FIELD STUDY OF THE AIR QUALITY IMPACT OF ROUTE I-195 AT RICHMOND, VIRGINIA

by

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(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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ABSTRACT

This investigation attempted to assess the mesoscale and microscale effects of the recently built Interstate Route I-195 in Richmond, Virginia. Measurement of the air quality before and after completion of the expressway showed that on the mesoscale, there was an improvement in the ambient CO concentration in the 14-square-mile area surrounding the new facility. This improvement can be attributed mostly to the implementation of national vehicular emission standards, but probably to a slight extent to the resulting improvement in the flow of local traffic brought about by the opening of the new facility.

On the microscale, there was actually a similar improvement in the ambient CO concentration in the immediate vicinity of the facility. This improvement was in contrast to expectations and probably resulted from a significant decrease in stop-and-go traffic on the nearby, parallel local streets and the construction of the new facility in a depression.

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INTRODUCTION

Roads are essential for the daily movement of people, goods, and services. The importance of highways couldn't be overstated since they have been this nation's lifelines and are essential to the achievement of its economic and social goals.

However, of equal importance is the effect of highway pollutants on air quality. It is clear that highway transportation must be harmonized with the environment so that economic and social goals are not achieved at the expense of the quality of life, or vice versa. It has been stressed that in order to achieve this balance vehicular air pollution should be a major consideration in the planning of highway corridors.(1) Such consideration requires an understanding of how and to what extent emissions from highways affect air quality. The development of line source dispersion models(2,3,4,5,6) and an area source diffusion model(7) has provided some understanding of the effect of highway emissions. However, no observation on the impacts on air quality of a new major facility and the resulting changes in traffic flow patterns has been reported.

This report describes some observations on the air quality of the area surrounding a newly built expressway, Interstate Route I-195, in Richmond, Virginia, before and after its completion. Completed in July 1976, the 3.8-mile, six-lane expressway crosses the city's West End. It extends from the interchange of Interstates 95 and 64 near the Joseph Bryan Park along the depressed corridor long occupied by the Seaboard Coast Line Railroad tracks southerly to a point south of Cary Street, where it connects with the Powhite Parkway, and then easterly to the vicinity of McCloy Street, where it connects with the Downtown Expressway (Figure 1). With its six through traffic lanes plus auxiliary lanes, the expressway is designed to carry an estimated 35,000 ADT at a minimum design speed of 50 mph.

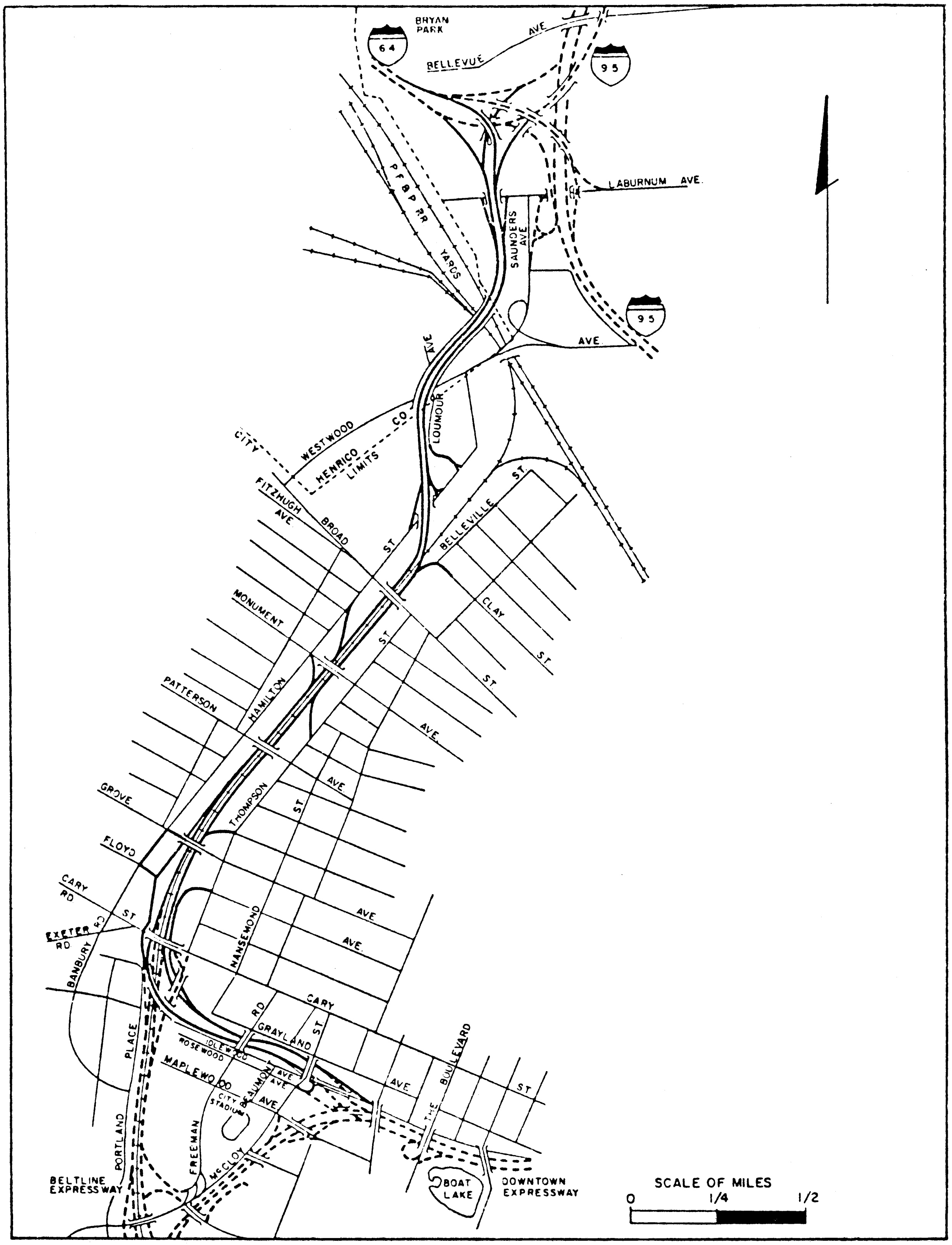

Figure 1. Route I-195 in Richmond, Virginia.

