NEW JERSEY STATE DEPARTMENT OF TRANSPORTATION

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ENVIRONMENTAL ANALYSIS AND REPORT
FOR
ROUTE 18 FREEWAY EXTENSION
CITY OF NEW BRUNSWICK AND PISCATAWAY TOWNSHIP
MIDDLESEX COUNTY, NEW JERSEY

VOLUME II - APPENDIX

SECTION 3 - FINAL REPORT

ROUTE 18 EXTENSION

NOISE IMPACT STUDY

JULY 1972

PREPARED BY

GENERAL ELECTRIC COMPANY

FOR

KING & GAVARIS
CONSULTING ENGINEERS

Re-entry & Environmental Systems Division

PHILADELPHIA, PENNSYLVANIA

FINAL REPORT

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Submitted to

KING & GAVARIS
Consulting Engineers

By The

General Electric Company
3198 Chestnut Street
Philadelphia, Pennsylvania 19101

Under Contract Agreement dated 6 March 1972

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I.0 INTRODUCTION

The proposed NJSDOT alignment for the extension of Route 18 Freeway through New Brunswick, N.J. proposes that the four lane divided highway pass the George Street dormitories of Rutgers University. The proposed alignment at this point follows the bed of the existing Delaware and Raritan Canal as shown in Figure 1-1. The NJSDOT has estimated the average daily traffic on the extended Route 18 Freeway behind the dormitories. This traffic projection indicates that the peak hourly volume behind the dormitories in 1975 will be 2700 vehicles per hour and will be 4300 vehicles per hour in 1995. This report is part of an environmental impact study to evaluate the noise impact of the proposed Route 18 Extension.

1.1 STUDY OBJECTIVES

The noise impact study conducted was structured to achieve two specific objectives. These were

a. To estimate the noise level that the Frelinghuysen dormitory would be subjected to as a result of vehicular traffic along the Route 18 Extension as proposed by the NJSDOT alignment.

b. To determine the attenuating effect, on the estimated traffic noise, if a deck were to be added over the roadway near the dormitory.

1.2 STUDY IMPLEMENTATION

The study objectives were achieved by a combination of noise level measurements and simulations and analytical evaluation of noise level recordings. The first objective was accomplished by tape recording traffic generated noise at an existing section of New Jersey Route 18 and then playing back this noise thru acoustic horns placed on the tow path at the dormitory site. Noise level readings were made both inside

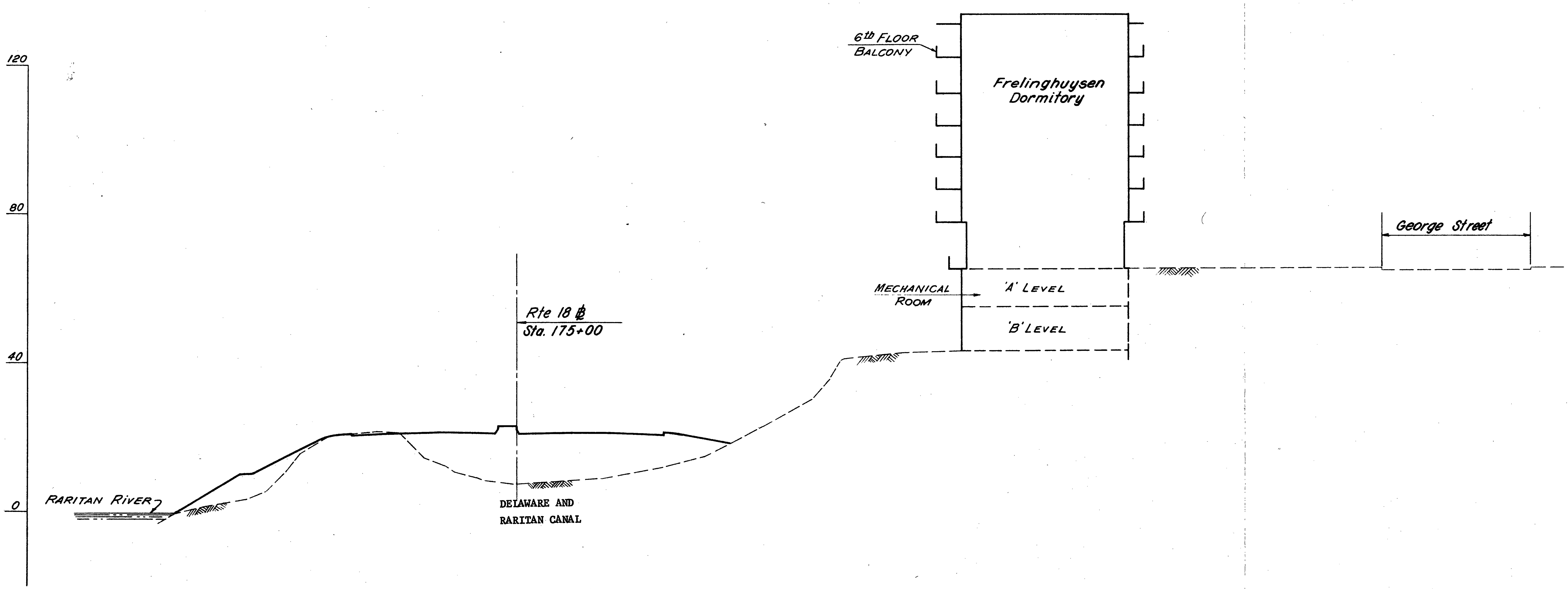

120
80
40
0
6th FLOOR BALCONY
Frelinghuysen Dormitory
George Street
MECHANICAL ROOM
'A' LEVEL
'B' LEVEL
Rte 18 ℄
Sta. 175+00
RARITAN RIVER
DELAWARE AND RARITAN CANAL

Figure 1-1

and outside the Frelinghuysen dormitory to determine the received noise during the simulated traffic periods. (Psychological reaction to the simulated traffic was sampled by others to supplement the noise level readings.)

The second objective was reached by determining the noise level attenuation of the existing deck over the Franklin D. Roosevelt Drive in New York City and applying the attenuation factors to the proposed Route 18 Freeway Extension behind the dormitories.

1.3 STUDY PARTICIPANTS

The field work and data analysis for this study were performed by the General Electric Company under a subcontract to King and Gavaris, Consulting Engineers. Traffic data was collected by the City of New York Department of Traffic and the New Jersey State Department of Transportation.

1.4 STUDY REPORT

This report describes the study, summarizes its results and presents noise level projections and conclusions based upon the results. Section 2.0 consists of the Summary and Conclusions. The Study Program, and the results are described in Section 3.0. Instrumentation and calibration techniques used are included in Section 4.0, Appendices. Photographs pertinent to this study are grouped in Section 5.0.

2.0 STUDY FINDINGS

The study of the noise impact of the proposed Route 18 extension behind the Rutgers George Street dormitories shows that the noise level in the area will be influenced by the highway. Numerous factors will determine the change in noise level outside and inside the dormitories. The specific impact on the noise level at both locations is dependent upon the resolution of these factors. The study findings associated with these factors are summarized below. The conclusions drawn are presented in section 2.2 following this summary.

2.1 SUMMARY

2.1.1 Existing Noise Level at Frelinghuysen Dormitory

The existing "A" weighted noise level at the Frelinghuysen dormitory resulting from campus activity and traffic flowing on George Street varied from 49.0 dB(A) to 68.0 dB(A) on the George Street side. The minimum noise level occurred between 3 & 4 AM on 24 April; the peak was recorded on Saturday, 22 April, between 4 & 5 PM as shown on Figure 2.1-1.

The average noise level in front of the dormitory for the 72 hour period was 61.6 dB(A). As expected the three day average diurnal pattern indicates the early morning hours are the quietest and daytime hours are the noisiest. The periods of low and high noise levels shift from day to day, depending upon the day of the week.

The average noise level in the parking lot, on the canal side of the Frelinghuysen dormitory was considerably lower than on the George Street side. Actual measurements ranged between 47 and 64 dB(A). However the equipment within the G.E. Co. van (used during the air pollution

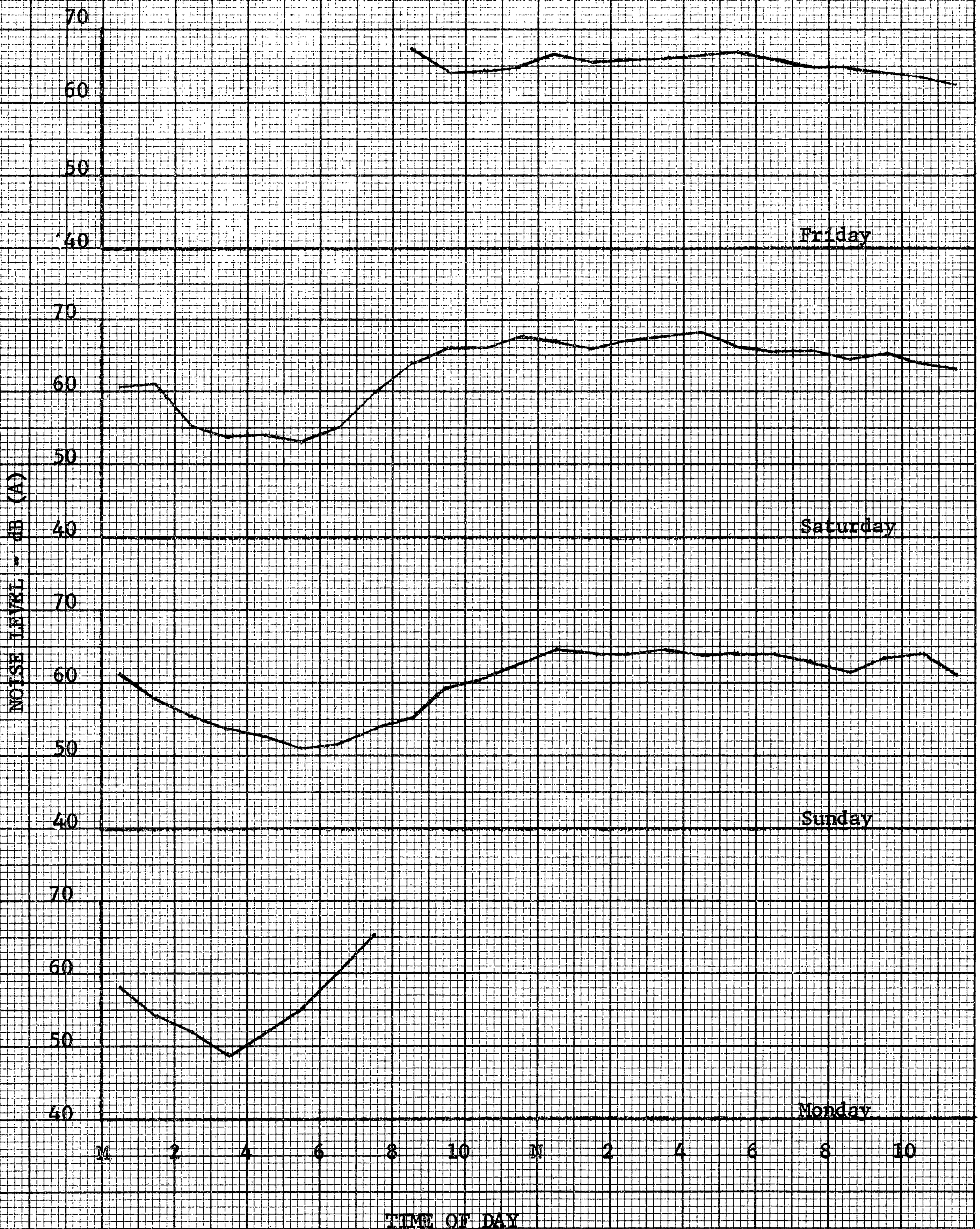


FIGURE 2.1-1 EXISTING NOISE LEVEL FRELINGHUYSEN - GEORGE STREET SIDE

study for monitoring carbon monoxide) biased all of these readings between 7 and 8 dB. A compressor within the dormitory produced noise peaks of 2 to 3 minute duration which raised the average noise level near its exhaust port. Eliminating these two sources, the parking lot average noise level ranged from 47.0 to 51.0 dB (48.5 dB average). Short duration noise peaks of 70 dB (A) resulting from motorcycles and train whistles were frequently heard. The noise output from the compressor raised the average noise level to 56-60 dB.

Under normal conditions (no noise from carbon monoxide measuring equipment) the traffic and other campus activity raises the noise level in the front of the dormitory from a low of 49 dB(A) to a high of 68 dB(A). The noise generated by George Street traffic and other campus activity has far less effect on the noise level on the canal side of the building. The minimum parking lot noise level of 47 dB(A) is raised only to 51 dB (A). The building compressor increases the parking lot noise level to 58 dB approximately four times each hour.

2.1.2 Anticipated Noise Level at Frelinghuysen Dormitory

The anticipated noise level on the parking lot (canal) side of the Frelinghuysen dormitory due to traffic on the extension of Route 18 along the Delaware Raritan Canal will be significantly higher than the existing noise level. It is estimated that the average daytime noise level will be increased from the current level of 51 dB(A) to approximately 75 dB (A) in 1975 and to 77 dB(A) in 1995.

The 1975 and 1995 noise levels on the outside of the canal side of the dormitory were determined by using noise level/traffic data obtained on an existing section of Route 18 and modifying this noise level on the basis of forecasts of traffic expected on the extended section. This is discussed in detail in Section 4.4. Briefly the anticipated noise level is derived from the following equation.

$$\text{Noise level dorm} = \text{noise level RTE18} - \Delta_1 + \Delta_2 + \Delta_3$$

Where: Noise level dorm = Anticipated noise level at Frelinghuysen

Noise level RTE18 = measured noise level at Sanitation Building (Fig. 3.2-1)

Δ_1 = dB representative of difference in line of sight distance between median strip and the dormitory and median strip and the Sanitation Building

Δ_2 = dB representative of traffic velocity differential at the two sites

Δ_3 = dB representative of traffic volume differential (1972 vs. 1975; 1972 vs. 1995)

For 1975 this equation is as follows:

$$\begin{aligned}\text{Noise level dorm} &= 74.0 - 1.7 + 4.0 - 1.1 \\ &= 74.0 + 1.2 \\ &= 75.2 \text{ dB(A)}\end{aligned}$$

Similarly, for 1995

$$\begin{aligned}\text{Noise level dorm} &= 74.0 - 1.7 + 4.0 + 0.9 \\ &= 74.0 + 3.2 \\ &= 77.2 \text{ dB(A)}\end{aligned}$$

It should be pointed out that tests or analyses were not performed to evaluate the noise impact of the extended highway during the evening and night hours. The change in noise level in the front of the dormitory, along

George Street, which might result from the Route 18 extension also was not determined. It is reasonable to assume that either directly transmitted or reflected noise from the highway will be heard in front of the dormitories, increasing both the daytime and nightime noise levels. Further data on the anticipated diurnal traffic variations would be required to permit an estimation of the impact of nightime traffic on the noise level on both sides of the dormitory.

The noise level at the George Street dormitory site will be impacted by the adjacent access ramps. The structure carrying Ramp U across the highway will block some of the highway noise. However, traffic using the access ramps will contribute to the area noise level, both at the end of the Frelinghuysen dormitory and by increased traffic on George Street. Due to the complex nature of the proposed ramp configurations in the vicinity of of the dormitories, the net effect of the ramps on the area noise level could not be determined for this report.

2.1.3 Attenuation of Traffic Generated Noise

Traffic generated noise from the extension of Route 18 past the George Street dormitories would be attenuated by the dormitory structures themselves. The magnitude of attenuation would depend upon the area of windows and doors on the canal side which remain open. The attenuation which occurs when the windows, etc. are closed is basically the same for the two levels of noise anticipated in 1975 and 1995, approximately 25 dB(A).

The noise level inside the dormitory is attenuated to a lesser degree when windows are open. From the measurements made in one room on the 6th floor and a classroom on the "A" level, see Figure 1.1-1, the inside noise level change, windows closed to windows open, ranges from 7 dB when the outside noise level was approximately 77dB to 14dB with 80dB outside. This apparent response to outside noise level is not a function solely of window attenuation. A constant change should have been recorded. Either the outside level changed (measurements were not made simultaneously) or different conditions occurred, i.e., area of open windows, location of measurement, etc. Data obtained inside and outside the ground floor lounge when the windows were open, show an 11dB reduction in noise level from outside to inside. The 25 dB attenuation previously identified for the building structure in reality is made up of 11dB for the brick and mortar and 14dB for the windows and doors.

Traffic generated noise from the proposed extension would be attenuated at least 21dB if the highway as seen in back of the dormitories was covered with a cantilevered deck. If there are either direct or reflected "line of sight" paths from the highway to the dormitory from "undecked" sections of the highway, the attenuation resulting from the deck would be reduced. The loss in attenuation would be a function of the angle subtended by the deck as seen from the dormitory compared to the total angle subtended by the highway.

