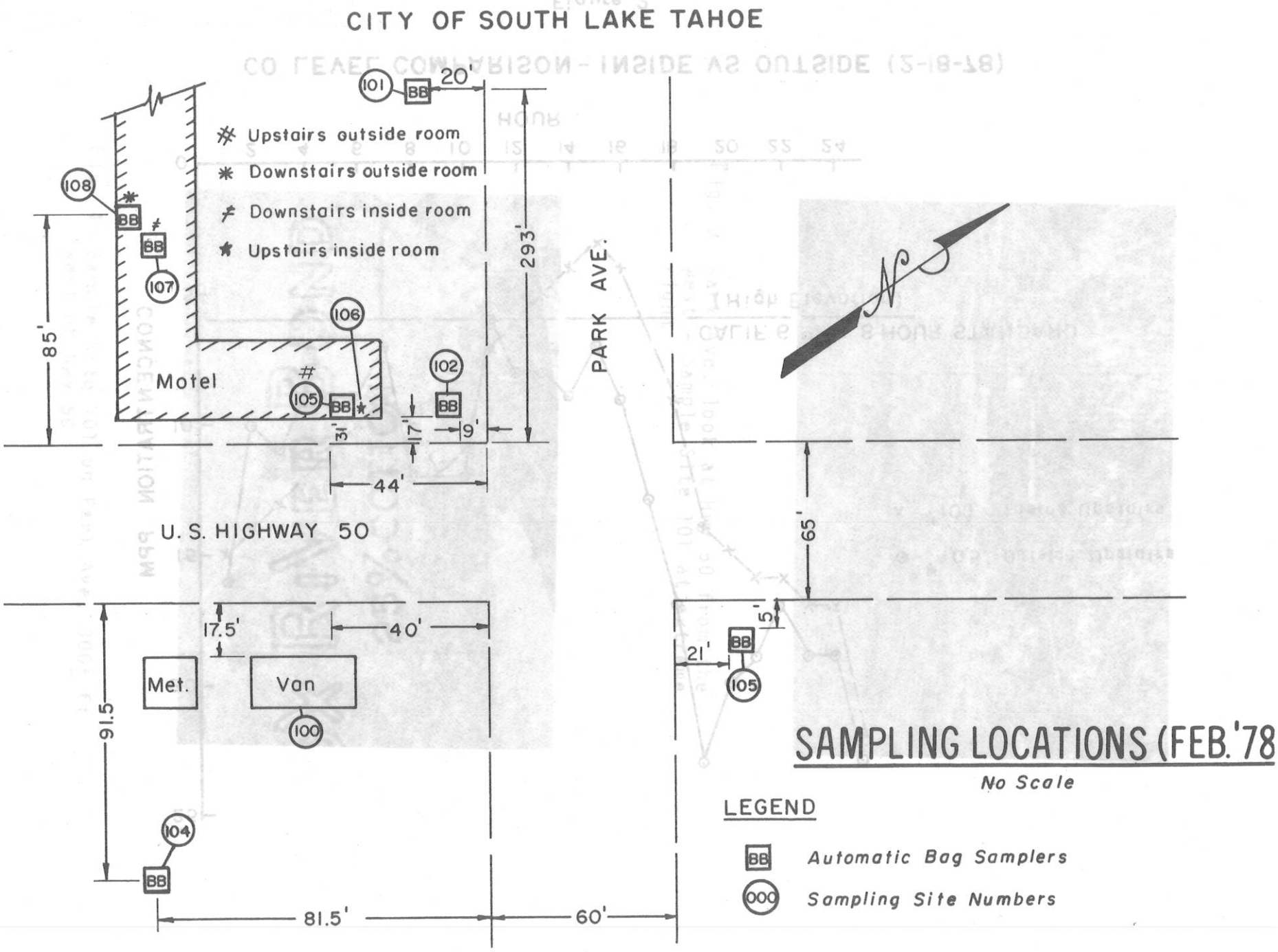
CITY OF SOUTH LAKE TAHOE
Upstairs outside room
Downstairs outside room
Downstairs inside room
Upstairs inside room
Motel
U. S. HIGHWAY 50
PARK AVE.
Met.
Van
20'
293'
85'
44'
31'
17'
9'
65'
5'
21'
17.5'
40'
91.5'
81.5'
60'
101
102
104
105
106
107
108
100
BB
SAMPLING LOCATIONS (FEB.'78
No Scale
LEGEND
Automatic Bag Samplers
Sampling Site Numbers

Figure 1

Fig. 5 Site 101 Air Monitoring Van
South Corner Park Ave. & Hwy 50

Fig. 6 Site 102 - Corner Park Ave. &
Hwy 50. Sites 105 & 106 upper
window nearest corner of motel.