OBSERVATIONAL PROCEDURE

Air Quality Measurement

The completion of an expressway will affect air quality insofar as it will affect vehicle operational modes, traffic volumes, and miles traveled. Theoretically, the air quality effects will be felt at two levels: the mesoscale and the microscale. The mesoscale effect covers the entire portion of the air basin affected by the resulting alteration in the pattern of traffic flow and, therefore, will be manifested by a change in the overall air quality of the area from approximately 0.2 mile (0.3 km) to approximately 10 miles (16 km) around the expressway, depending upon local conditions. On the other hand, the microscale effect is limited to the immediate vicinity of the expressway; i.e., from the expressway out approximately 0.2 mile (0.3 km) on either side.

Mesoscale

In an attempt to assess the mesoscale effect of Interstate Route I-195, the concentration of carbon monoxide (CO) over a large area around the expressway was surveyed before and after the facility was completed. The survey period for the before-completion situation was from May to September of 1974, while the after-completion period was from May to September 1978. These periods were approximately two years before and two years after completion of the expressway.

The survey area was approximately 14 square miles (36 square kilometers). Land use in this area was approximately 30% light industry and commerce, with the remainder being given over to single-family and multifamily residences and open spaces. In obtaining the representative CO concentrations for the survey periods, the area was divided into nine equal squares, and the center of each square was designated as an air sampling location (Figure 2). Then air samples were collected from these nine locations (SL1, SL2, ... and SL9) throughout the survey periods using a random spatial sampling scheme similar to one described by Ott.[9]

Briefly, the sampling scheme used was as follows:

1. A weekday was randomly selected for performing the sampling through each of the weeks in a survey period. (When the weekday happened to be a holiday in a particular week, the following day was used.)

Figure 2. The 14-square mile study area. The sampling locations are labelled SL1-SL9. The continuous CO monitor stations, Nos. 158-Q and 158-R, which were discontinued in the 4th quarter of 1979, are also shown.

2. From May through September of 1974, roughly between 9:00 a.m. and 3:00 p.m. of the selected weekday of each week, the following steps were performed.

   a. Using a table of random numbers in a stratified manner, one of the nine sampling locations was designated as the starting point for a particular sampling run.

   b. From the starting point, a 10-minute air sample was collected at "breathing height".

   c. Proceeding clockwise to the next nearest sampling location in the grid (Figure 2), another separate 10-minute air sample was collected.

   d. Step c was repeated until separate air samples were collected from all nine locations to constitute one sampling run.

   e. For the second run of the day, Steps (a) to (d) were repeated, starting at approximately a half-hour after the first run.

3. Step (2) was repeated for the period from May to September of 1978.

The collection of air samples was carried out using bag-sampling units. Each unit consisted of a portable, battery-operated diaphragm pump connected through Teflon tubing to an aluminized polyester bag. Each collected air sample was analyzed for CO concentration using a Bendix gas chromatograph with a precision of $\pm$ 1% of full scale. The chromatograph was calibrated at the beginning of each survey day and checked at least once during the day with certified span gas and zero gas.

CO concentrations continuously measured by the Virginia State Air Pollution Control Board at the two monitoring stations in the metropolitan Richmond area from 1973 to 1978 inclusive were also obtained. Station No. 158-Q was located within the study area, at Hermitage and Robin Hood Roads, while Station No. 158-R was located just outside the study area at Main and Laurel Streets (Figure 2). (The stations were closed in the 4th quarter of 1979.)

Meteorological data such as wind speed and direction were also measured throughout the survey periods at a recreation park beside the new expressway and Thompson Street and Hanover Avenue. This park is centrally located in the study area.

Microscale

To assess the microscale effect, hourly air samples were collected from locations on both sides of the expressway, as illustrated in Figure 3, during the rush hour of 5 p.m. to 6 p.m. on all the sampling days of each survey period. These locations were in the middle of the blocks of Hamilton and Thompson Streets bordered by Patterson and Grove Avenues on the north and south, respectively. Air samples collected in this manner were then analyzed for CO concentrations.

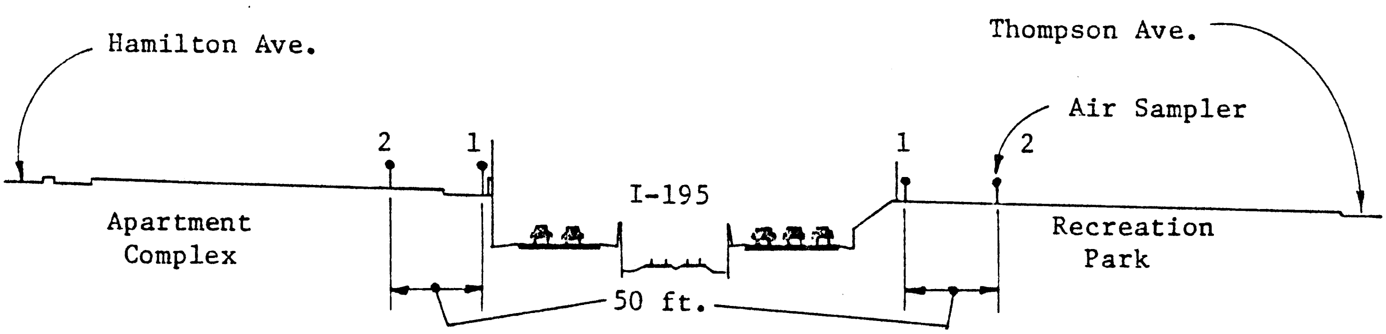

Figure 3. Locations of air samplers around the expressway, looking north.