Noise generated on the extension of Route 18 would be attenuated somewhat by the existing slope between the canal and the rear of the parking lot, see Figure 1.1-1. This effect would reduce the noise level transmitted tothe bottom floors of the dormitory. Little or no attenuation would occur for the upper floors however.

2.1.4 <u>Projected Noise Level at Frelinghuysen</u>

The average daytime noise level outside the canal side of Frelinghuysen would be 75 dB in 1975 and 77 dB(A) in 1995 if Route 18 were extended as proposed.

The noise level inside this face of the dormitory will be 66dB and 69 dB(A) for those years respectively if the doors and windows are left open. If the doors and windows are kept closed, the inside noise will be approximately 52dB and 55dB for 1975 and 1995.

Construction of a cantilevered deck over the highway to block all direct or reflected traffic generated noise will control the noise level outside the dormitory resulting from the highway to less than 56dB(A) in 1975 and to less than 59dB(A) in 1995. The noise level inside the dormitory for these conditions will be essentially the same as it is at the present time. The noise inside the dormitory will be primarily due to George Street traffic and other noise sources above the cantilevered deck.

2.2 CONCLUSIONS

Three primary conclusions are derived from the noise impact study performed with respect to the proposed Route 18 extension adjacent to the George Street dormitories of Rutgers University. These are:

a. The noise level on the face of the dormitories overlooking the extension of Route 18 as proposed will be increased to approximately 75dB(A) weighted in 1975 and to about 77dB(A) weighted in 1995 during peak traffic periods on the highway.

b. A cantilevered deck constructed over the proposed highway to block all direct or reflected traffic generated noise will control the noise level outside the dormitory, resulting from the highway, to less than 56dB(A) in 1975 and to less than 59dB(A) in 1995. The noise level inside the dormitory for these conditions will be essentially the same as it is at the present time.

c. The traffic generated noise level inside the dormitories will be attenuated as much or more by keeping doors and windows closed as it would be by construction of a cantilevered deck.

As indicated, the quantitative effect of a deck over the proposed extension is subject to several factors which were not covered in the impact These are:

a. The length of the deck

b. The "look angle", if any, from the uncovered sections of the highway to the dormitories.

c. The configuration of access ramps to and from the highway. The above includes the volume and velocity of traffic using the ramps as well as the attenuation of highway noise produced by the ramp structure.

On the assumption that the deck is configured so that all direct line of sight from the highway to the dormitories is eliminated, the noise level at the dormitories resulting from the extension of Route 18 would be at least 21dB less than the 75 and 77dB level stated above.

The access ramps in the vincinity of the dormitories would alter the noise level at the ends and the George Street side of the dormitories. As previously stated, due to the complex nature of the ramp configuration in the vicinity of the dormitories, the net effect of the ramp traffic on the area noise level could not be determined for this report.

It is to be expected that George Street traffic will be greater in 1975 and 1995 than during 1972 regardless of the location or configuration of Route 18. This increased traffic will raise the noise level at the dormitories. A two or three fold increase in George Street traffic will not adversely effect the noise level inside the dormitories. (A threefold increase will raise the midday noise level outside the dormitory from 66.0dB to 70.5dB. This 70.5dB noise level will be attenuated by 11dB(A) by the building when the windows and doors are open and by 25dB(A) when they are closed. The inside noise level due to George Street traffic therefore will range between 45 and 59dB(A).

3.0 STUDY PROGRAM

The impact study of the proposed Route 18 Extension on the noise level at the George Street dormitories of Rutgers University was conducted to achieve two objectives. These were:

a. To estimate the noise level that would be received inside and outside the Frelinghuysen dormitory as a result of vehicular traffic along the Route 18 extension if the highway is constructed as proposed and to compare that noise level with the existing noise level at the dormitory.

b. To determine the attenuating effect on the estimated traffic noise level if a deck were to be added over the roadway near the dormitory.

The first objective was achieved by noise recordings, simulations, measurements and analytical steps as described below:

a. Tape recording traffic generated noise near the New Street Overpass of Route 18 between 7:00 AM and 5 PM on 29 March 1972.

b. Measuring the vehicular traffic on Route 18 during the daylight hours of 29 March.

c. Preparing a 15 minute magnetic tape loop recording representative of the noise level due to high traffic density conditions on Route 18.

d. Playing back the tape recorded noise thru acoustic horns placed on the tow path at the Frelinghuysen dormitory site. The noise was played back at two different noise levels representative of 1975 and 1995 traffic conditions. Each level was continuously broadcast for two days.

e. Measuring the received noise level at different locations inside and outside the Frelinghuysen dormitory during the playback periods.

f. Measuring the noise level at the Frelinghuysen dormitory generated by traffic along George Street.

g. Comparing the George Street and simulated Route 18 traffic generated noise levels.

The second objective was achieved by the following noise measurement and analytical steps.

a. Measuring the traffic generated noise at different locations above and below the cantilevered deck over the Franklin D. Roosevelt Drive at the site of the United Nations Headquarters in New York City on 22 and 23 March 1972.

b. Measuring the vehicular traffic on the Franklin D. Roosevelt Drive during the noise measurement periods.

c. Determining the noise attenuation of the cantilevered deck for the measured traffic conditions.

d. Extrapolating the deck attenuation for the anticipated traffic conditions on the proposed Route 18 Extension.

e. Estimating the received noise level at the Frelinghuysen dormitory that would result from the Route 18 Extension with a deck over the highway adjacent to the George Street dormitories.

The noise recording and simulation steps outlined above were performed in four groups broadly categorized as follows:

1. Deck Attenuation

2. Existing Route 18 Noise

3. Noise Simulation at Frelinghuysen Dormitory

4. George Street Traffic Generated Noise at Frelinghuysen Dormitory

The detailed description of each site and the data obtained during the field work are presented and discussed in sections 3.1 thru 3.4.

3.1 DECK ATTENUATION

3.1.1 Site Description and Data

Noise level measurements were taken of traffic generated noise at various different locations inside and outside the United Nations Headquarters Conference Building in New York City. The U.N. Conference Building is situated on a cantilevered deck, as shown on Figure 3.1-1, over the Franklin D. Roosevelt Drive. The deck is 9.5 inches thick and is supported by 18 by 36 inch steel beams resting on a concrete wall on the west and concrete pillars along the median strip. It is open to the East River on the east and extends from 42nd to 48th Streets, approximately 1460 feet. The Conference Building is located 200 feet from the south edge of the deck and 23 feet from the fascia on the East River side. The building face, parallel to the FDR Drive, is 394 feet long.

The noise level measurements were obtained, with both portable and fixed mounted equipment using "A" weighting, on 22 and 23 March 1972. The measurement locations are shown on Figure 3.1-1.

Continuous noise level measurements were made from 8:00 AM on 22 March to 8:00 AM on 23 March of the traffic generated noise under the deck. This data was acquired from a microphone mounted above the median strip (location M) and recorded on a paper chart recorder. Short duration measurements were made on the 22nd at eight other locations (1 thru 8). These measurements were made with a second microphone (obtaining paper chart recordings) and a portable sound level meter. Table 3.1-1 presents the noise level data obtained together with the time of measurement at each location and identifies those measurements made with the portable equipment. Continuous noise level data was obtained at the edge of the northbound traffic lanes south of the end of the deck, (location 7) and on the deck north of the Conference Building

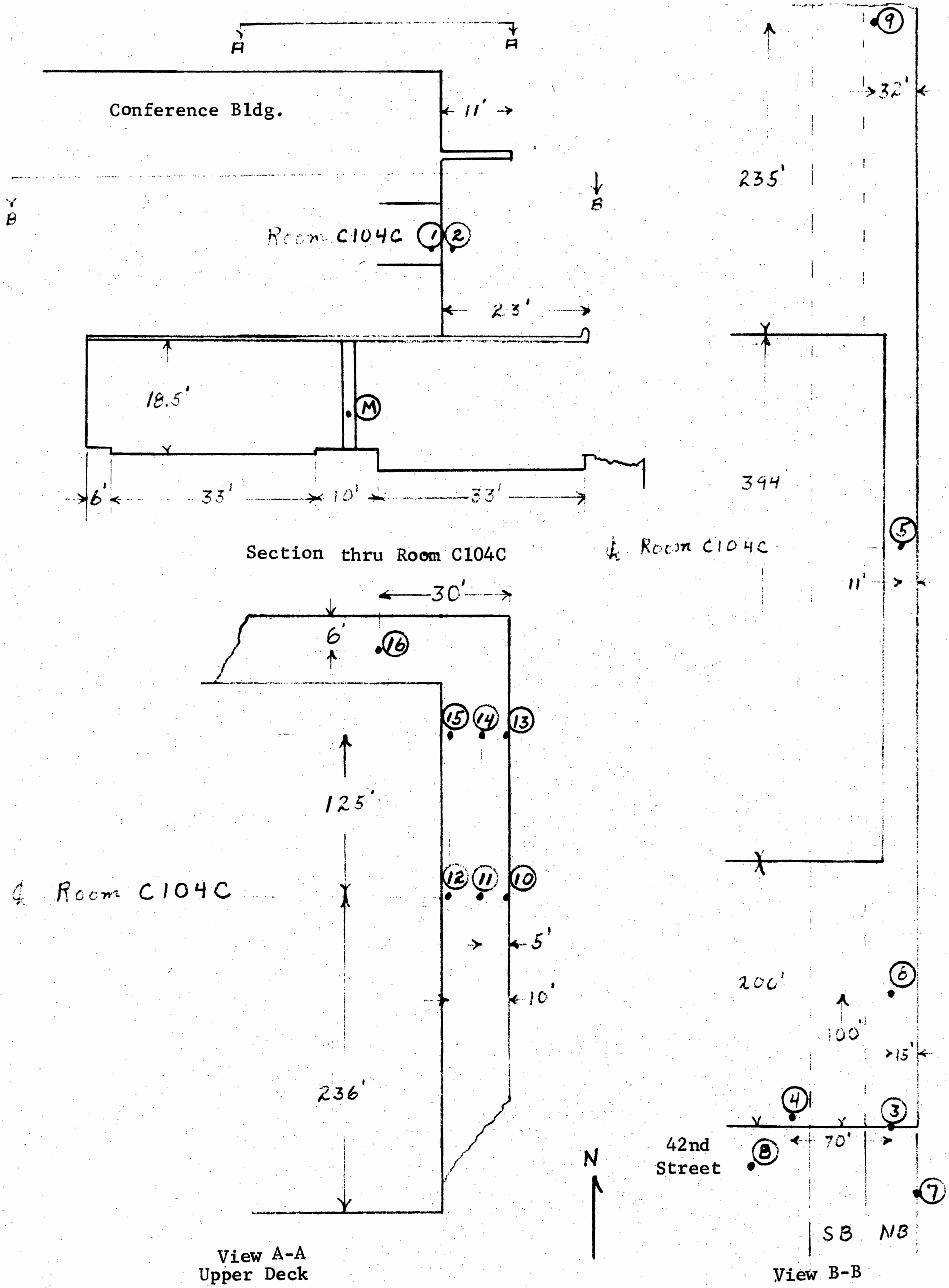


Figure 3.1-1 United Nations Site

TABLE 3.1-1

NOISE LEVEL
UNITED NATIONS SITE

DAY	HOUR	MEDIAN	MIKE 2							
			1	2	3	4	5	6	7	8
3/22/72	0800 - 0900	91.0	51.0*	66.0*						
	0900 - 1000	90.5								
	1000 - 1100	90.0			79.5					
	1100 - 1200	90.0		67.5		73.0				
	1200 - 1300	90.5					67.5			
	1300 - 1400	90.5								
	1400 - 1454	90.5			79.0		65.5			
	1454 - 1536	90.0				70.0		70.0*		
	1536 - 1618	89.5						70.0*	79.5	
	1618 - 1630	90.0								
	1630 - 1700	90.5								79.0*
	1700 - 1800	90.0								
	1800 - 1900	89.0								
	1900 - 2000	90.0								
	2000 - 2100	89.5								
	2100 - 2200	88.5								
	2200 - 2300	88.5								
	2300 - 2400	88.5								
3/23/72	2400 - 0100	85.5								
	0100 - 0200	82.5								
	0200 - 0300	78.0								
	0300 - 0400	75.0								
	0400 - 0500	77.0								
	0500 - 0600	83.0								
	0600 - 0700	91.5								
	0700 - 0800	92.0								

* Portable Equipment Readings

(location 9) between 10:00 AM and 2 PM on 23 March. Both chart recorders and two microphones were used for these measurements. Short duration measurements were also made on the upper deck of the Conference Building using a portable sound level meter at seven other locations between 1:30 and 2:00 PM (locations 10 thru 16). Simultaneously with these seven readings, the noise levels at road edge and on the lower deck were read. These data are shown on Table 3.1-2. The instrumentation and calibration techniques used are described in Section 4.0.

Vehicular traffic flow (volume and speed), on both the North and South bound lanes of the Franklin D. Roosevelt Drive, opposite East 48th Street, was recorded in hourly increments by the City of New York, Department of Traffic from 1 PM on 20 March to 10 AM on 24 March. The total traffic data obtained is listed in Table 3.1-3. Figure 3.1-2 shows the diurnal pattern of the two-way traffic on the FDR Drive as averaged for the four days of traffic flow measurements.

Examination of the traffic data for the hours between 8 AM and 5 PM for 22 and 23 March shows that, in general, traffic on 22 March was about 12.5% higher than the average and, on 23 March, about 17% lower than average. Traffic on the 23rd during the 9 AM to 2 PM period of noise level measurements was approximately 25% lower than that measured for the comparable hours on the 22nd. Accordingly, the noise level in close proximity to the roadway on the 23rd is expected to be between 0.7 and 1.0 dB lower than measured on the 22nd.

3.1.2 <u>Noise/Traffic Relationships</u>

Figure 3.1-3 depicts the "A" weighted noise/traffic relationship for this segment of the FDR Drive for the 24 hour period starting 8 AM on

TABLE 3.1-2

NOISE LEVEL
UNITED NATIONS SITE

3/23/72

HOUR	1	7	9	10	11	12	13	14	15	16
0924 - 1000		81.5								
1000 - 1100		81.0	60.5							
1100 - 1200		81.0	60.0							
1200 - 1300		81.5	60.5							
1300 - 1330		81.5	60.0							
1330		82.0								
1338		81.0	59.0	62						
1340		86.0	59.0		59					
1343		83.0	59.0			57				
1347		78.0	58.0				60			
1348		83.0	59.0					55		
1350		83.0	59.5						58	
1354		85.0	62.0							57
1400			60.0							
1412		82.0								
1418 - 1436	45									
1448 - 1506	48									

TABLE 3.1-3

VEHICULAR VOLUME
FRANKLIN D. ROOSEVELT DRIVE
@ E. 48TH STREET

Date	3/21/72			3/22/72			3/23/72			3/24/72		
Hour	NB	SB	TOT	NB	SB	TOT	NB	SB	TOT	NB	SB	TOT
12-1 AM	990	628	1618	1081	1021	2102	1080	892	1972	1116	482	1598
1-2	484	306	790	551	453	1004	607	435	1042	633	252	885
2-3	320	206	526	309	317	626	349	289	638	375	144	519
3-4	195	118	313	211	204	415	224	189	413	219	86	305
4-5	244	155	399	234	206	440	236	239	475	265	125	390
5-6	385	345	730	421	399	820	410	533	943	401	331	732
6-7	1276	1186	2462	1284	1268	2552	1296	1703	2999	1281	1277	2558
7-8	2473	2415	4888	2715	1631	4346	2569	2513	5082	2431	1928	4359
8-9	2526	1895	4421	2588	3405	5993	2656	2189	4845	2673	1876	4549
9-10	1912	1746	3658	2122	3040	5162	2044	1948	3992	2123	1842	3965
10-11	1885	1533	3418	1903	2974	4877	1999	2252	4251	-	-	-
11-12	2093	1464	3557	2054	2471	4525	2074	1826	3900	-	-	-
											3/20/72	
12-1 PM	2144	2474	4618	2183	2439	4622	2263	1639	3902	-	-	-
1-2	2401	2568	4969	2166	2390	4556	2282	1575	3857	2423	2522	4945
2-3	2708	2643	5351	2552	2520	5072	2087	1524	3611	2592	3589	6181
3-4	3509	2828	6337	3089	2667	5756	1671	1564	3235	2778	3178	5956
4-5	3893	3118	7011	3079	2657	5736	1537	1782	3319	2201	2976	5177
5-6	3748	2827	6575	2352	2731	5083	2397	2066	4463	2741	2886	5627
6-7	3358	2355	5713	2999	2096	5095	3069	1783	4852	3326	2194	5520
7-8	2652	2227	4879	2611	1766	4377	2654	1337	3991	2603	1818	4421
8-9	2200	1635	3835	2119	1231	3350	2101	1084	3185	2067	1306	3373
9-10	1874	1361	3235	1789	916	2705	2042	876	2918	1813	908	2721
10-11	1677	1295	2972	1663	1059	2722	1673	944	2617	1483	1044	2527
11-12	1391	1470	2861	1362	1017	2379	1505	928	2433	1292	893	2185
Total	46338	38798	85136	43437	40878	84315	40825	32110	72935	-	-	-