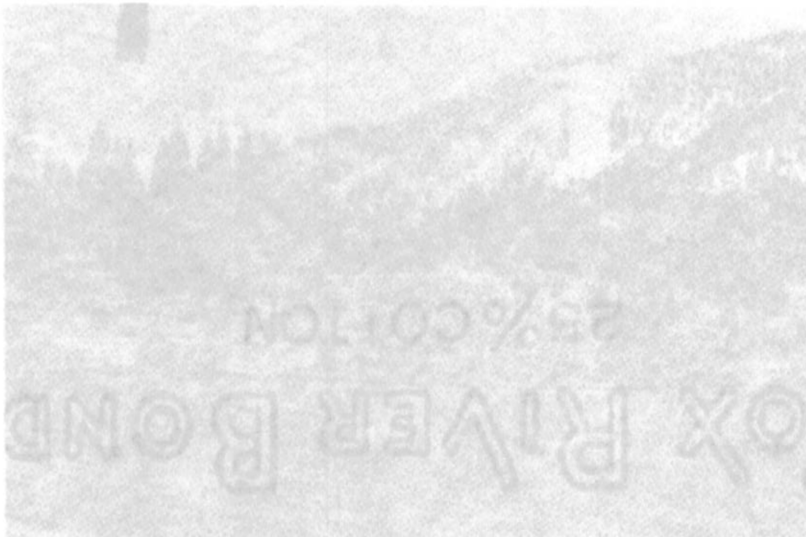

Fig. 5 Site 101 Air Monitoring Van
South Corner Park Ave. & Hwy 50

Fig. 6 Site 102 - Corner Park Ave. &
Hwy 50. Sites 105 & 106 upper
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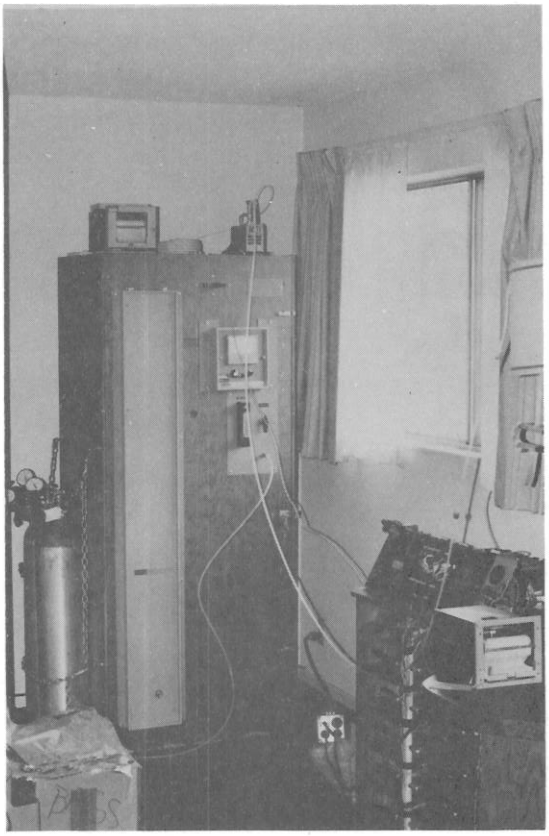