DISCUSSION OF RESULTS

Mesoscale Effect

The CO concentrations measured at each of the nine sampling locations in the large survey area surrounding the expressway are presented in Appendices A and B for the survey periods before and after completion of the facility, respectively. These data indicate that there was an improvement in the air quality, or a reduction in ambient CO concentrations, in all locations. Depending on the sampling location, the observed decrease ranged from 38% to 52% of the base year 1974 concentrations, with an average decrease of 43% (Table 1). This improvement in the air quality is vividly illustrated in Figure 4, which shows the combined frequency distributions of the CO concentrations observed during the two survey periods.

An examination of the data on wind speed and atmospheric conditions — two meteorological factors which were confirmed by the United States Environmental Protection Agency's several ambient CO studies[10] to be influential in determining the likelihood of high ambient CO concentrations — indicated that it is not possible to attribute this improvement to favorable meteorological conditions that may have occurred during the 1978 survey period. Wind speeds observed in the survey area during the latter survey period were actually less favorable for dispersion, i.e., they were slightly slower, than those observed during the 1974 survey period (Figure 5). This is similarly indicated by wind speeds recorded at the National Weather Station at the R. E. Byrd International Airport, which serves metropolitan Richmond and is located about 10 miles (16 km) from the study area (Figure 6). On the other hand, insolation during the latter survey period averaged slightly stronger than that during the 1974 survey. The stronger insolation, together with the slower wind speed, would probably have resulted in more unstable atmospheric conditions and, therefore, more favorable CO dispersion for the 1978 survey period than for the earlier one. Overall, the favorable effect of the unstable atmospheric conditions would very likely have been neutralized by the unfavorable effect of the slower wind speed for the 1978 survey period; so there probably were no significant differences in the meteorological conditions during the two survey periods to account for the lower CO concentrations observed in the later survey.

Table 1

Improvement in Air Quality in Survey Area

Sampling Location	CO, ppm* 1974	CO, ppm* 1978	Change Relative to 1974
SL1	2.0	1.2	-40%
SL2	2.2	1.3	-41%
SL3	2.2	1.1	-50%
SL4	2.1	1.2	-43%
SL5	1.8	1.1	-39%
SL6	2.0	1.2	-40%
SL7	2.1	1.2	-43%
SL8	2.5	1.2	-52%
SL9	2.1	1.3	-38%

*Arithmetic mean of CO concentrations observed at a location during a survey period.

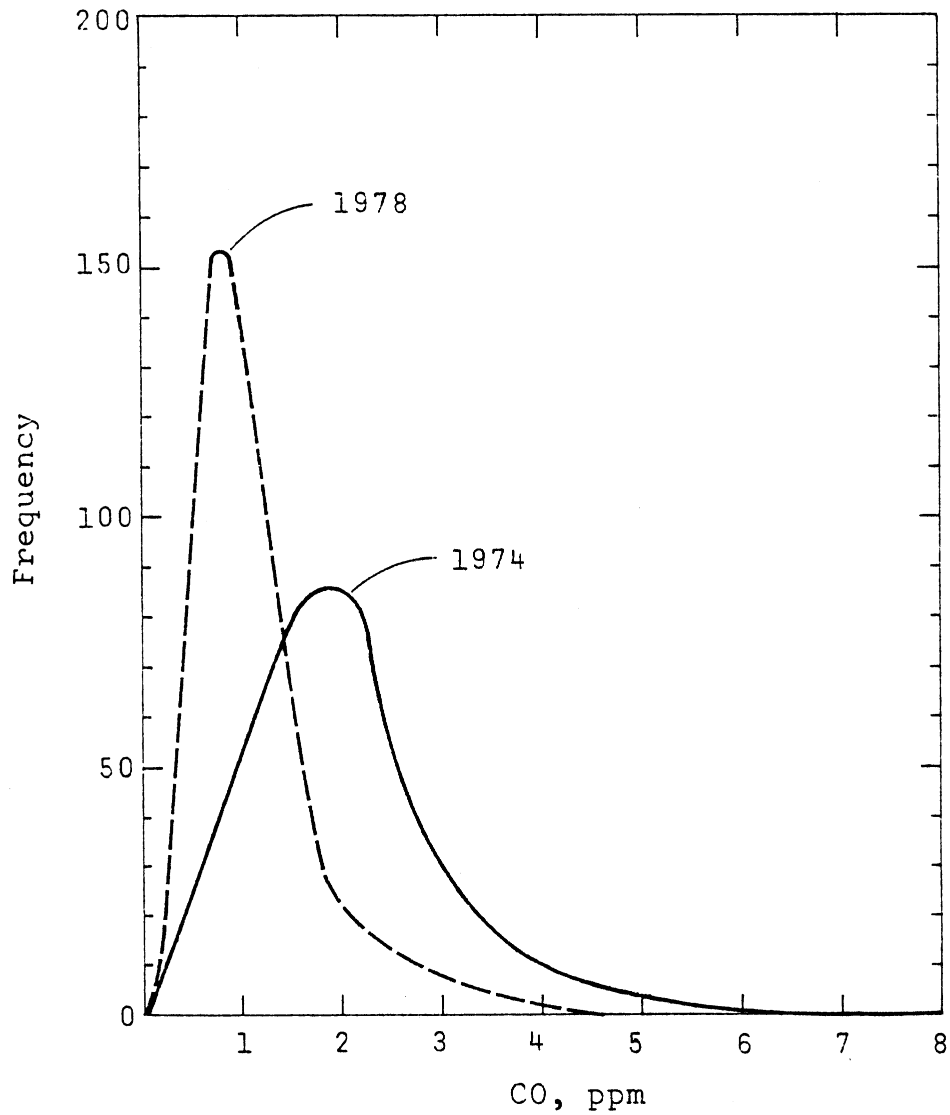

Figure 4. Combined frequency distributions of ambient CO concentrations around I-195.