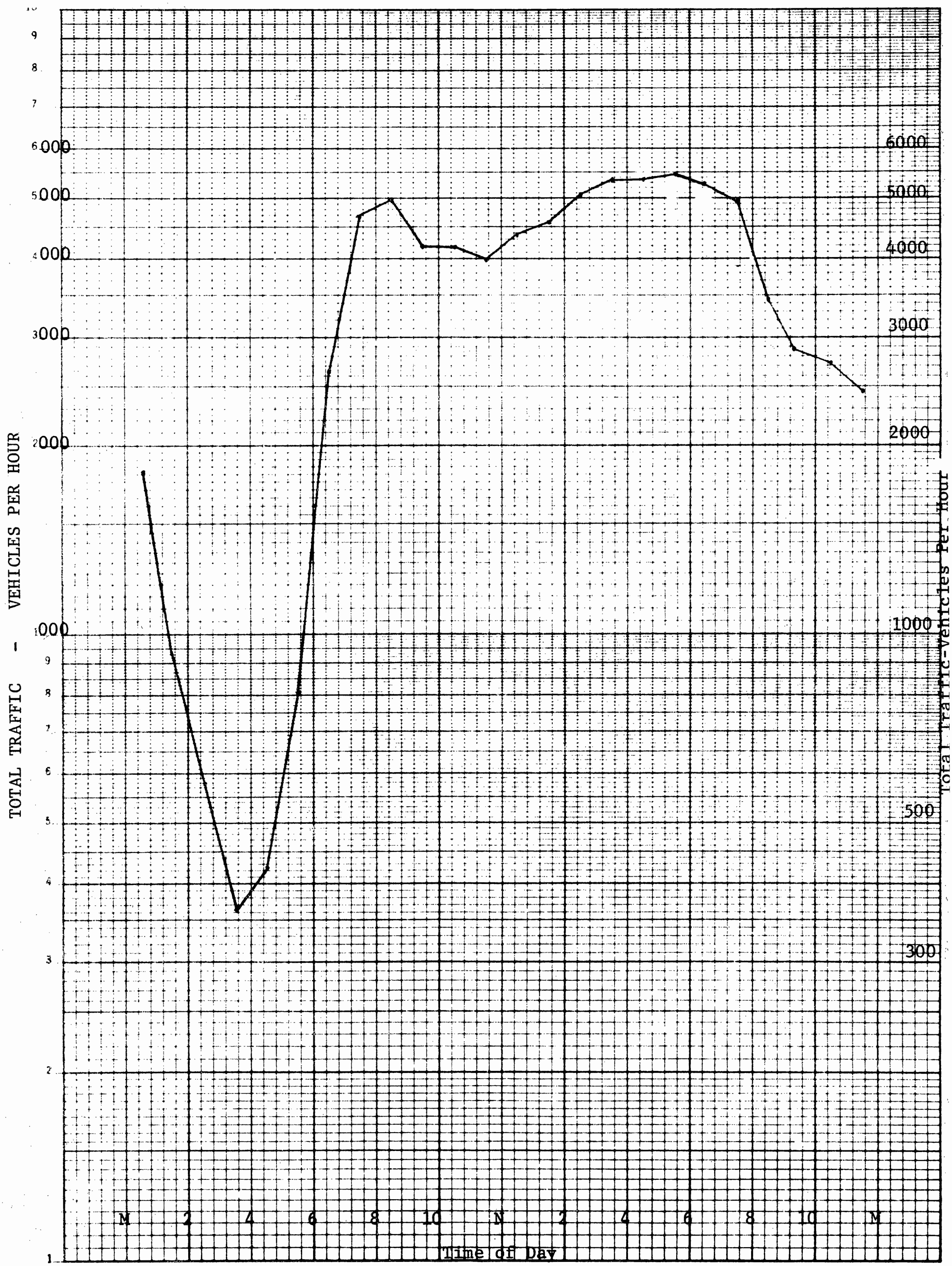


FIGURE 3.1-2 AVERAGE DIURNAL TRAFFIC - FRANKLIN D. ROOSEVELT DRIVE

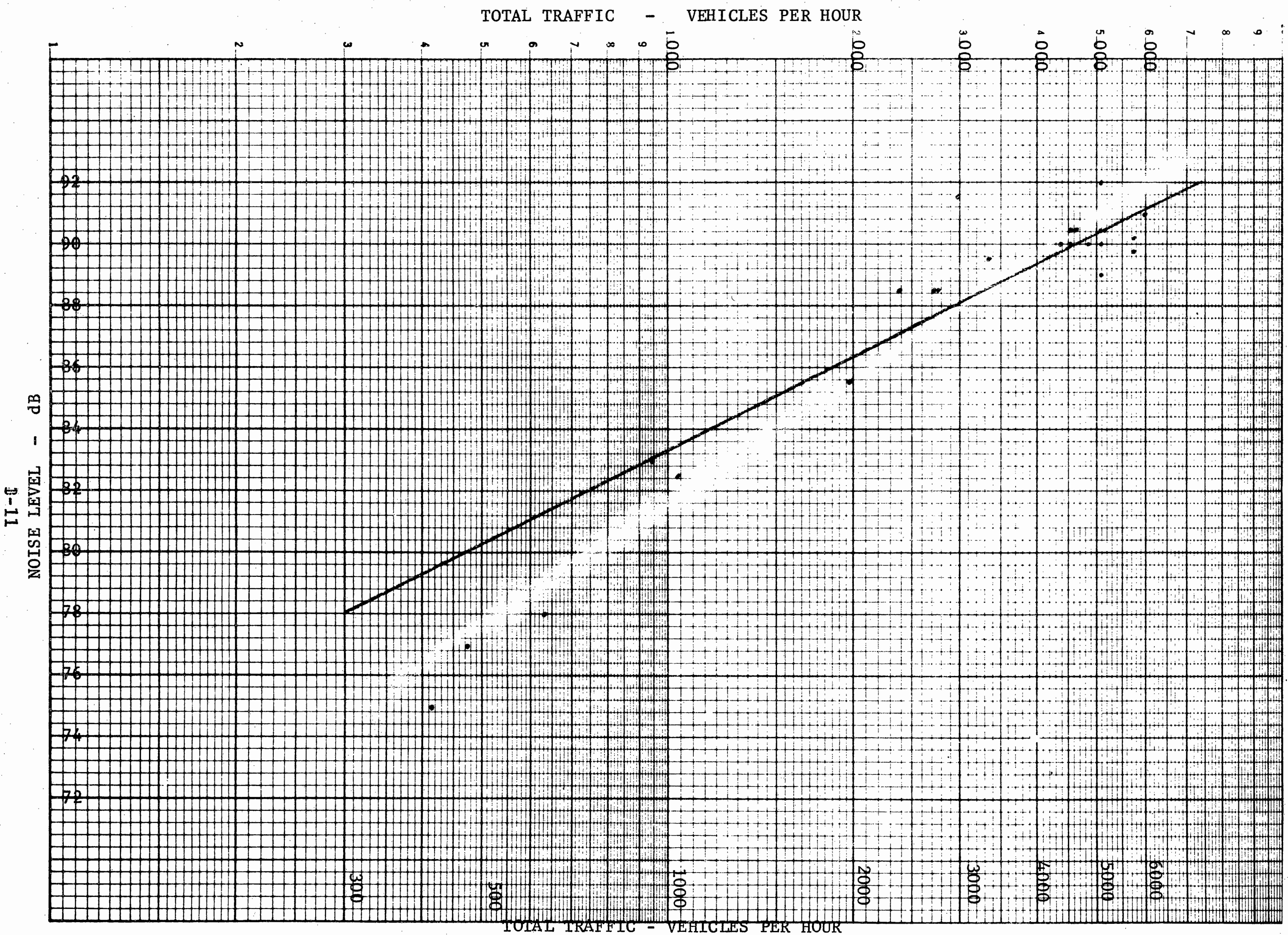


FIGURE 3.1-3 MEDIAN STRIP NOISE VS TRAFFIC - FRANKLIN D. ROOSEVELT DRIVE - 22 MARCH

22 March, as recorded under the deck at the median strip. It shows that "A" weighted noise under the deck increases approximately 3.0dB for each doubling of traffic volume.

Figures 3.1-4 and 3.1-5, for 22 and 23 March respectively, show the pertinent data obtained during the noise measurement periods. The numbers on the figures denote the location of the reading. Median strip noise measurements were not made after 8:00 AM on 23 March. The median strip noise shown on Figure 3.1-5 was determined by use of the traffic data for 23 March and the noise/traffic relationship shown on Figure 3.1-3. It can be seen from Figure 3.1-5 that the "A" weighted noise level on the median strip, under the deck, is approximately 8dB higher than that measured at the road edge of the northbound lanes. The differential between the same measurement points on 22 March under higher traffic conditions was 10dB (see Figure 3.1-4, median strip and location 7). Since the road edge noise and traffic flow rates for the 23 March measurement period are essentially flat, the difference in noise level between the two points (locations M&7) cannot be related to traffic flow rate. Therefore, for traffic flow rates between 3500 and 6000 cars per hour, the cantilevered deck increases the traffic generated noise level close to the highway by approximately 10 dB.

3.1.3 Deck Attenuation

Noise level measurements on the deck above the median strip (location 9) approximately 830 feet from the south end of the deck are essentially constant at 60.0DB "A" weighted. As shown on Figure 3.1-4, other noise level measurements taken on 22 March on the deck and closer to its south end (locations 5,6&3) are progressively higher as the measurement location nears the south

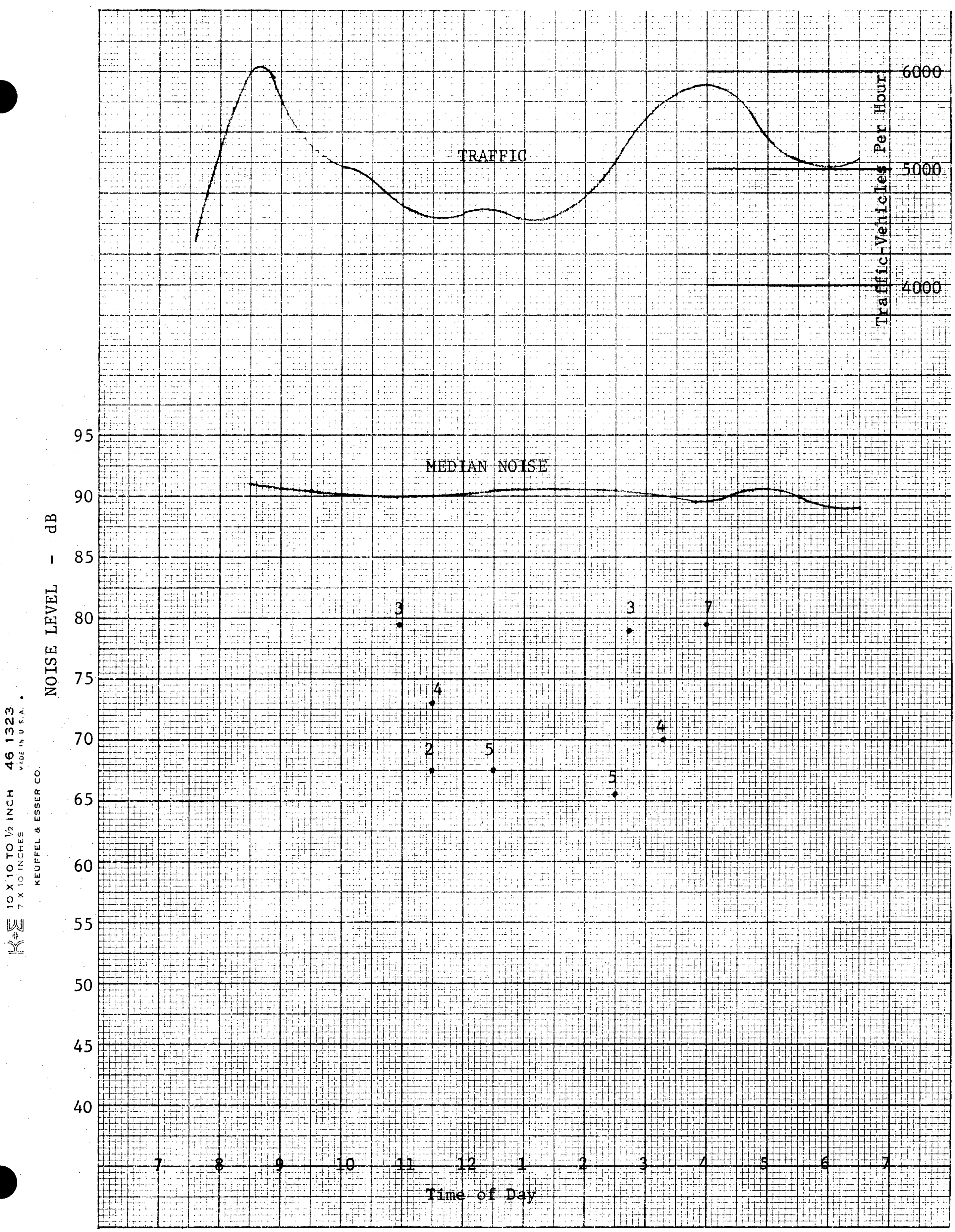


FIGURE 3.1-4 TRAFFIC/NOISE RELATIONSHIP - F.D.R. DRIVE - 22 MARCH

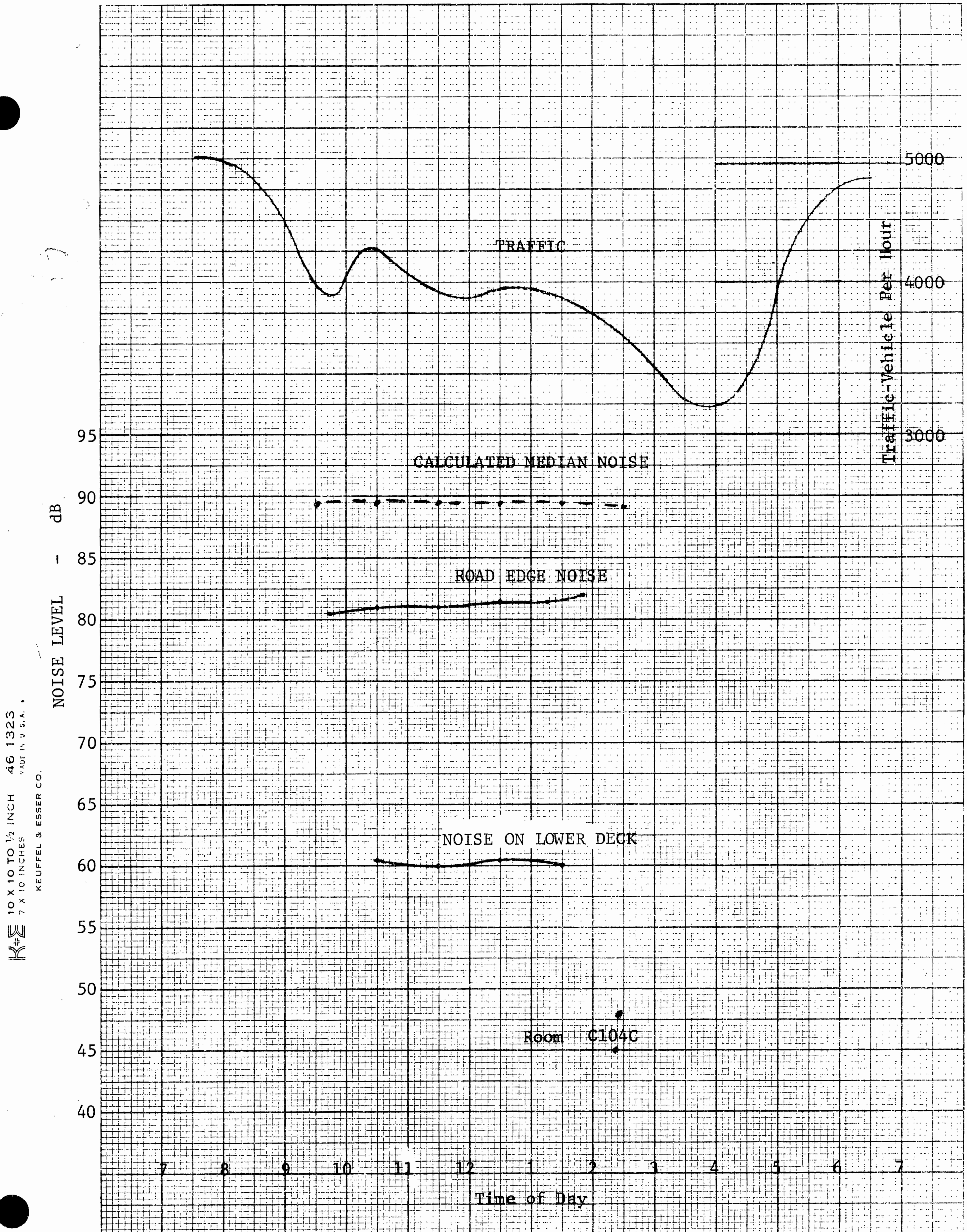


FIGURE 3.1-5 TRAFFIC/NOISE RELATIONSHIP - F.D.R. DRIVE - 23 MARCH

end. This phenomenon suggests that the noise level above the deck is directly received noise rather than noise transmitted thru the deck. Additional measurements made off the deck (location 8) show that the blowers in the ventilation building for the Queens Midtown Tunnel south of the deck contribute to the noise level above the deck over the FDR Drive. Therefore it is concluded that on-deck noise is made up of noise transmitted from traffic generated noise on highway south of the deck, from blower noise west of the highway and other noise sources in the vicinity. Direct correlation was observed during the test period of short duration noise peaks with the nearby presence of helicopters and tugboats. Noise attenuation thru the deck therefore is in excess of the 29.5 dB difference between the calculated median strip noise level and the above deck noise level readings.