Fig. 7 CO Analyzer in Motel Room

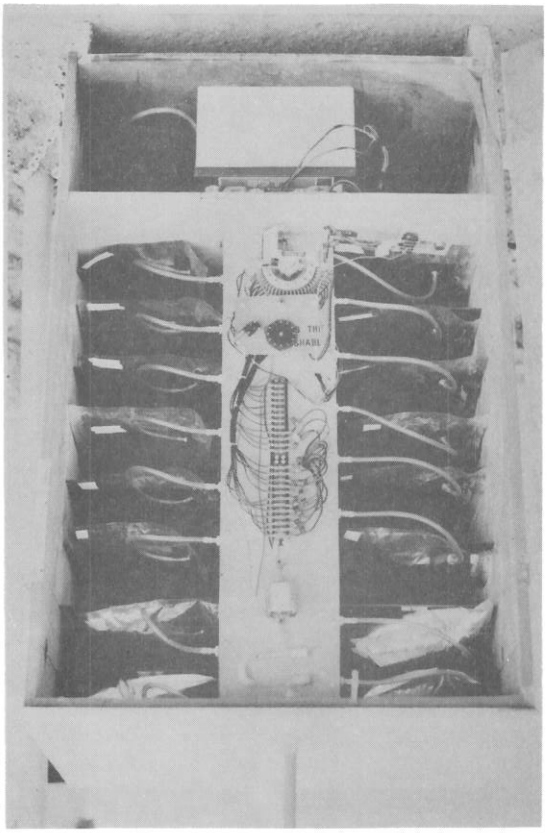

Fig. 8 Interior of Automatic Bag Samplers

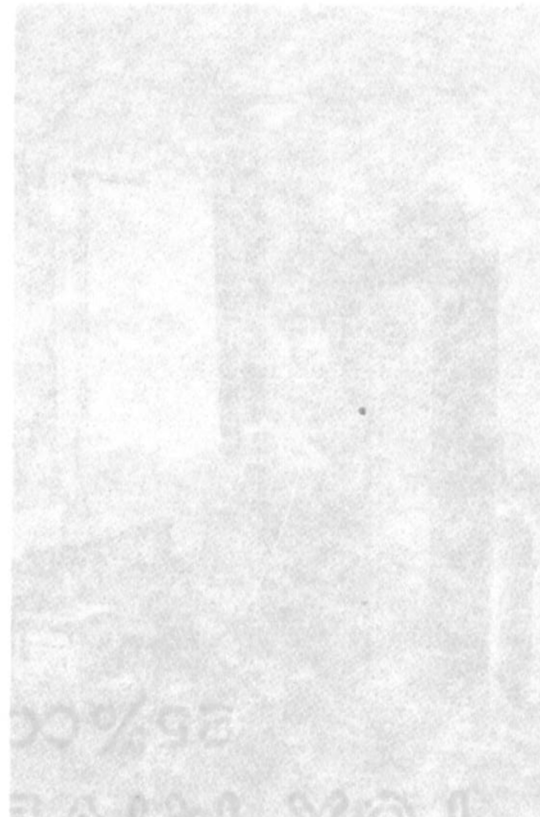

Fig. 7 CO Analyzer in Motel Room

Fig. 8 Interior of Automatic Bag Samplers

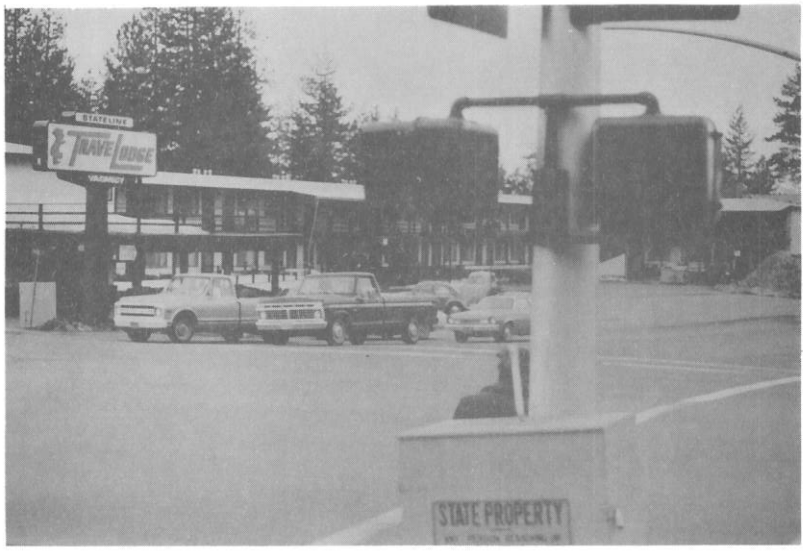

Fig. 9 Site 103 Sampler in Foreground

Fig. 10 Meteorological Trailer equipped for wind speed, wind direction and temperature lapse rate

Fig. 9 Site 103 Sampler in foreground

Fig. 10 Meteorological Tower equipped
for wind speed, wind direction
and temperature lapse rate

Caltrans

CALIFORNIA DEPARTMENT OF TRANSPORTATION

TRANSPORTATION LABORATORY

FOUNDED IN 1912