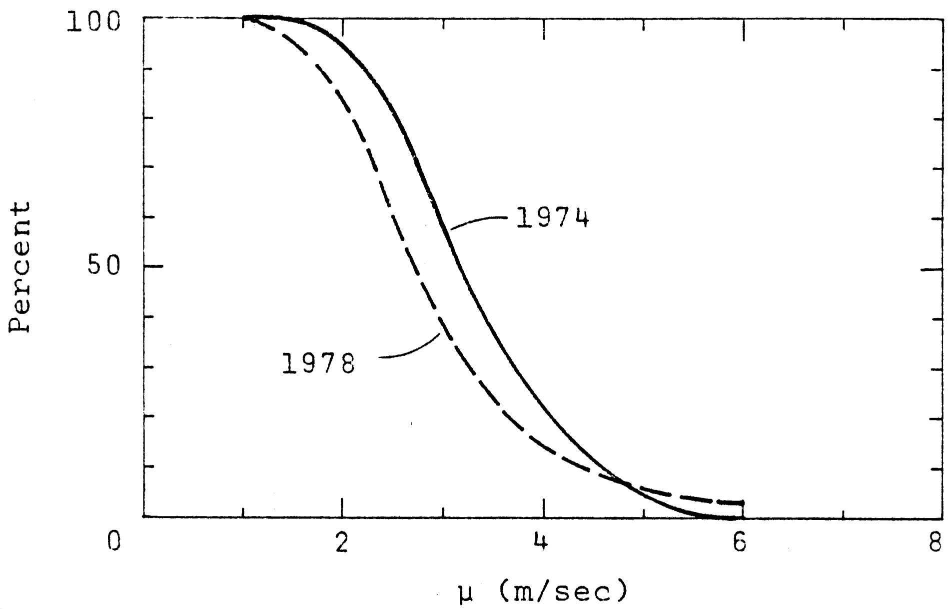

Figure 5. Cumulative frequency curves of wind speeds in study area.

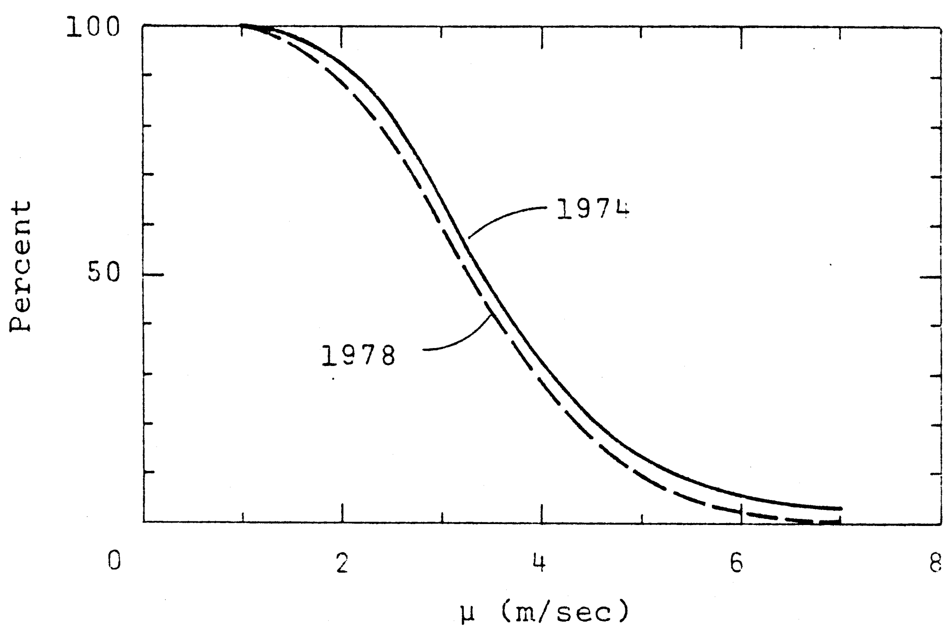

Figure 6. Cumulative frequency curves of wind speeds at R. E. Byrd International Airport.

Data on ambient CO concentrations collected by the Virginia State Air Pollution Control Board[11] at their two continuous air monitoring stations showed steady accumulated improvements from 1974 to 1978 that averaged to approximately 34% for the two stations (Figure 7). This improvement had occurred despite a 6% increase in the vehicular traffic in the whole of metropolitan Richmond,[12] as illustrated in Figure 8, and very likely resulted from the implementation of the motor vehicle emission standards formulated by the federal government as part of the overall effort in improving the nation's air quality. In fact, the steady improvement in the air quality in the Richmond area, as indicated by the SAPCB data, closely accompanied the steady decrease in the areawide CO emission loads, as illustrated in Figure 9, which were estimated by this investigator from available traffic data[12] and published CO emission factors.[13]

Figure 8 also shows that the average traffic volumes recorded at the 67 count stations within the study area significantly decreased immediately after I-195 was completed in 1976. This decrease was in contrast to the steady rise in the average traffic counts at the remaining 278 count stations throughout the metropolitan area. Apparently, it resulted in part from a diversion of traffic from existing facilities onto the new expressway, which recorded a volume of approximately 40,000 ADT at one point in 1977. This diversion, exemplified in Figure 10 by the decreased traffic on Malvern Avenue and Hamilton Road, which parallel the new facility, resulted in an improvement in the overall traffic flow of the study area. Therefore, it likely contributed to some extent toward the improvement in the air quality of the area.

A careful consideration of these observations would indicate that the improvement in the overall, or mesoscale, air quality in the study area can be attributed mostly to the positive effect of the vehicular emission standards and, probably, slightly to the opening of the new expressway. It can be concluded that if the expressway didn't significantly contribute toward the improvement in the air quality of the area, it certainly had no adverse effect.