This 29.5+dB difference is indicative only of the sound suppression characteristics of the deck and not a measure of the impact of a deck on the off roadway noise level. The impact of the deck is better seen by comparing the road edge noise with the above deck noise shown on figure 3.1-5. The average differential between these readings is approximately 21dB. Neither of these readings, however, are exact definitions of the desired measurements. The 60.0dB noise level on the deck includes some non highway related noise. The 81.0dB is road edge rather than median strip noise level. Accordingly the true noise level above the deck due solely to the highway is lower than 60.0dB and the median strip noise level for the "undecked" portion of the highway is slightly higher than 81.0dB. The noise attenuation of the deck therefore is somewhat more than 21dB.

3.1.4 Distance Attenuation

Examination of the average "A" weighted noise levels recorded thru microphone 2 at locations 3, 6 & 5 on 22 March and at location 9 on 23 March (see Figure 3.1-1) shows a reasonably linear attenuation with distance from the south end of the deck considering the site geometry, as shown below:

Location	3	6	5	9
Distance (ft.)	0	100	436	829
dB	79.0	70.0	67.5	60.0

The noise levels for locations 3, 6 & 5 were taken at approximately the same distance from the railing along the east side of the deck. Location 9 is twice the distance back from the railing such that the Conference Building shields it from noise from the south end of the deck. The microphone at location 3 was directly over the northbound traffic lanes. The decrease in noise level with distance parallel to the east edge of the deck indicates that the on-deck noise during the daytime is not a function of traffic generated noise coming over the east side of the deck. This is further substantiated by noting that there is no difference in noise level at locations 2 and 5, (see Table 3.1-1) even though location 2 is twice as far from the east fascia of the lower deck.

Simultaneous readings of the noise level on the upper deck of the Conference Building and on both the surface of the lower deck and the road edge location were obtained between 1:30 and 2:00 PM on March 23. The upper deck noise level readings were taken at seven locations (10 thru 16), as shown on Figure 3.1-1. These readings are shown on Table 3.1-2 and are repeated in matrix form below. The matrix is structured as a function of distance westward from the upper deck railing and northward from the 42nd Street (south) edge of the lower deck.

Distance Rail	Distance Edge	Road Edge	Upper Deck	Diff. RE-UD	Lower Deck	Diff. RE-LD
0	436	81.0	62.0	19.0	59.0	22.0
0	561	78.0	60.0	18.0	58.0	20.0
5	436	86.0	59.0	27.0	59.0	27.0
5	561	83.0	55.0	28.0	59.0	24.0
10	436	83.0	57.0	26.0	59.0	24.0
10	561	83.0	58.0	25.0	59.0	23.5
30	599	85.0	57.0	28.0	62.0	23.0

It should be noted that the location 30 feet from the rail and 599 feet from the lower deck edge (location 16) is 6 feet from the upper deck railing on the north face of the building.

The matrix shows that neither the upper deck nor the lower deck noise levels responds to the road edge variations. The upper deck noise is influenced more by distance back from the edge of the upper deck than distance from either the east or south edges of the lower deck. This is more evident when the differential level between the upper and lower deck measurements is examined as a function of north south distance between measurement locations as well as distance back from the upper deck rail.

NOISE LEVEL DIFFERENCE -dB

DISTANCE FROM UPPER DECK RAIL (FT.)	NORTH SOUTH DISTANCE (FT.) 393	268	230
0	3.0	2.0	-
5-6	0	-4.0	-5.0
10	-2.0	-1.5	-

Thus it is seen that a deck edge sharply attenuates the noise level below it in the first few feet, explaining why little or no effect was recorded in the lower deck readings as a function of distance from its east fascia at distances in excess of 10 feet.

3.1.5 Building Attenuation

Noise level measurements were made inside and outside Room C104C during the two day testing period. These readings at locations 1 and 2 are repeated below:

	Inside (1) Window Closed	Window Open	Outside (2)
dB	45.0	48.0	67.5

The attenuation of the building (19.5 or 22.5 dB) is very comparable to the 21+dB attenuation of the deck.

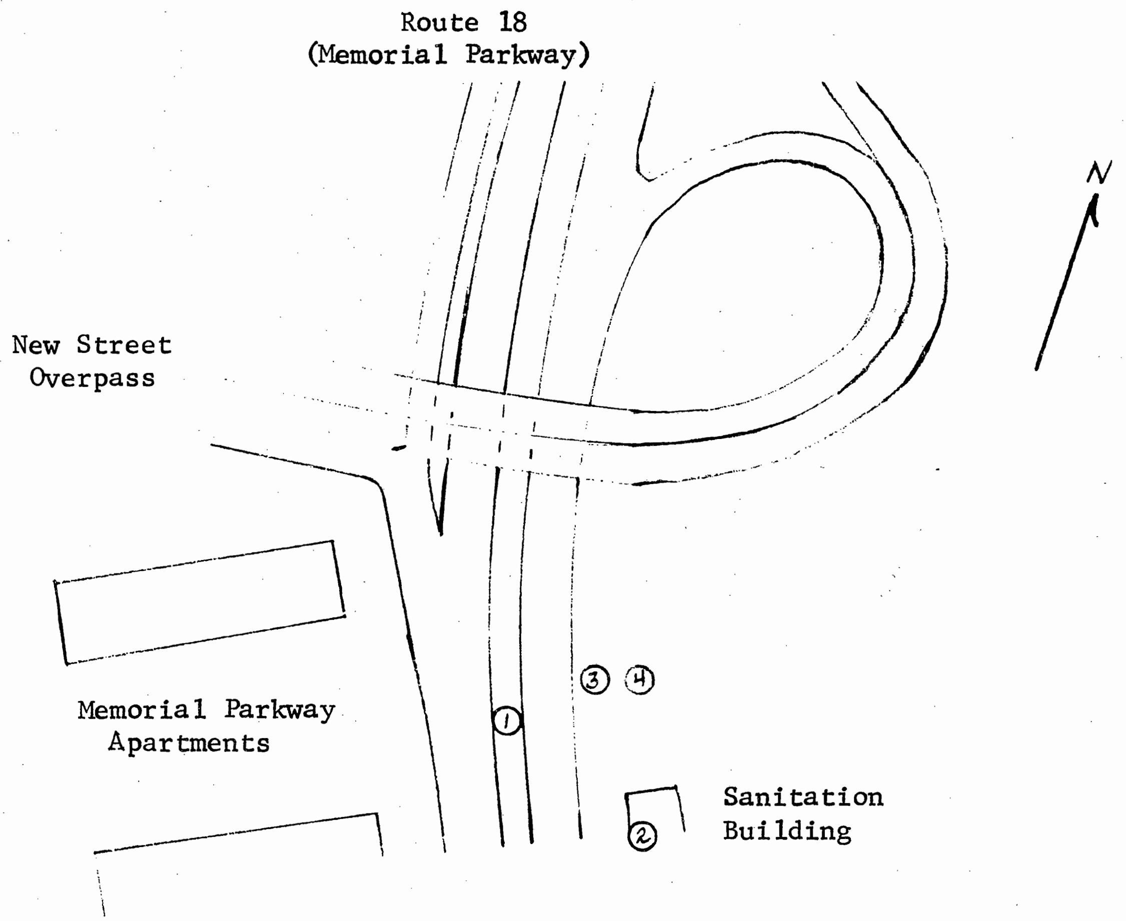
3.2 NOISE LEVEL ON EXISTING ROUTE 18

3.2.1 Site Description and Data

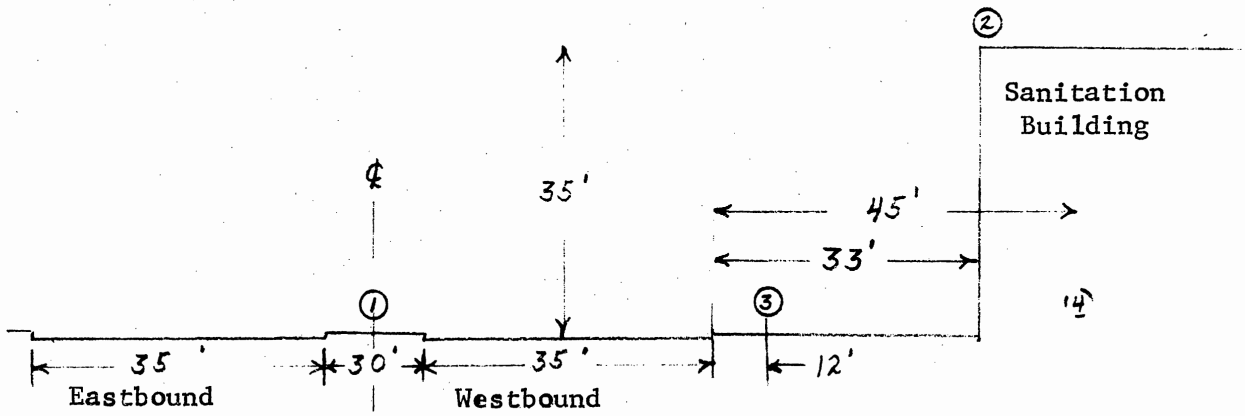
Noise level recordings and measurements were taken of Route 18 traffic generated noise on an existing section of the highway, south of the New Street overpass. The highway, at this point, is an "open" type four lane divided highway. West and East bound traffic lanes are separated by a wide grass covered median strip. At the test site, a Westbound exit lane channels part of the traffic to the overpass. An Eastbound entrance lane provides access to the highway from Albany Street.

The noise level data consisted of magnetic tape and paper chart recordings obtained on 29 March from four locations. The measurement locations are shown on Figure 3.2-1. One microphone was mounted on the median strip (location #1) throughout the day. The second microphone was moved during the day to obtain measurements at locations 2,3 and 4. Table 3.2-1 indicates the noise level data recorded on the paper charts, the "weighting" scale used and the time of measurement at each location. Tape recordings were made of the traffic noise, using flat weighted at locations 1,2 and 3, simultaneously with the Flat weighted chart recordings at those locations. Instrumentation and calibration techniques used are described in Section 4.0.

Vehicular traffic flow (volume and speed) on both the West and East bound lanes of Route 18 south of the New Street overpass, was recorded in hourly increments between 7 AM and 6 PM by the New Jersey State Department of Transportation. This traffic was divided into cars and trucks by a classified traffic count. Table 3.2-2 shows the traffic volume by travel direction. Figure 3.2-2 shows the total traffic pattern for the hours for which data is available. Table 3.2-3 lists the average vehicular speed for both



PLAN VIEW



ELEVATION VIEW - ENLARGED

Figure 3.2-1 - Route 18

Table 3.2-1

Noise Level
Route 18 - South of New Street
3/29/72

	"A" Weighted				Flat Weighted		
	1 Med	2 Roof	3 12'	4 45'	1 Med	2 Roof	3 12'
745-839	75.5						
842-905					83.5		
900-1000	75						
944-1028		73					
1000-1100	75						
1030-1054						81	
1100-1200	75						
1054-1130		73					
1200-1300	75.5						
1150-1228			71				
1230-1248							80
1300-1400	75						
1250-1316			71				
1318-1344				65			
1400-1500	75.5						
1355-1425		74					
1430-1456						80	
1500-1517	75						
1517-1536					84.5		
1456-1556		74					
1536-1600	77						
1600-1620					84.0		
1556-1634		74.5					
1636-1728						82	
1620-1720	77						
1720-1732	76.5						
1728-1758		73					

Table 3.2-2

Vehicular Volume
Route 18 - South of New Street
3/29/72

HOUR	WB			EB			TOTAL		
	Cars	Trucks	Total	Cars	Trucks	Total	Cars	Trucks	Total
700-800	1724	63	1787	1182	101	1283	2906	164	3070
800-900	2364	93	2457	1156	104	1260	3520	197	3717
900-1000	1128	98	1226	1181	126	1307	2309	224	2533
1000-1100	1074	115	1189	1047	114	1161	2121	229	2350
1100-1200	1011	101	1112	1220	131	1351	2231	232	2463
1200-1300	1110	83	1193	1301	111	1412	2411	194	2605
1300-1400	1108	89	1197	1327	112	1439	2435	201	2636
1400-1500	1087	94	1181	1437	111	1548	2524	205	2729
1500-1600	1252	105	1357	1820	77	1897	3072	182	3254
1600-1700	1262	71	1333	2207	86	2293	3469	157	3626
1700-1800	1104	56	1160	2067	40	2107	3171	96	3267
TOTAL	14224	968	15192	15945	1113	17058	30169	2081	32250
AVE.	1293	88	1381	1450	101	1551	2743	189	2932
% TRUCKS			6.4			6.5			6.5

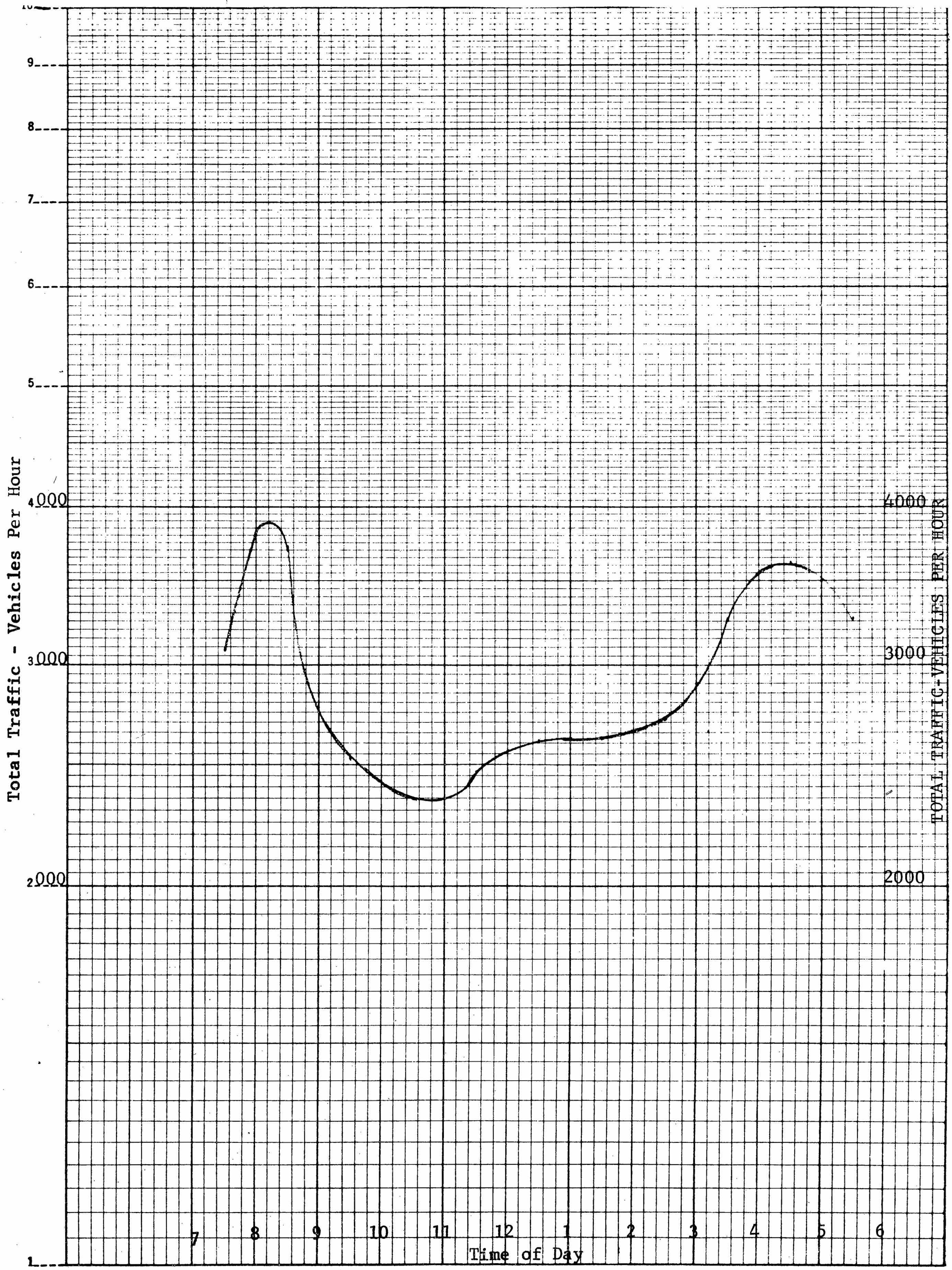


Figure 3.2-2 - Total Traffic Pattern - Route 18 South of New Street

TABLE 3.2-3

VEHICULAR SPEED

ROUTE 18 - South of New Street

3/29/72

Hour	WB	EB
700- 800		40.66
725- 741	38.72	
800- 900		39.43
812- 840	32.69	
900-1000		38.07
930- 957	36.05	
1000-1100		39.99
1010-1033	37.76	
1100-1200		39.01
1045-1115	36.56	
1200-1300		39.06
1226-1246	38.48	
1300-1400		37.88
1400-1430		37.42
1432-1500	43.09	
1430-1500		35.93
1500-1535	40.35	
1500-1600		34.35
1552-1613	40.02	
1600-1700		33.45
1622-1646	42.05	
1647-1706	42.96	
1700-1800		34.34
1730-1753	43.80	
Ave.	39.37	37.32
Total Ave.	38.35	

directions of traffic.

Examination of the traffic data shows that truck traffic varied between 3 and 10% of total traffic during the 11 hour period. Average truck traffic was 6.5%. Total traffic per hour varied between 2350 and 3717 vehicles per hour. Vehicular speed in both directions of traffic varied inversely as a function of the traffic volume on that side of the highway. The average bi-directional traffic speed was slightly over 38 mph.

3.2.2 Noise/Traffic Relationship

Figure 3.2-3 depicts the "A" weighted noise/traffic relationship for the daylight hours on the median strip of Route 18 at the test site. This limited data shows approximately a 3.0 dB increase in the "A" weighted noise level for each doubling of the traffic flow for the existing truck/total traffic relationship. This rate of change closely duplicates the 3.3dB characteristic previously determined for the Bruckner Expressway in New York City.(1) The Route 18 median strip noise level is about 4.5 dB lower than the Bruckner noise level, for 5-15% truck composition, for comparable traffic volume. Three factors contribute to this noise level difference.

1. Route 18 median strip is wider and microphone is further from closest lane of traffic.
2. Route 18 traffic velocity is about 10 mph slower.
3. Average truck percentage of total traffic on Bruckner Expressway is nearly double that of Route 18.

(1) Study of Noise Pollution Aspects of Various Roadway Configurations - New York State Contract - DOT D42157

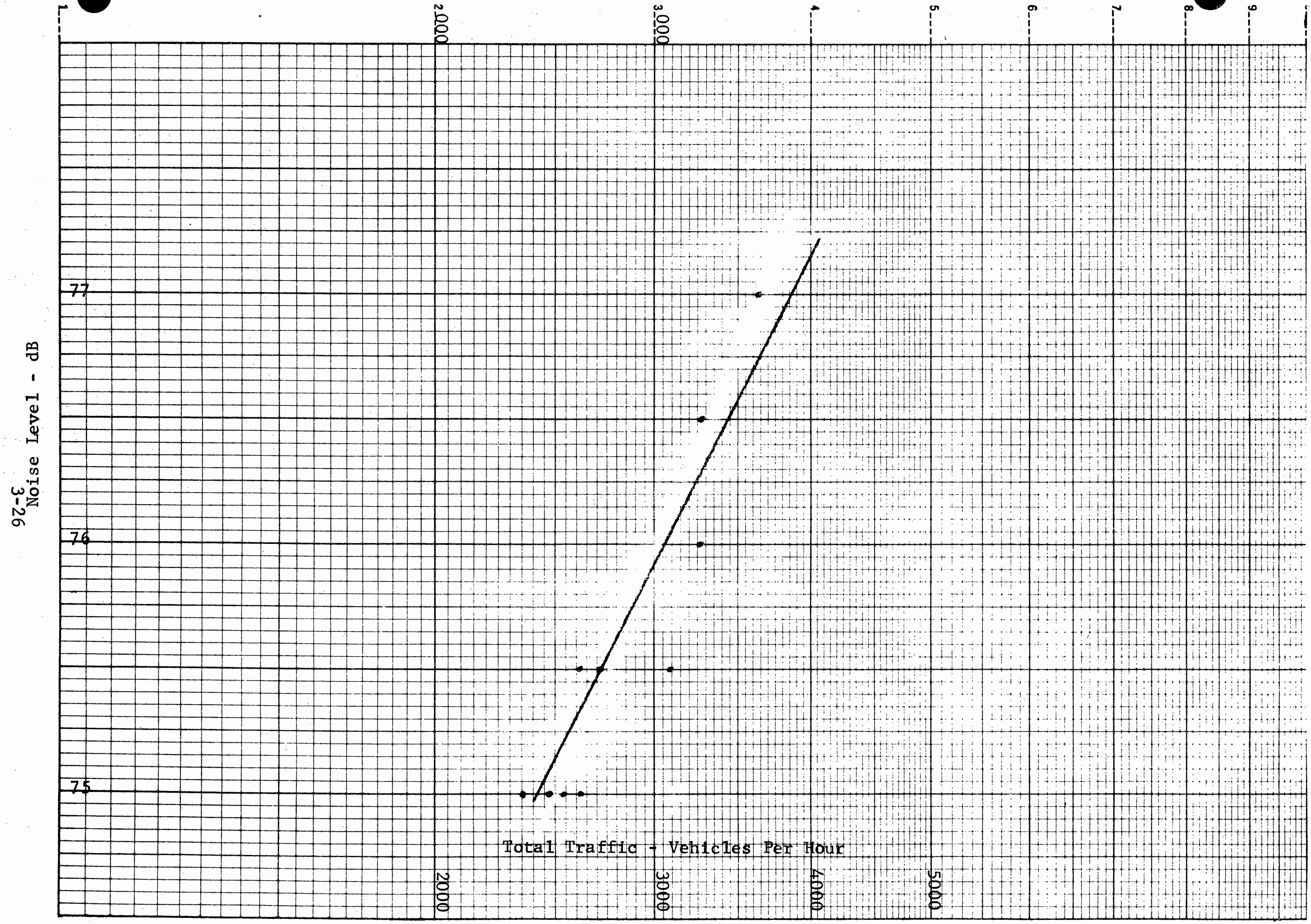


Figure 3.2-3 - Median Strip Noise vs. Traffic - Route 18 South of New Street

3.2.3 Comparison of Noise Level Weightings

The noise level measurements were made using both "A" and Flat weighted scales. A comparison of the sequential measurements taken shows an average difference of plus 8.0 dB between "A" and Flat weighting at each of the three locations for which Flat weighted measurements were made. This characteristic also closely duplicates the plus 7.5 dB relationship from "A" to Flat weighting determined for the Bruckner Expressway.

3.2.4 Site Attenuation

Noise level measurements were made at different times during the day at four locations. The "A" weighted data obtained between 12 and 2 PM, when traffic volume, velocity and truck percentage are essentially constant, at locations 1, 3 and 4 is tabulated below as a function of distance from the center of the median strip.

Dist.(Ft.)	0	62	95
dB	75	71	65

This apparent non-linearity of sound propagation is to be expected. The noise level recorded at each location is the sum of the traffic generated noise from the two directions of traffic. The noise level resulting from each source will be attenuated equally with distance from each line source. At the median strip, the microphone is halfway between the two noise sources. Location 3 and 4, however, are at different distances from the two line sources of noise. During conditions of equal traffic on both sides of the highway and equal number of vehicles per lane, the noise level will be flat from the center line of the south bound lane to the center line of the northbound lane. The noise level will then decrease with distance from the center line of the highway. Under light traffic conditions the peak noise level per highway side will move to the right of its center line. This trend is furthered by the exit ramp on the westbound side. Accordingly, attenuation with distance at the Route 18 site is determined by the noise level change between locations 3 and 4, i.e., a 6 dB decrease for each 33 feet from a point 12 feet off the curb line. This attenuation slope indicates that the centerline of the westbound traffic noise source was about 38 feet to the right of the median strip microphone location, or approximately at the edge of the right lane, westbound.

The noise level recorded on the roof of the Sanitation Building (see Figure 3.2-1) was consistently only 2.5 dB lower than that measured on the median strip and 2.0 dB higher than the ground level measurement 20 feet closer to the highway. This suggests that the roof level location is receiving noise not reaching the off highway ground level microphones. The similarity of the hourly fluctuations indicates that a noise source or sources which are time phased with the Route 18 traffic strongly affects the roof top noise level. These sources could be either the traffic using the New Street overpass or the traffic generated noise reflected off the face of the apartment buildings across the highway, or both. It is possible that the microphone on the Sanitation Building roof, because of its height, is actually receiving Route 18 noise which is blocked from the ground level microphones by the overpass and the crowned median strip.

3.2.5 Tape Recordings of Route 18 Noise

Magnetic tape recordings were made of the traffic generated noise on Route 18 near the New Street overpass at selected times during 29 March. Each recording was approximately 20 minutes long. The start time of each recording and the microphone location recorded is tabulated below.

Time	Location
842	Median Strip
1030	Sanitation Building Roof
1230	12' from curb
1430	Sanitation Building Roof
1517	Median Strip
1600	Median Strip
1636	Sanitation Building Roof
1700	Sanitation Building Roof

As shown on Figure 3.2-2, the total traffic on Route 18 was relatively constant between 9:00 AM and 3:00 PM, rising to its afternoon peak between 4 and 6 PM. Since highway generated noise is blended with distance, i.e. instantaneous peaks measured at one spot due to a vehicle passing the spot are smoothed out by distance off the highway as the vehicle traverses along the highway, the noise level recordings made on the roof of the Sanitation Building were deemed most desirable for playback at the Frelinghuysen dormitory. The 15 minute segment of the noise recorded on the roof between 1636 and 1651 was selected for this purpose.

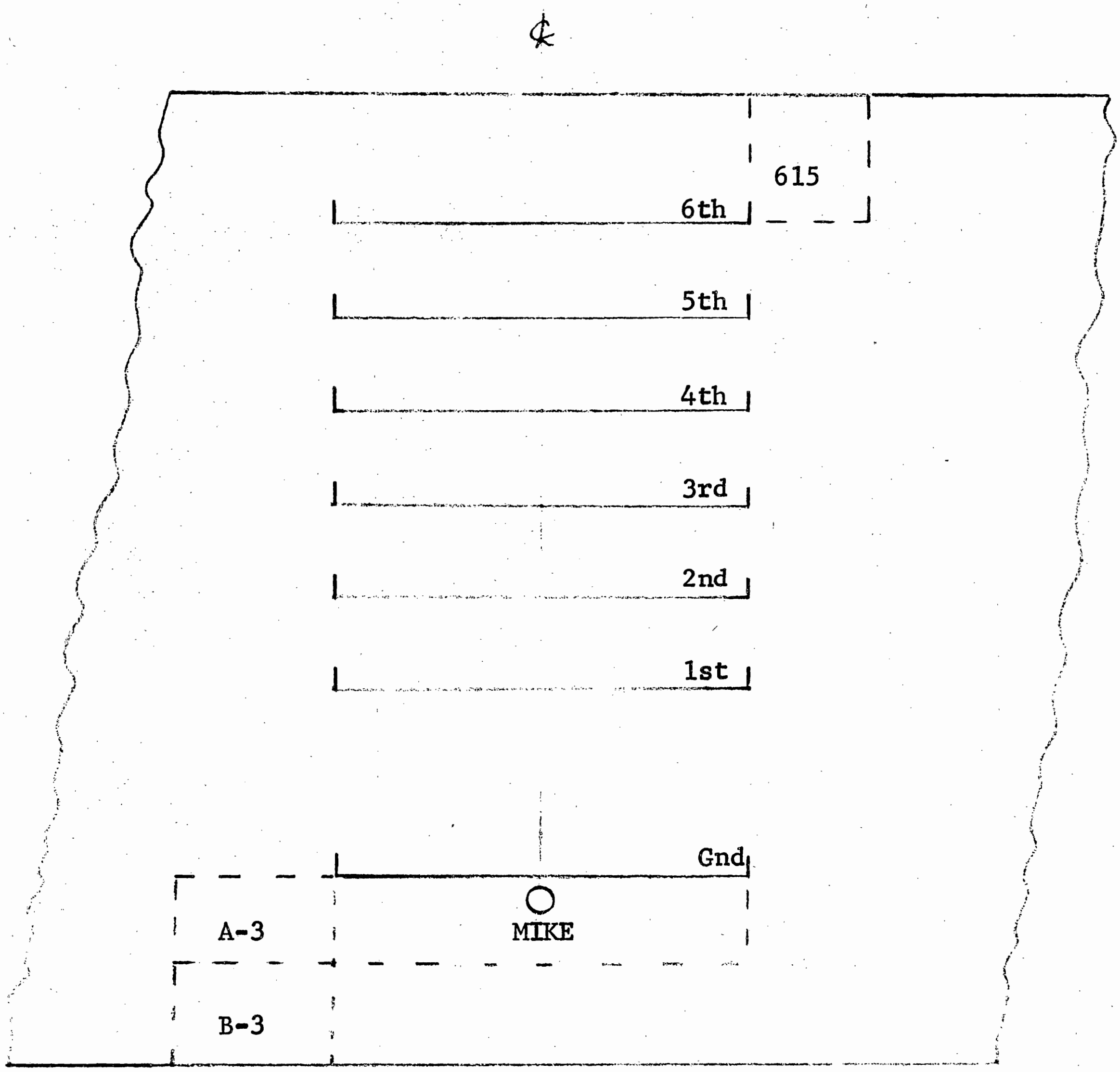
The flat weighted noise at this time was 82 dB. It occurred at a period of relatively high traffic (approximately 3500 vehicles) on Route 18. The truck percentage of total traffic was under 4.5%, lower than average. Traffic was significantly unbalanced on the two sides of the highway. Westbound traffic was approximately 1300 vehicles per hour and travelling about 42 miles per hour. Eastbound traffic was heavier and slower. The 2200 vehicles Eastbound averaged 33 miles per hour.

3.3 SIMULATION AT FRELINGHUYSEN DORMITORY

3.3.1 Site Description and Data

The noise level that would result from traffic traveling on the proposed extension of Route 18 at the Frelinghuysen dormitory was simulated by repetitive playback of the previously recorded Route 18 traffic generated noise. The recorded noise was broadcast thru four loudspeakers mounted on the tow path between the canal and the Raritan River. The speakers were spaced approximately 75 feet apart on a line parallel to the centerline of the proposed highway. They were angled such that the centerline of their cones intersected at the mechanical room of the dormitory. At this point, the perpendicular distance between the line of speakers and the dormitory was 165 feet. This configuration is shown in Figure 3.3-1. A discussion of this simulation technique is included in Section 4.0. The simulated traffic noise consisted of continuous reproduction of a 15 minute tape loop of the Flat weighted noise recorded on 29 March . The noise level broadcast was adjusted to control the amplitude received at the window of the mechanical room in the Frelinghuysen dormitory. The received noise level was set at approximately 80 dB A weighted on 14 and 18 April and at about 77 dB (A) on 17 and 19 April to simulate 1975 and 1995 traffic conditions respectively.

Two different sets of speakers were used during the traffic simulation period. Twenty four inch speakers were used for the first two days of simulation. These were replaced with thirty one inch speakers for the noise broadcasting on 18 and 19 April. The larger speakers were used to improve the fidelity of the lower frequency noise.