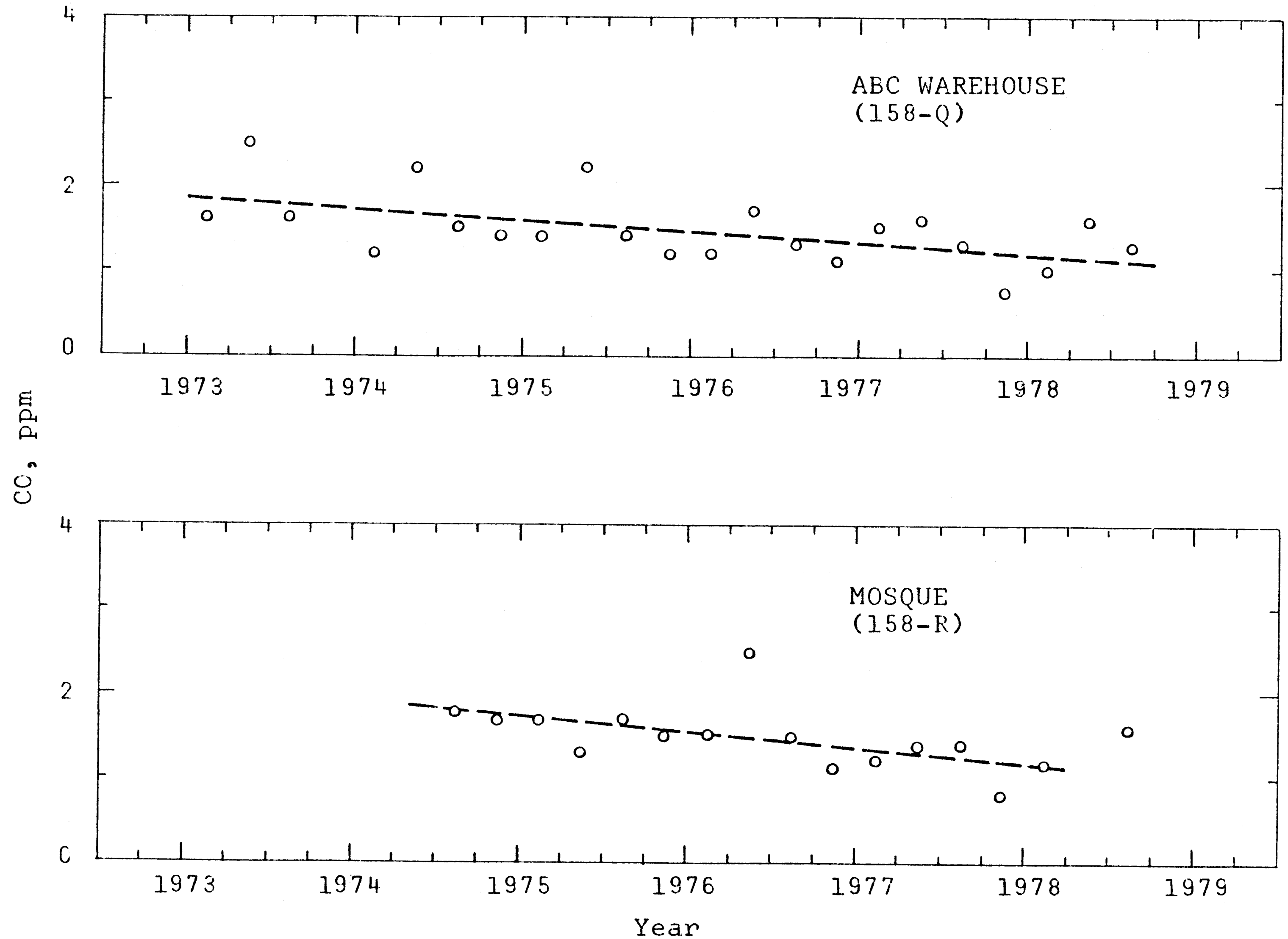

Figure 7. Quarterly arithmetic means of CO concentrations measured at two SAPCB stations in Richmond.

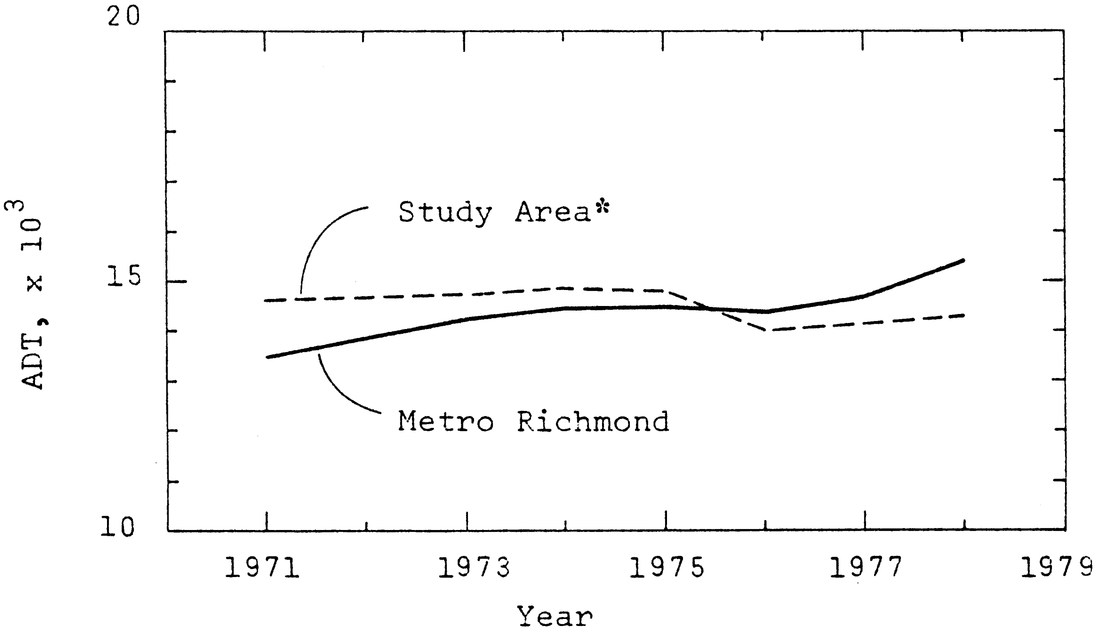

Figure 8. Average ADT per station throughout metropolitan Richmond and study area. (*Not including Route I-195)