ELEVATION VIEW FROM PARKING LOT

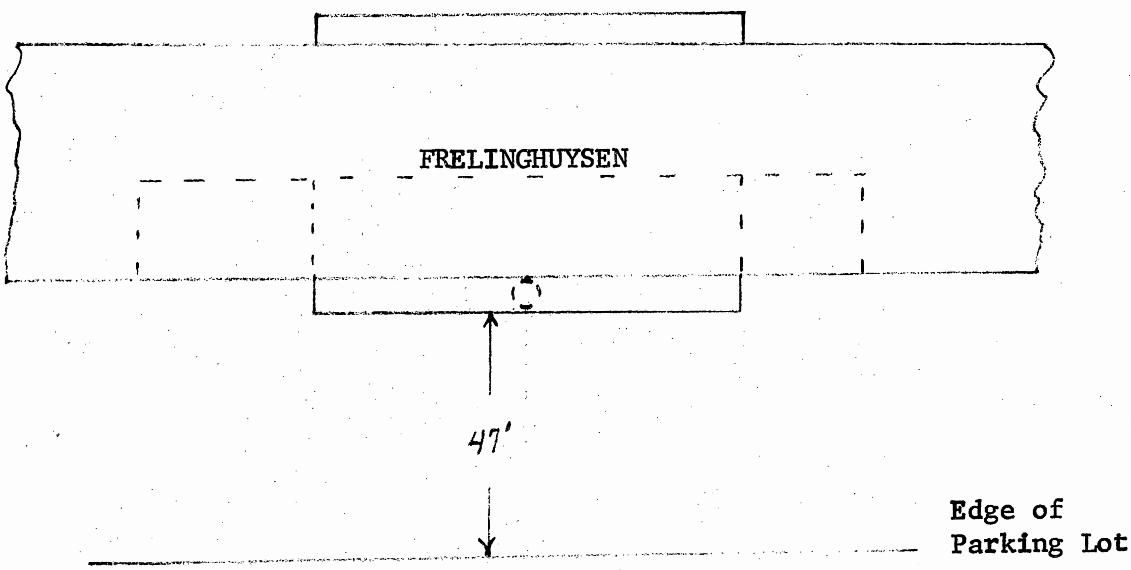


FIGURE 3.3-1 Noise Simulation Site

Instantaneous noise level measurements were made each day inside and outside the Frelinghuysen dormitory at various locations. The noise levels recorded are listed by time and location on Table 3.3-1. Figures 3.3-2 and -3 present this data by location only for the high (80dB) and low (77dB) transmission periods respectively. It should be recognized that the transmitted traffic generated noise was a 15 minute tape. Instantaneous flat weighted recorded noise levels varied plus and minus 7 dB from the average level during the recording period.

3.3.2 Received Noise Level Outdoors

The vertical profile of received traffic generated noise was examined by measuring the noise level at each balcony on the seven floors of Frelinghuysen. Examination of the data shows that the average daily variation in received noise at the 7 elevations was 5dB(A) for all four days. The variation from floor to floor is random, indicating the variation is caused by the fluctuations in transmitted noise. On the two days of "high" noise level transmission, the average received noise level for the 7 outdoor points was 80.1 and 81.4 dB. Similarly, the "low" noise level transmission days' average levels were 77.7 and 78.1 dBA. The received noise for each day of the two noise level periods is essentially identical.

3.3.3 Received Noise Level Indoors

Indoor noise level measurements were made at each of the same seven elevations in conjunction with the balcony measurements. The indoor received noise level pattern as a function of height showed the same randomness floor to floor as noted outdoors. The indoor measurements in the lounges on floors

TABLE 3.3-1
Received Noise at Frelinghuysen

			14 APR				17 APR		18 APR		19 APR	
			Time	dB	Time	dB	Time	dB	Time	dB	Time	dB
6th	Balcony	(0)	1118	80	1601	78	1134	76	1434	81	1331	81
	Lounge	(I)	1119	55	1600	53		51		55		52
5th	Balcony	(0)	1124	82	1604	84	1136	79	1437	82	1339	77
	Lounge	(I)	1126	59	1603	57		55		55		57
4th	Balcony	(0)	1130	80	1606	82	1139	80	1439	81	1341	76
	Lounge	(I)	1128	54	1605	54		48		59		61
3rd	Balcony	(0)	1133	79	-	-	1142	78	1441	80	1343	77
	Lounge	(I)	1132	50	-	-		51		55		52
2nd	Balcony	(0)	1136	78	1608	84	1145	76	1444	85	1345	78
	Lounge	(I)	1135	54	1607	54		51		57		53
1st	Balcony	(0)	1140	82	-	-	1147	79	1445	80	1346	81
	Lounge	(I)	1138	56	-	-		55		50		53
Gnd	Balcony	(0)	1115	80	1557	80	1150	76	1447	81	1350	77
	Lounge	(I)	1116	68	1558	70		65		69		67
	Room	Open	1120	63	-	-	1702	62	1450	66	1337	56
	615	Closed	1122	49	-	-	1700	55	1451	52	1336	49
	Room A-3	Open	-	-	-	-	1159	60	1457	69	1408	62
		Closed	-	-	-	-	1200	54	1456	55	1409	57
	Room B-3	Open(I)	-	-	-	-	1210	60	1500	69	1410	65
		Closed(I)	-	-	-	-	1205	66	1501	65	-	-
	Room B-3	Open (0)	-	-	-	-	1210	62	1500	71	-	-
		Closed(0)	-	-	-	-	1205	72	1501	72	-	-
	Parking Lot	Edge	-	-	-	-	1214	75	1502	81	1417	81
		Bldg.	-	-	-	-		65		75		74

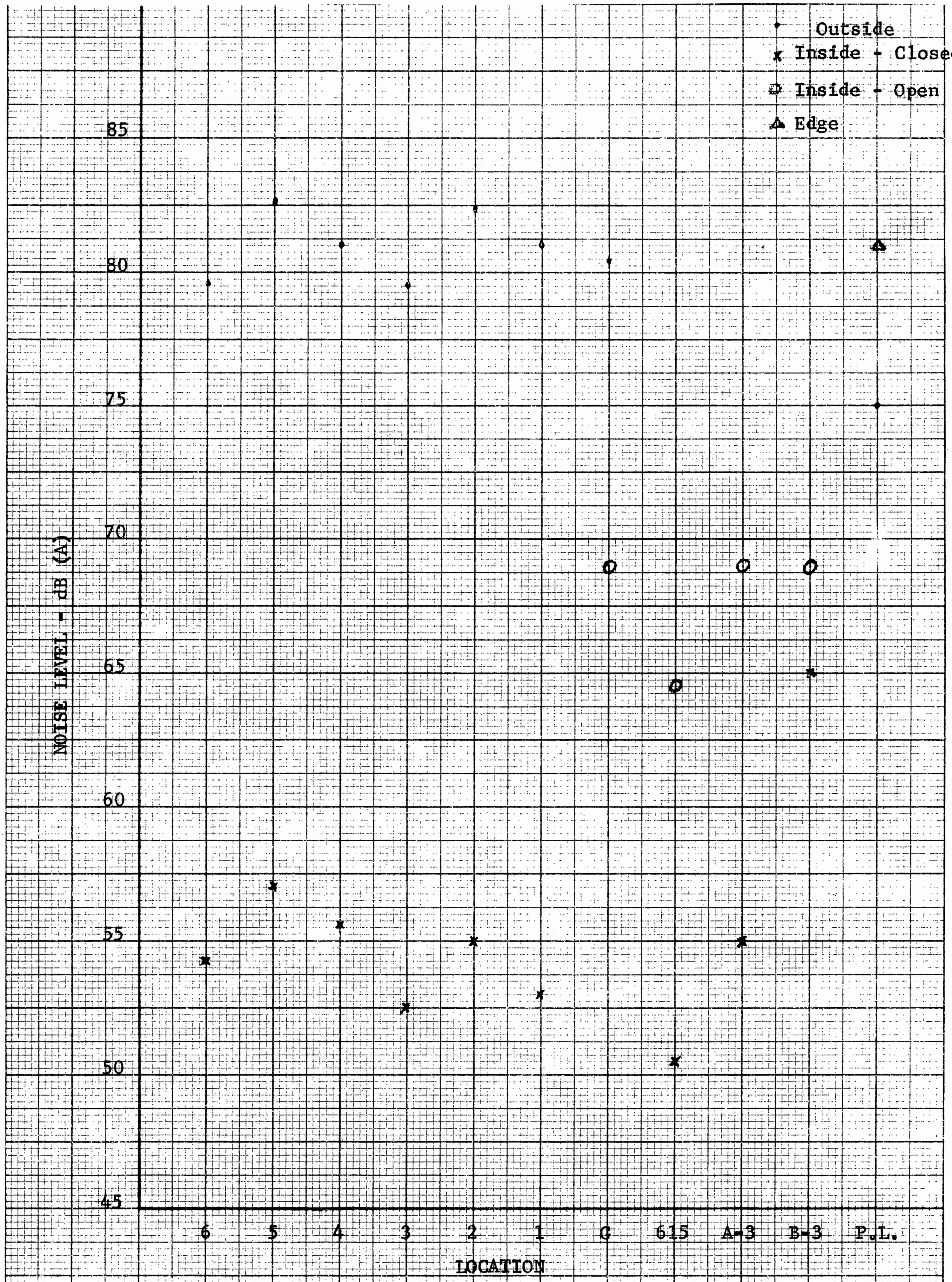


FIGURE 3.3-2 RECEIVED NOISE PER LOCATION - 80 dB (1995)

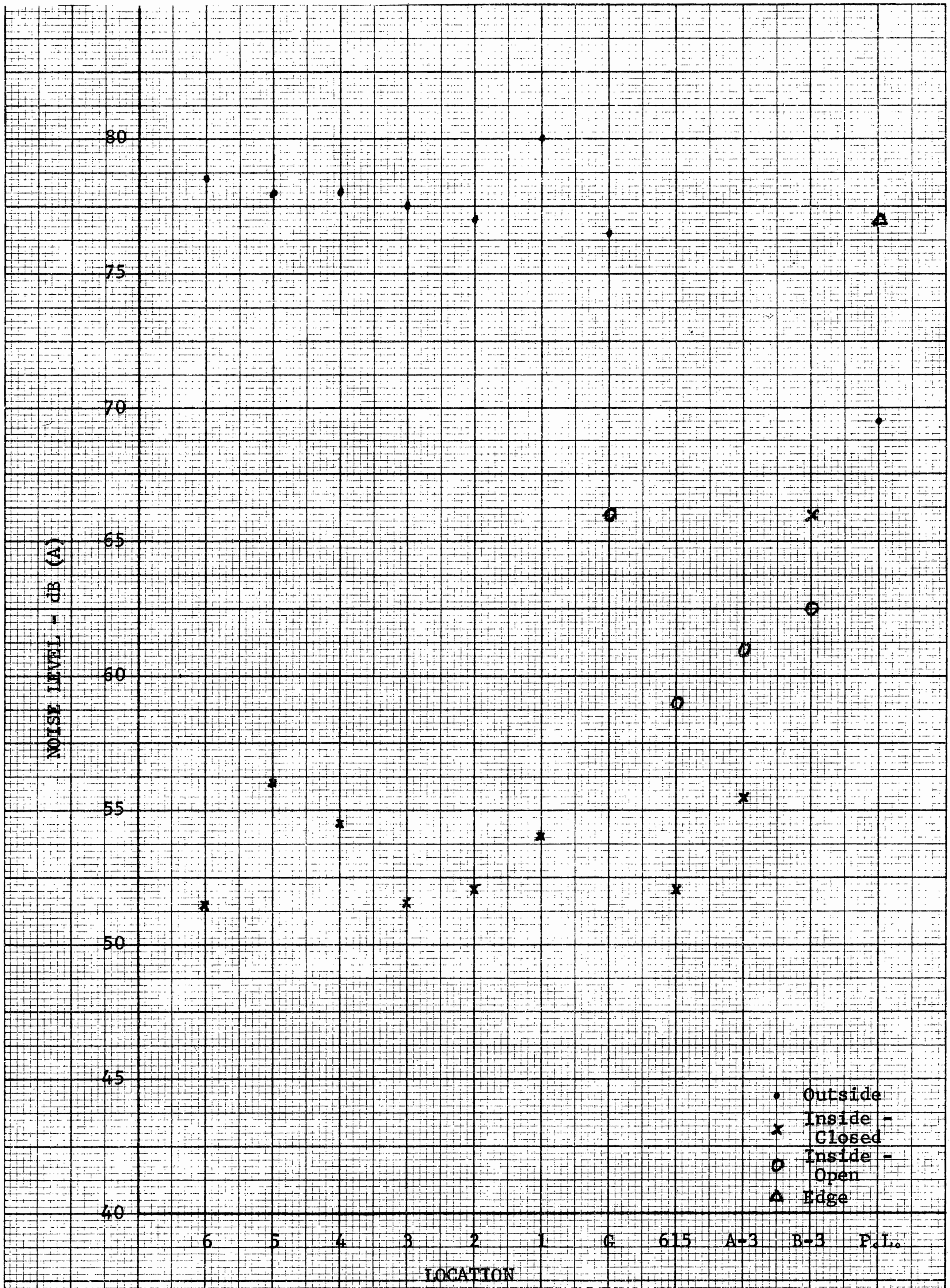


FIGURE 3.3-3 - RECEIVED NOISE PER LOCATION - 77dB (1975)

6 thru 1 were taken with the windows closed. The ground floor measurements, however, were taken with the windows open. For the top six floors, the average daily variation in received noise level was close to 9dB. This spread in measurements on 17 and 19 April is primarily due to the large variation (48 and 61 dB) recorded in the fourth floor lounge. Excluding these readings, the average daily variation for these six floors on 17 and 19 April is only 5 dBA; the average indoor noise levels are 54.6 and 55.2 dB for "high" level transmission and 52.6 and 53.4dB for "low" level.

3.3.4 Differential Noise

Differential noise level, i.e., indoors to outdoors, with the windows closed for the top six floors is responsive to the level of the traffic generated noise. On both of the "high" level days, the average daily indoor noise levels were 26.3 lower than outdoor averages. The indoor daily averages on 17 and 19 April ("low" level days) were 25.4 and 24.9 dBA lower than outdoors.

The effect of the windows on the indoor noise level can be seen from the measurements made at the ground floor level and inside rooms on the 6th, A and B levels. The indoor/outdoor measurements of received noise at the ground floor were made with the lounge window open. The average of the indoor to outdoor differential for the four days was only 11 dB. These differentials are approximately 15 dB smaller than those determined for the upper six floors (lounge windows closed). The noise level readings in rooms 615, A-3 and B-3 were made both with the windows closed and opened. These measurements show that the window open/closed differential for these rooms is responsive to the level of the transmitted noise. At the 6th floor level, the indoor noise level with the windows closed was 14dB lower than when they were open on both days of "high" level transmission. However, on "low" level days, the differential was only 7 dB. This characteristic also occured in Room A-3.

The data taken for Room B-3 appears inconsistent with that obtained for the other two rooms. The readings are shown below to simplify understanding.

	Noise Level dB			
	Inside B-3		Outside B-3	
	4/17	4/18	4/17	4/18
Windows Open	60	69	65	71
Windows Closed	66	65	72	72
Differential	-6	4	-7	-1

First, it is noticed that the noise level on 17 April is higher inside with the windows closed than the windows open. However, the simultaneous readings taken outside this room show that the outside noise level was 7dB lower at the time of the window open reading than for the window closed measurement. (This is very possible due to the approximate 15dB range in transmitted noise level). It is possible therefore, that the window open/closed readings, taken 5 minutes apart, are not a true indication of the window attenuation.

The average window closed noise level in B-3 for the two days of data is 65.5dB. The comparable window closed noise level average for rooms 615 and A-3 were approximately 51 and 55 dB respectively. The noise level inside the dormitory therefore is 10 to 14 dB higher in room B-3 than the other two rooms studied. This increased background noise level also contributes to the apparent inconsistency.

As shown in the previous table, the difference in the differential noise level in Room B-3, windows open/closed, shows the same reaction to the level of transmitted noise as noted in room 615 and A-3. The absolute differential is not the same, primarily due to the increased background in B-3. It is concluded that the low level transmitted noise (77dB) has little or no effect inside Room B-3; the high noise level (80dB) is recognized within B-3.

3.3.5 Attenuation Across Parking Lot

Noise level readings were taken on the last three days of simulation in the parking lot to the rear of Frelinghuysen. One set of readings was taken close to the dormitory. The other set was made at the canal edge of the lot. The attenuation between these points was 10dB on 4/17 and 6 and 7dB on 4/18 and 19 as shown below.

	Noise Level - dB		
	4/17	4/18	4/19
Canal Edge	75	81	81
Building	65	75	74
Attenuation	10	6	7

The similarity in data for the last two days suggests that the horns used for broadcasting the recorded traffic generated noise influenced these readings. The noise level at the edge of the lot is the same on 4/18 and 4/19, even though the "level" of broadcast noise was different. The 4/17 measurements are appreciably lower than comparable data for the other "low" level transmission day (4/19). The noise level attenuation across the parking lot was primarily determined by the speakers used and not the transmitted noise.