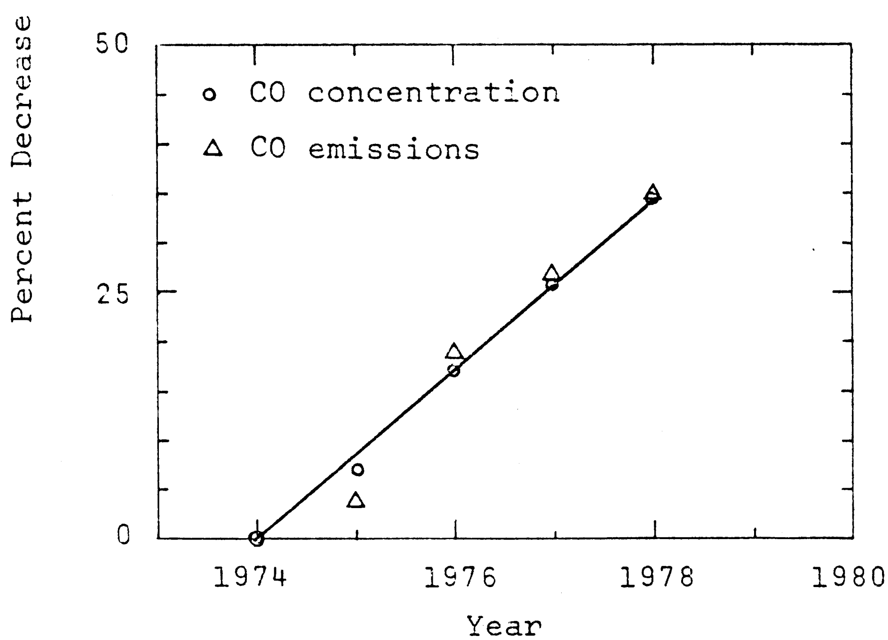

Figure 9. Percentage decrease in average CO concentrations at SAPCB stations and estimated vehicular CO emissions.(Base year is 1974.)

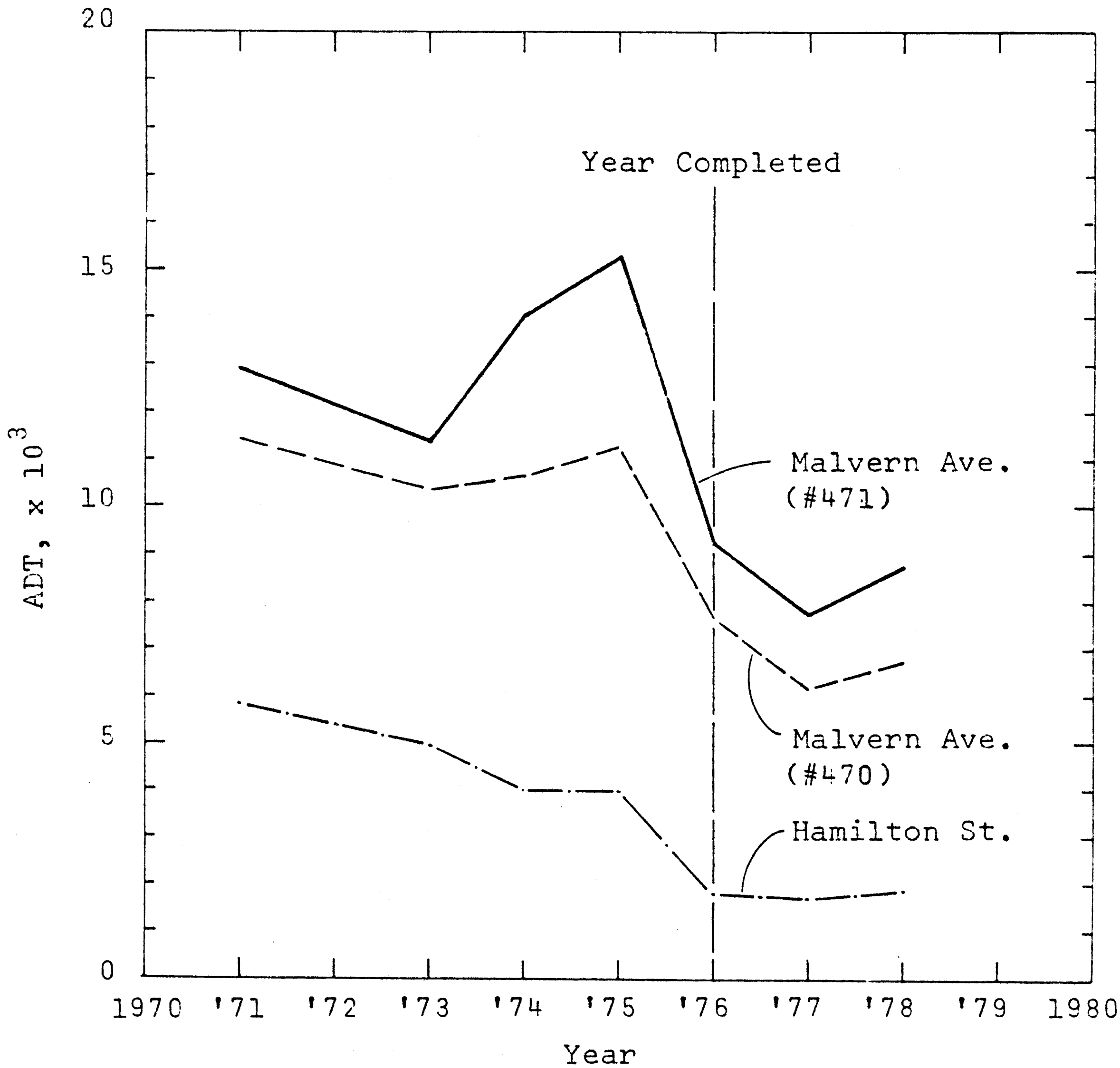

Figure 10. Average daily traffic on roads parallel to I-195.

Microscale Effect

Prior to completion of the expressway, it was expected that the air quality in the immediate vicinity of the new facility would be slightly worse than before. However, the air quality measurements made on both sides of the expressway before and after its completion (Appendices C and D) actually indicated the opposite; i.e. there was some improvement in the air quality. This welcome surprise was probably attributable to the parallel roads on each side of the expressway (Hamilton Street on the west and Thompson Street on the east), both within several hundred feet of the expressway, so that the sampling locations (Figure 3) were not only within the microscale regime of the expressway but also that of either Hamilton Street or Thompson Street. These two roads, being at-grade, probably contributed more predominantly than the new depressed expressway toward the air quality in the immediate vicinity and, therefore, at the sampling locations. Consequently, when the expressway was opened to free-flowing traffic and some slow moving traffic was diverted from the two parallel roads, the overall vehicular CO emissions must have decreased and provided an improvement in air quality.