3.4 EXISTING NOISE LEVEL AT FRELINGHUYSEN

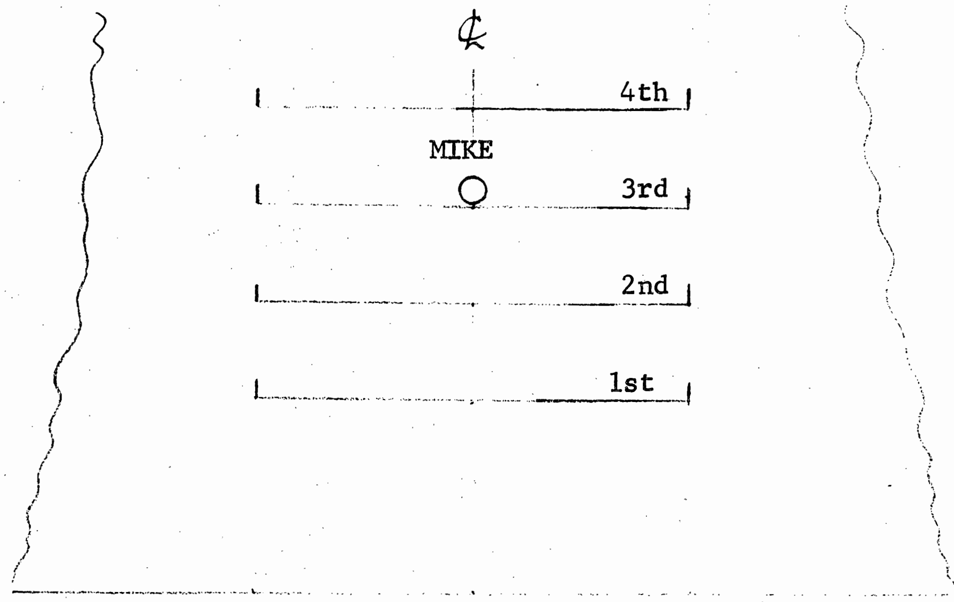
3.4.1 Site Description and Data

Noise level measurements were taken of the George Street traffic generated noise and other background noise as seen at the from of the Frelinghuysen dormitory. These measurements were made continuously from 8 AM on 21 April to 8 AM on 24 April. Paper chart recordings were made of the noise level received by a microphone located on the third floor balcony outside of the dormitory, as shown in Figure 3.4-1. Table 3.4-1 indicates the average hourly noise level measured on the "A" scale for the 72-hour period.

Additional noise level recordings were made of ambient noise as seen in the parking lot at the rear of the dormitory. These measurements were made outside the mechanical equipment room during the simulation and backgound noise level data collection periods. Representative data obtained at this location are included on Figure 3.4-2. (The van shown in this diagrm housed the contractors carbon monoxide measurement equipment used in the air pollution impact study.)

3.4.2 Noise/Traffic Relationship

The noise level on the outside of the Frelinghuysen dormitory, facing George Street shows typical diurnal variations for the three measurement days. Thethree day average minimum (52.0dB) occurred during the early morning hours as seen in Figure 3.4-3. The noise level gradually increased during the day-light hours to a plateau of about 66.0dB in the early afternoon and then slowly decreased during the evening and night hours to the minimum level. As expected, the hourly levels on the three days differ slightly from day to day,



Elevation View From George St.

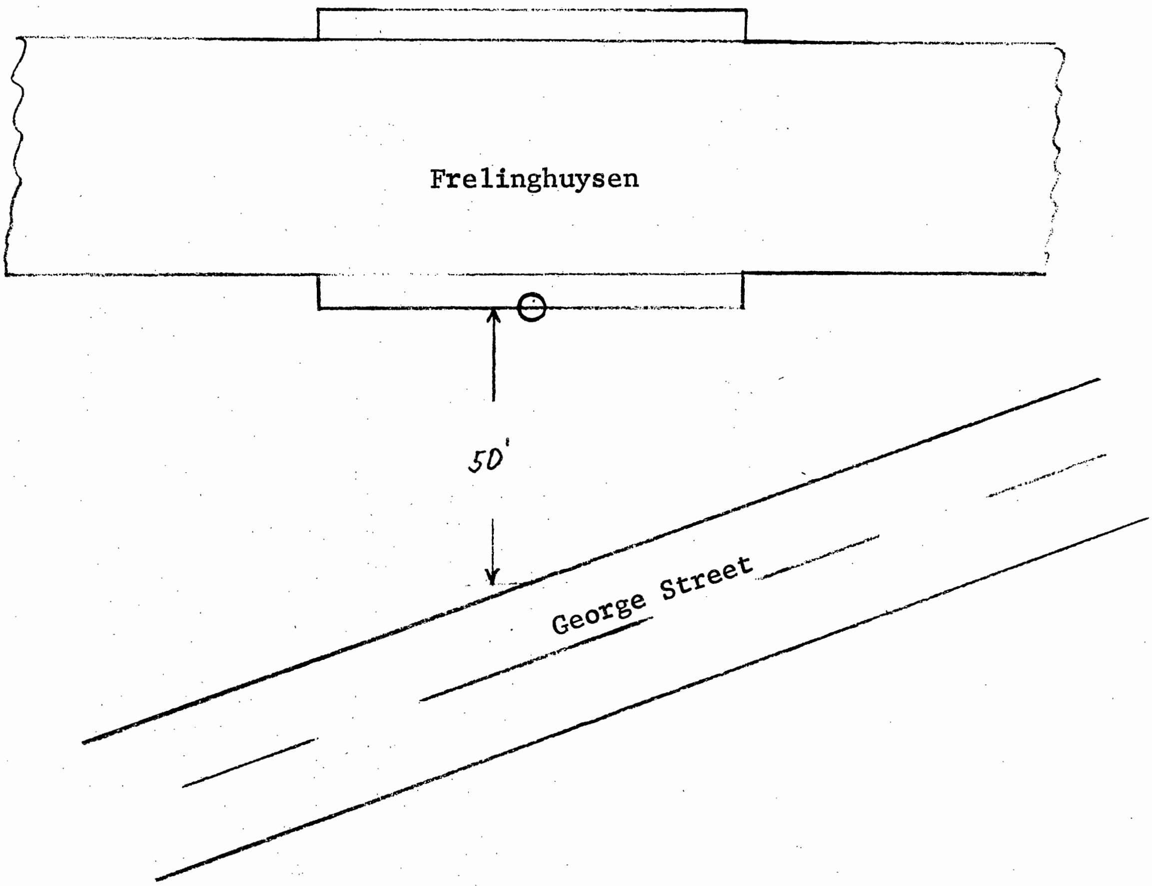
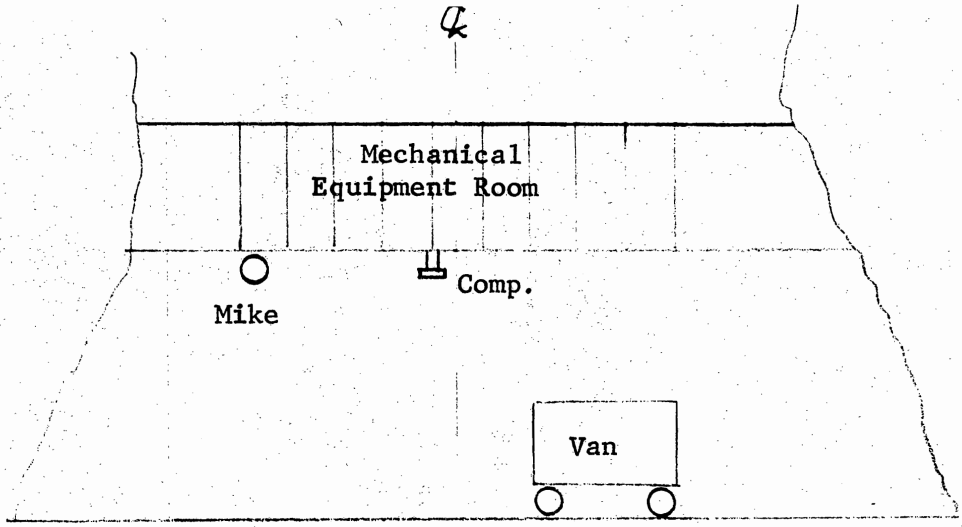


Figure 3.4-1 Ambient Noise - George Street

TABLE 3.4-1
Noise Level

Frelinghuysen Dormitory
George Street

	Date			
	4/21/72 (Fri.)	4/22/72 (Sat.)	4/23/72 (Sun.)	4/24/72 (Mon.)
12 - 1 AM		60.5	61.5	58.0
1 - 2		61.0	58.0	54.0
2 - 3		55.0	55.5	52.0
3 - 4		53.5	53.5	49.0
4 - 5		54.0	52.5	52.0
5 - 6		53.0	51.0	55.0
6 - 7		55.0	51.5	60.0
7 - 8		60.0	53.5	65.5
8 - 9	67.5	64.0	55.0	
9 - 10	64.5	66.0	59.0	
10 - 11	64.5	66.0	60.5	
11 - 12	65.0	67.5	62.5	
12 - 1 PM	66.5	67.0	64.5	
1 - 2	65.5	66.0	64.0	
2 - 3	66.0	67.0	64.0	
3 - 4	66.0	67.5	64.5	
4 - 5	66.5	68.0	63.5	
5 - 6	67.0	66.0	64.0	
6 - 7	66.0	65.5	64.0	
7 - 8	65.0	65.5	63.0	
8 - 9	65.0	64.5	61.5	
9 - 10	64.0	65.0	63.5	
10 - 11	63.5	64.0	64.0	
11 - 12	62.5	63.0	61.0	



Elevation View from Parking Lot

Representative Noise Data

HOUR	3/21 dB	3/22 dB	3/23 dB	3/24 dB
12-1 AM	-	56	56	56
3-4	-	-	-	56
5-6	-	56	57	-
6-7	-	-	-	58
9-10	56	-	-	-
10-11	-	58	-	-
12-1 PM	-	-	55	
1-2	54	-	-	-
2-3	-	58	-	-
7-8	55	57	55	-

Figure 3.4-2 Ambient Noise Frelinghuysen Parking Lot

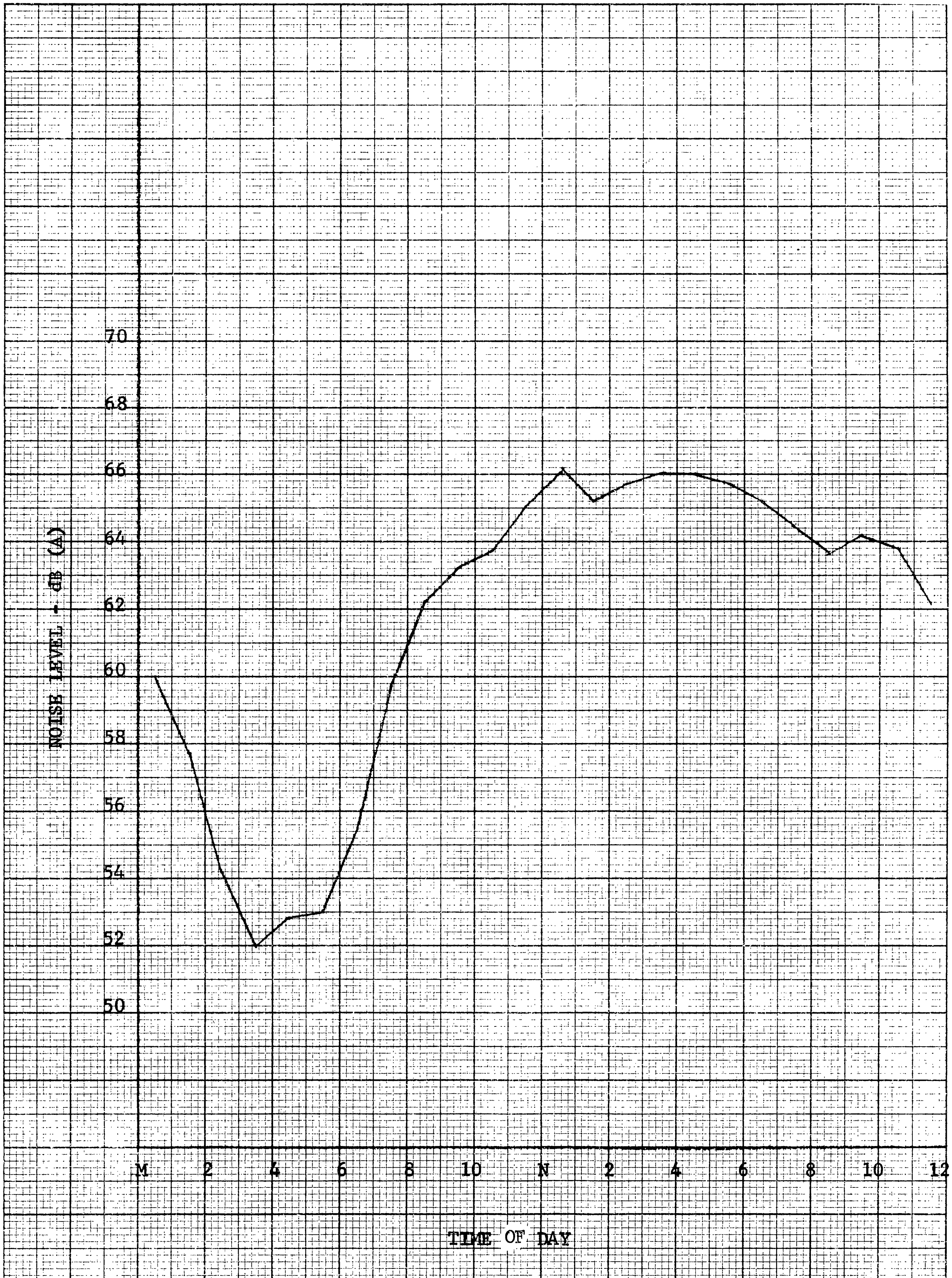


FIGURE 3.4.3 THREE DAY DIURNAL AVERAGE NOISE LEVEL - GEORGE STREET SIDE

reflecting the variations in daily traffic and campus activity. The average noise level for the 72-hour period was 61.6 dB. The midnight to 8 AM average for the three days was 55.6 dB while the comparable average from 8 AM to midnight was 64.5dB. In general, the 24-hour period from 4 AM on Sunday to 4 AM Monday was about 2dB lower than comparable periods on the other days.

3.4.3 Background Noise Level

The front (George Street) side of Frelinghuysen dormitory has a higher average ambient noise level than the parking lot (canal) side. The parking lot noise level measurements ranged from a low of 47.0dB to a high of 64.0dB. These measurements were biased by localized noise sources and do not accurately describe the ambient in the lot. During the measurement period, equipment within the contractors van parked beneath the mechanical equipment room acted as a constant noise source. The exhaust line from a compressor within the dormitory produced a cyclic noise which also influenced the recordings. The data presented in Figure 3.4-2 represents the noise level during the 72 hour period at times when the building compressor was not contributing to the parking lot noise level. The noise level jumped to between 60 & 64dB each time the compressor came on. The "compressor off" noise level, in general, smoothly varied between 54 and 58dB and reflected parking lot activity.

The equipment within the contractors van was shut off intermittently for calibration purposes between 7 & 9 AM on 23 April. During this two hour period the compressor cycled both while the van equipment was operating and shut down. The noise level, for the four conditions recorded is shown below

Noise Sources	Noise Level dB
Van, Compressor & background	59
Compressor & background only	57
Van & background only	55
Background only	47

It will be noticed that the van equipment was contributing 8 dB to the ambient noise level. The change in ambient due to the compressor is dependent upon the ambient. Eliminating these two sources, the realistic parking lot ambient varied between 47.0 and 51.0 dB. In general this averages 13.0 dB less than the average ambient noise level in front of the dormitory. (It should be noted that numerous short term noise disturbances are heard in the parking lot throughout each day, such as student motorcycles and train whistles. These noise sources produce instantaneous peaks of over 70dB).

4.0 APPENDICES

4.1 Test Equipment Used

The following test equipment was used to gather noise level data at the four test sites.

- 2 - Precision Broadband Ceramic Microphones (General Radio #1560-P5)
- 2 - Broadband Microphone Preamplifiers (G.R. #1560-P40)
- 2 - Precision Sound Level Meters (G.R. #1561-R)
- 2 - Graphic Level Recorders (G.R. #1521-B)
- 1 - Sound Level Calibrator (G.R. #1562-A)
- 1 - Magnetic Data Recroder (G.R. #1525-A)
- 1 - Sound Level Meter (G.R. #1565-A)
- 1 - Sound Level Meter (G.R. #1565-B)

The traffic simulation at the Frelinghuysen dormitory was accomplished by use of the following equipment.

- 1 - Magnetic Data Recorder (G.R. #1525-A)
- 1 - Amplifier
- 4 - 24" Speakers
- 4 - 31" Speakers

4.2 Data Collection Procedures

At each site, the procedures followed for collecting noise level data were fitted to the types of measurements being made. The basic data collection system consisted of one each of the microphone, pre-amplifier, precision sound level meter and graphic level recorder interconnecting with two conductor shielded cables. Two data collection systems were used at the sites as indicated below.