CONCLUSION

Although the sample sizes investigated may be small, it is believed that they were sufficient and randomly enough scattered to provide valid comparisons of before and after CO concentrations. In view of the foregoing discussions, the following conclusions can be established.

1. As expected by transportation planners, I-195 has provided relief to northbound and southbound local traffic on several streets in the study area. In addition, as part of the arterial network, it has probably provided improved travel for the many motorists who regularly use the Richmond-Petersburg Turnpike and all of the James River crossings in the Richmond metropolitan area.

2. The improvement in the local traffic flow contributed at least slightly toward the observed improvement in the air quality of the study area. The major contribution probably came from the implementation of vehicular emission standards, which have steadily benefited the whole metropolitan area of Richmond as they have most major urban areas in the nation.

3. In contrast to expectations, the expressway has actually improved the ambient CO concentrations in the immediate vicinity. This is probably due to the significant decrease of stop-and-go traffic on nearby parallel streets and the depressed level of I-195.

This investigation has demonstrated to some extent that the construction of a needed expressway through an urban area will not adversely affect the surrounding air quality, provided that proper consideration is given to the design of the roadway and the environment.

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APPENDIX A

AMBIENT CO CONCENTRATIONS IN THE SURVEY AREA BEFORE CONSTRUCTION

Site \ Date	5/15	5/23	5/24	6/6	6/12	6/19	6/26	7/3	7/10	7/18	7/24	7/31	8/8	8/15	8/19	8/27	9/5	9/12	9/18	9/26	Arithmetic Mean
SL1	1.5 2.0	1.0 1.8	1.2 0.5	1.0 1.5	0.5 0.6	1.3 0.9	– 1.5	1.7 1.4	4.2 2.0	1.8 1.6	2.2 1.6	1.5 1.3	2.5 1.9	1.8 2.0	3.2 1.6	2.1 3.5	2.5 2.0	2.5 2.3	5.7 4.0	3.7 3.7	2.0
SL2	2.0 2.5	1.5 2.0	1.5 4.2	1.8 1.5	0.6 2.0	1.3 1.1	2.3 1.2	1.8 1.6	2.8 2.2	2.5 2.0	1.7 2.0	2.1 1.2	3.1 1.9	1.6 1.7	3.5 1.5	2.8 2.8	2.2 2.1	2.5 2.5	5.4 3.5	3.6 3.5	2.2
SL3	1.5 1.5	1.0 1.8	1.0 0.5	3.5 1.0	1.0 0.6	1.0 1.3	3.6 1.8	1.6 1.8	2.1 2.4	1.9 1.6	1.4 2.5	1.7 1.6	2.0 1.7	2.0 1.8	4.0 1.7	2.4 2.5	2.1 2.1	2.2 2.6	2.8 3.7	4.6 4.0	2.2
SL4	1.0 1.5	1.0 2.4	1.9 1.0	3.0 2.5	0.6 1.0	1.0 1.2	4.5 1.7	2.2 1.8	2.8 2.1	2.2 1.6	1.4 1.4	1.5 1.2	2.2 1.6	2.0 1.8	3.6 1.9	2.2 –	2.4 2.2	3.0 2.5	3.8 3.7	4.0 3.7	2.1
SL5	1.5 1.5	1.0 1.0	1.0 0.2	1.8 1.0	0.6 0.5	0.8 0.9	2.6 1.1	1.4 1.8	2.1 2.3	1.5 1.7	1.7 1.2	2.0 1.3	1.4 1.4	1.6 1.7	2.5 1.6	2.5 2.2	2.2 1.8	2.4 2.2	3.7 3.8	4.2 3.2	1.8
SL6	1.0 1.5	1.0 2.0	1.9 1.0	1.2 0.5	0.6 0.5	1.2 0.9	2.3 1.6	1.5 1.9	2.6 2.7	1.8 2.2	1.8 1.3	3.0 1.4	1.5 1.6	2.2 1.9	3.0 1.9	2.3 2.5	2.5 2.0	2.7 2.6	4.3 5.0	4.0 3.3	2.0
SL7	1.5 1.5	1.0 3.1	1.5 1.0	1.2 0.5	1.0 0.6	0.9 0.9	3.3 2.1	2.3 2.6	3.2 2.8	2.3 2.9	2.3 1.6	1.5 1.6	1.6 1.8	1.6 1.7	2.1 2.3	2.1 2.7	2.1 2.1	2.8 2.4	4.0 3.8	3.6 3.8	2.1
SL8	2.4 2.4	1.5 3.1	2.1 1.0	1.0 0.5	1.5 0.5	1.8 1.2	3.1 2.0	2.7 3.2	4.2 3.4	2.2 2.5	2.4 2.1	3.2 1.9	1.9 1.9	2.2 2.0	4.2 1.8	2.8 2.5	2.3 2.2	3.3 2.8	6.4 4.3	4.0 4.3	2.5
SL9	2.0 2.4	1.0 1.8	1.2 1.0	1.2 1.2	1.0 0.6	1.4 1.1	– 1.1	1.7 1.6	2.6 3.2	1.7 2.1	2.0 1.4	2.2 1.4	3.3 1.8	1.8 2.2	2.6 1.3	2.2 2.8	2.3 2.6	3.2 2.3	3.7 4.0	5.6 3.3	2.1

APPENDIX B

AMBIENT CO CONCENTRATIONS IN THE SURVEY AREA AFTER CONSTRUCTION

Date / Site	5/23	5/30	6/6	6/13	6/20	6/27	7/5	7/11	7/18	7/25	8/1	8/8	8/15	8/22	8/29	9/5	9/12	9/19	9/26	Arithmetic Mean
SL1	1.3 0.6	1.0 0.7	0.5 0.6	1.1 0.8	1.0 1.3	1.0 1.2	3.4 0.4	1.0 1.5	2.1 1.7	0.9 1.0	1.2 0.9	1.3 1.2	1.8 1.3	1.7 0.8	1.1 1.0	1.5 0.7	2.7 0.8	1.6 1.4	1.2 0.8	1.2
SL2	0.8 0.5	1.5 1.7	0.7 0.5	1.4 0.8	0.6 1.4	0.8 0.7	0.9 0.6	1.4 1.1	1.6 3.1	0.6 1.0	1.4 2.7	2.5 1.4	1.7 1.4	1.6 1.0	1.1 0.8	1.4 0.6	1.8 0.8	1.3 0.7	0.8 2.8	1.3
SL3	0.7 0.6	1.3 1.0	0.7 0.7	1.3 0.9	1.0 2.1	0.9 0.7	0.7 0.6	1.2 1.2	0.8 2.6	1.0 1.2	1.1 1.6	1.1 1.3	2.3 1.3	1.1 0.9	1.3 1.1	0.8 0.7	1.0 0.8	1.1 0.9	0.7 1.0	1.1
SL4	0.6 0.4	1.4 3.4	1.0 –	0.9 0.5	1.4 1.1	0.5 0.8	1.1 0.6	0.9 1.0	1.7 1.0	0.8 1.2	3.3 1.3	1.1 2.4	2.6 1.4	1.2 1.6	1.0 1.0	0.7 0.8	– 0.9	0.7 0.7	0.7 0.5	1.2
SL5	1.2 0.6	1.4 3.0	0.6 0.5	1.1 0.6	1.1 1.1	0.7 0.9	1.3 0.4	0.9 1.3	2.1 1.6	1.4 1.0	1.6 1.3	1.1 1.1	2.2 1.3	0.7 0.8	0.9 0.8	– 0.6	0.9 0.7	0.8 0.7	0.8 0.6	1.1
SL6	1.0 0.5	2.6 0.7	0.8 0.5	0.7 0.8	0.8 0.6	0.6 1.7	2.2 0.4	1.0 1.5	2.4 1.8	0.8 0.9	1.1 1.2	1.5 2.9	3.6 1.5	1.8 0.9	0.9 0.9	1.7 1.2	0.8 0.8	1.5 1.1	0.8 0.5	1.2
SL7	1.1 0.6	2.6 0.7	0.9 0.7	1.0 1.0	1.1 0.6	0.5 0.8	0.7 1.3	1.3 1.4	1.1 1.5	1.2 0.7	1.4 1.3	1.7 1.3	2.9 1.6	1.6 1.1	0.9 1.0	1.6 0.6	1.0 1.0	1.3 0.8	0.6 3.8	1.2
SL8	0.8 0.7	1.0 –	0.6 0.6	0.9 0.7	1.0 0.9	1.1 4.1	0.8 0.7	0.8 1.2	1.7 1.8	1.3 1.2	1.1 1.0	1.8 0.8	2.4 1.8	1.6 0.7	1.3 1.0	1.6 1.1	1.0 1.2	1.3 0.9	0.6 1.0	1.2
SL9	0.8 0.5	1.3 2.4	0.9 0.7	2.7 0.6	1.7 0.9	1.3 3.5	1.0 0.5	1.2 1.2	2.1 1.1	1.2 1.6	1.0 0.9	1.3 2.2	2.3 1.5	0.7 1.7	1.4 1.1	1.3 0.6	2.2 0.8	1.2 1.3	1.2 0.6	1.3

APPENDIX C

AMBIENT CO CONCENTRATIONS AROUND I-195 BEFORE CONSTRUCTION

Sampling time = 1700-1800

Date \ Sampler	West Side		East Side	
	2	1	1	2
May 15, 1974	1.9 ppm	- ppm	1.9 ppm	2.9 ppm
23	3.4	3.4	2.1	2.0
29	1.0	1.0	1.0	-
June 6	2.0	2.2	2.0	2.0
12	1.0	1.5	1.0	2.0
19	1.5	2.0	3.0	2.5
26	1.9	2.2	1.4	1.4
July 3	1.8	1.9	3.9	2.4
10	3.3	3.5	5.9	6.2
18	2.3	2.2	2.6	2.1
24	1.9	2.0	1.5	1.6
31	1.6	2.7	1.9	1.8
Aug. 8	2.4	2.7	2.4	2.5
15	2.4	2.5	2.2	2.0
19	3.0	2.1	3.7	2.5
27	2.4	4.8	2.4	3.0
Sept. 5	2.4	3.2	2.6	2.3
12	3.0	5.4	3.3	3.3
18	3.2	3.0	3.2	2.8
26	3.6	3.8	3.5	3.6
Arithmetic Average	2.3	2.7	2.6	2.6

APPENDIX D

AMBIENT CO CONCENTRATIONS AROUND I-195 AFTER CONSTRUCTION

Sampling time = 1700-1800

Date \ Sampler	West Side		East Side	
	2	1	1	2
May 23, 1978	1.1 ppm	1.7 ppm	0.7 ppm	0.8 ppm
30	1.8	1.1	1.0	1.1
June 6	1.0	0.9	1.0	1.3
13	0.7	1.7	1.2	0.8
20	2.3	1.4	4.1	1.2
27	2.1	1.6	1.4	1.2
July 5	1.0	2.0	1.1	1.3
11	0.8	1.7	1.2	1.2
18	2.1	3.5	1.3	3.6
25	0.9	2.1	0.9	0.9
Aug. 1	1.7	2.0	2.5	1.6
8	1.3	2.1	1.4	1.2
15	2.1	4.2	1.8	1.9
22	2.8	1.2	1.3	1.6
29	2.2	1.4	1.4	1.2
Sept. 5	1.5	2.1	1.3	0.8
12	1.3	-	1.1	1.2
19	1.2	1.7	1.3	-
26	2.2	1.3	1.0	0.9
Arithmetic Mean	1.6	1.9	1.4	1.3