	U.N.	Route 18	Frelinghuysen	George Street
System #1	Median Strip & Road Edge	Median Strip	Transmitted Noise	Front
System #2	Lower Deck Locations	Off Roadway Locations	N.A.	Parking Lot

The portable sound level meters were used for data acquisition on the upper deck at the U.N. site and for all measurements at the Frelinghuysen site. In addition, at the U.N. site, instantaneous readings were taken from the sound level meters of each data collection system for the road edge and lower deck noise levels from 1330 to 1400 hours on 23 March.

The continuous noise levels monitored by the two microphones were recorded on their Graphic Level Recorders. The paper charts were carefully synchronized with each other and the precise hourly times marked on each chart.

The overall sensitivity of the combination of the microphone, preamplifier, sound level meter and recorder was carefully calibrated using the Sound Level Calibrator. At the beginning of each site's recordings, the calibrator tones were applied to the microphone while connected to the coaxial cable to be used, and the correct level was verified on the Graphic Level Recorder. Simultaneously the reading of the interconnected Sound Level Meter was checked. The accuracy of the portable sound level meters was also checked using the Sound Level Calibrator.

The paper chart recordings were digitized and the data obtained was adjusted as necessary to incorporate the calibration biases. Portable sound level readings were similarly corrected during the data reduction processes.

The tape recordings taken of traffic generated noise at Route 18 were obtained by interconnecting the magnetic recorder to the appropriate data collection system. The magnetic recorder was switched from one data collection system to the other to obtain the desired noise level recording.

4.3 Noise Simulation Procedure

Simulation of traffic on the proposed extension to Route 18 at the Frelinghuysen dormitory was achieved by playing back a continuous 15-minute tape loop using the Magnetic Data Recorder. The output of the recorder was fed through the amplifier to four speakers located on the tow path opposite the dormitory. The location of the speakers to properly simulate a line source of noise (the proposed highway) by means of four point sources (the set of speakers) was determined by a math model. This math model, described in Section 4.5, was used to analytically compare the line source versus point source noise as a function of speaker location. Trial values of the speaker locations were varied until an acceptably small deviation from match ($\leq \pm 0.5$db) was obtained.

Using the results of the math model, the speakers were located on the tow path on a line parallel to and 37.5 feet behind the centerline of the proposed highway. The center point of the line of speakers was 167 feet from the Frelinghuysen dormitory. The speakers were located 35 and 80 feet on either side of this centerpoint. They were angled inward so that the centerline of their cones intersected on the wall of the dormitory on a vertical line thru the center of the dormitory.

The amplifier gain was adjusted to produce the desired noise level at the dormitory as recorded by the data collection system monitoring the transmitted noise level. The microphone for this system was mounted outside the mechanical room of the dormitory.

4.4 Noise Simulation Technique

The noise simulation performed at the Frelinghuysen dormitory was based on the following ground rules.

a - For traffic volumes and velocities occurring during the daylight hours, both the existing section of Route 18 near the New Street Overpass and the proposed extension at the dormitory site were considered to be line sources of noise located at the center of the median strip of the highway.

b - The noise propagation characteristics of the two sites are, for all practical purposes, identical. Therefore the traffic generated noise at the dormitory would be identical in composition to the noise recorded at the roof of the Sanitation Building. The noise level received at the two sites would differ as a function of the difference in their distance from the center of the roadway.

c - The truck/car mixture at the dormitory site would be the same as that observed at the Sanitation Building.

d - The average velocity of traffic at the dormitory site would be approximately 50 miles per hour.

e - The NJSDOT projections of peak hourly traffic volumes of 2700 and 4300 vehicles per hour for 1975 and 1995 respectively would be increased, for the purposes of this noise simulation, to 4000 and 8000 vehicles per hour to cover other agency estimates of somewhat higher traffic volume for the extended Route 18 Freeway.

Accordingly, the noise level at the outside of the Frelinghuysen dormitory would be the same as that measured at the Sanitation Building modified by corrections for differential distance, traffic velocity and traffic volume.

4.4.1 Correction Due to Distance

The noise level measurements made on the roof of the Sanitation Building were accomplished with the microphone approximately 35 feet above the road surface and 83 feet horizontally from the center of the median strip. The diagonal, or "line of sight" distance therefore was 90 feet.

At the Frelinghuysen dormitory site, the microphone was located approximately 37 feet above the surface of the proposed highway and 127.5 feet horizontally from the center of the proposed median strip. The "line of sight" distance from the centerline of the highway to the "control" microphone was 132.5 feet.

The dormitory therefore is about 43 feet further from the centerline of the roadway. The received traffic generated noise level will be lower than at the Sanitation Building in the ratio of 133 to 90 or 1.48. The db reduction is determined by the equation

$$\begin{aligned} dB &= 10 \log \frac{1.48}{1} \\ &= 10 \log 1.48 \\ &= 10 \times .1700 \\ &= 1.7 \text{ dB (A)} \end{aligned}$$

4.4.2 Correction Due to Change in Traffic Velocity

The noise level recorded at the Sanitation Building resulted from traffic on both sides of the highway moving at an average velocity of 37.5 miles per hour. It is anticipated that the average of traffic on the proposed section of Route 18 past the dormitory will be 50 miles per hour. This increase in average speed is due to the change from a highway thru residential areas with frequent traffic lights, to one with less impeded traffic flows. On the basis that the truck car ratio remains relatively unchanged and the roadway surface is similar, this increase in average velocity corresponds to a 4dB (A) noise level increase*.

4.4.3 Correction Due to Change in Traffic Volume

It was estimated that the traffic on the proposed section of Route 18, when opened in 1975, will have a peak of 4,000 vehicles per hour during the daytime hours. Again, assuming a constant truck car ratio, this traffic volume represents a 15% increase over that which occurred during the noise level recording period at the Sanitation Building. Using the same equation shown in paragraph 4.4.1, this increased traffic volume will increase the noise level in 1975 by 0.6 dB (A). Similarly the 1995 traffic projection of a peak of 8000 vehicles per hour corresponds to an increase of 3.6dB(A) over that measured in 1972.

4.4.4 Estimated Traffic Generated Noise Levels

As indicated in paragraph 3.2.5, the average flat weighted noise tape recorded at the Sanitation Building was 82 dB. The flat to A weighting relationship was 8 dB. Therefore the recorded noise was 74 dB (A). Applying the correction factors for differential distance, traffic velocity and traffic volume described above, the 1975 and 1995

*National Cooperative Highway Research Program Report #78
National Academy of Services - Highway Research Board - 1969

noise at the dormitory is:

$$dB_{1975} = 74-1.7 + 4.0 + 0.6$$

$$= 76.9$$

$$dB_{1995} = 74-1.7 + 4.0 + 3.6$$

$$= 79.9$$

Accordingly, the noise level broadcast was adjusted so that the noise received at the control microphone was 77 dB (A) for simulated 1975 traffic and 80 dB (A) for the 1995 condition.

4.5 ROAD NOISE SIMULATION MODEL

I. Introduction

A. Purposes of the Model -

The mathematical model that is described in this Appendix was developed for two purposes: one is to design a physical simulation of the traffic noise produced at a heavily-travelled road by means of a set of loudspeakers that broadcast tape recorded road noise. The parameters of the design would include correct placement of the speakers and intensity level determination. Since it is generally understood that a finite number of loudspeakers can not exactly simulate a continuous roadway, it must be realized that the optimum design is that configuration producing an acceptably small amount of deviation from the expected traffic noise from a real road.

The second purpose is a corollary of the first; to evaluate a simulation by comparing the sound intensity expected from a proposed road to the sound intensity expected from a given set of speakers, at several points at various distances from the respective sound sources. This latter purpose differs from the first one in that certain constraints on the placement of speakers, setting of intensities, etc., may not allow an optimum design configuration to be realized; the resulting compromise can still be evaluated for its effectiveness using the mathematical model.

B. Bases of Model -

The mathematical model is built upon the four main considerations of 1) traffic flow description, 2) physics involved in propagation, 3) geometry of roads, speakers, and observation points, and 4) intensity calibration.

The model is applicable to those situations where the traffic is continuous, and the road can properly be described as a linear source of sound. Instantaneous sound levels then can be described in terms of the number of vehicles per unit length along the road and in terms of the average vehicle velocity.

The physical principles involved are the following: Sound waves originating from a point source spread out so that their intensity is inversely proportional to the square of the distance from the source. Both loudspeakers and moving vehicles can be considered as point sources of sound at sufficient distances. Under the above assumptions of traffic flow, the sound from the vehicular point sources can be integrated over the whole roadway; it is found that the resulting sound intensity is inversly proportional to the first power of the distance from the road. Sound waves propagating in any medium are attenuated by absorption and by scattering processes, as well as by the beam spreading effects mentioned above. These attenuation mechanisms result in an exponential decay of the sound intensity with distance. These mechanisms are frequency dependent; thus there is a different attenuation coefficient for each acoustic frequency, and higher frequencies are attenuated more than lower frequencies.

The following geometrical assumptions were used in the development of the model: All roadways are straight lines of long length. This applies to the road where the traffic noise is recorded as well as to the road to be simulated. The model assumes that the recording of the traffic noise is played back through several loudspeakers; the location of each speaker is not restricted with respect to the road to be simulated. Another important assumption is that the propagation of the sound is not influenced by any obstacles such as reflectors, absorbers, or diffracting edges. The presence of the ground,which is a giant reflector, acts only to increase the effective intensity coming from each source, and does not add a set of virtual sources below the ground. This is only true when ground-level roadways are considered, and when the loudspeakers are very near the ground.

The model assumes that the ratio of the intensity of the sound from all of the speakers as measured at a definite point in space, to the intensity of the sound from the real road as measured at the point of tape recording, is set to a known value.

II. Development of the Mathematical Model

A. Basic Equation -

Equation C-2 of Reference RP3 is the starting point for our model. The authors of Ref. RP3 have used this equation as the starting point for a computer simulation of traffic noise; they did not construct a model for a physical simulation. Their expression for the noise level contribution from a random distribution of vehicles having a given mean flow is

$$dBA = 10 \log_{10} \left\{ \left(2\pi W_o\right)^{-1} \sum_i \sum_j \sum_k T_k T_k^* N_{ij} \overline{W}_{ijk} \frac{r_o^2}{r_i^2} e^{-2a_k r_i} \right\} \qquad (1)$$

in which

- dBA = decibels as measured on A-scale of a sound level meter
- T_k = transfer function of the A-scale weighting network in the kth band
- $T_k{}^*$ = complex conjugate to T_k
- W_o = 10^{-12} watts per square meter
- N_{ij} = number of vehicles at ith interval of the jth vehicle class
- W_{ijk} = average sound intensity in watts per square meter in the kth frequency band of a vehicle of the jth class located at the ith interval, traveling at a given mean speed at a distance r_o
- r_i = distance from the observer to a vehicle at the ith interval
- a_k = air abosrption in decibels per unit length in the kth frequency band.

In this work, we are interested in evaluating a simulation over all frequency ranges; therefore we will modify equation (1) to find the flat weighted sound level. For this case, the product $T_k \; T_k{}^* = 1$.

Also for simplification of notation, we define the parameter

$$g \doteq \left(2\pi W_o\right)^{-1}$$

The flat-weighted sound level is then

$$dBF = 10 \log \left\{ g \sum_i \sum_j \sum_k N_{ij} \overline{W}_{ijk} \left(\frac{r_o}{r_i}\right)^2 e^{-2a_k r_i} \right\} \qquad (2)$$

Keeping in mind that when we simulate a proposed road by means of a tape recording made at an existing road, it is understood that we expect the traffic mix to be about the same in both spots, we can make the following simplification with out loss of generality:

$$\text{Let} \quad W_{roki} \equiv \sum_j N_{ij} \overline{W}_{ijk} \tag{3}$$

Let $W_{roki} = W'_{roi}\left(f_k\right) df$,

where $W'_{roi}\left(f_k\right)$ is the spectral power density of the total mix of vehicles at frequency f_k and df is the width of the frequency band around f_k. Then the summation over all frequency bands can be replaced by an integration over all frequencies:

$$dBF = 10 \log \left\{ g \sum_i \int_0^\infty W'(f) \left(\frac{r_0}{r_i}\right)^2 e^{-2\alpha(f) r_i} df \right\} \tag{4}$$

where $\alpha\left(f_k\right) \equiv a_k$,

$$dBF = 10 \log \left\{ g r_0^2 \sum_i \frac{1}{r_i^2} \int_0^\infty W'_{roi}(f) e^{-2\alpha(f) r_i} df \right\} \tag{5}$$

is thus the form of the intensity equation for a set of point sources.

Refer to Figure RP7 for the coordinates used in the description of the intensity from a line source. Let r be the straight line distance between an observer at P and a line source of sound (roadway).

Let

$$W'_{roi}(f) = W''_{ro}\left(x_i, f\right) dx$$

where $W''_{ro}\left(x_i, f\right)$ is the spectral power density per unit roadway length. One of our initial assumptions is that the traffic is uniform along the whole road; therefore, this parameter is not a function of x:

$$W''_{ro}(x_i, f) = W''_{ro}(f) \qquad \text{for all x.}$$

$$\therefore \quad W'_{rci}(f) = W''_{rc}(f)\,dx \;.$$

The summation over all intervals i becomes an integration over x:

$$dBF = 10 \log \left\{ g\, r_o^2 \int_{-\infty}^{\infty} \int_{0}^{\infty} \frac{W''_{ro}(f)}{r_i^2}\, e^{-2\alpha(f) r_i}\, df\, dx \right\} \tag{6}$$

Now $r_i^2 = r^2 + x_i^2$ from Figure RP7.

$$2 r_i\, dr_i = 2 x_i\, dx_i \;, \qquad \text{since r is constant.}$$

$$\therefore \quad dr_i = \frac{\pm\sqrt{r_i^2 - r^2}}{r_i}\, dx_i$$

Thus the integral over x becomes

$$\int_{-\infty}^{\infty} \frac{e^{-2\alpha(f) r_i}}{r_i^2}\, dx =$$

$$\int_{\infty}^{r} \frac{e^{-2\alpha(f) r_i}}{r_i^2} \frac{r_i(-dr_i)}{\sqrt{r_i^2 - r^2}} + \int_{r}^{\infty} \frac{e^{-2\alpha(f) r_i}\, r_i\, dr_i}{r_i^2 \sqrt{r_i^2 - r^2}} \tag{7}$$

$$= 2 \int_{r}^{\infty} \frac{e^{-2\alpha(f) r_i}\, dr_i}{r_i \sqrt{r_i^2 - r^2}} \tag{8}$$

By substituting in the dummy variable θ and setting $r_i = r\sec\theta$,

$$\int_r^{\infty} \frac{e^{-2\alpha(f) r_i}\, dr_i}{r_i^2 \sqrt{r_i^2 - r^2}} = \frac{1}{r}\int_0^{\pi/2} e^{-2r\alpha(f)\sec\theta}\, d\theta \tag{9}$$

Let us define the variable Y so that

$$Y\left[a, \alpha(f)\right] \equiv \frac{1}{a}\int_0^{\pi/2} e^{-2a\alpha(f)\sec\theta}\, d\theta \tag{10}$$

$$\therefore \int_{-\infty}^{\infty} \frac{e^{-2\alpha(f) r_i}}{r_i^2}\, dx = 2Y\left[r, \alpha(f)\right] \tag{11}$$

Thus we arrive at the experssion for the intensity of a line source at a distance r from the source as

$$dBF = 10 \log \left\{ 2g\, r_0^2 \int_0^{\infty} W''_{ro}(f)\, Y\left[r, \alpha(f)\right] df \right\} \tag{12}$$

B. Expression for Intensity from Proposed Road -

Let the drawing in Figure RP7 represent the configuration at the site of the proposed road, with r set equal to r_r. The intensity of sound at a distance r_r from the proposed road is (from Eq. 12)

$$\mathcal{L}_i = 10 \log \left\{ 2g\, r_0^2 \int_0^{\infty} I''_{ro}(f)\, Y\left[r_r, \alpha(f)\right] df \right\} \tag{13}$$

where $I''_{rc}(f)$ is the instantaneous spectral power density per unit roadway distance.

C. Expression for Intensity from Speaker -

Since we are to simulate the proposed road traffic using the sound recorded at a real road, $I''_{ro}(f)$ is also the spectral density per unit length at the recording site.

Let us now consider specifically the intensity recorded on the tape which is to be played back during the simulation. Let the distance between the median of the real road and the recording microphone be r_s. Then the intensity at the microphone (i.e., the intensity recorded on the tape at a given moment) is

$$\mathcal{L}_1 = 10 \log \left\{ 2 g \, r_o^2 \int_0^\infty I''_{ro}(f) \, Y\left[r_s, \alpha(f) \right] df \right\} \tag{14}$$

In Equation (5), $W'_{roi}(f_k)$ is the spectral density at f_k coming from a point source at point i. In the simulation, the sound from a loudspeaker (a point source) is derived from the intensity $\mathcal{L}_1$ of equation (14). The relationship between $W'_{roi}(f_k)$ and $I''_{ro}(f_k)$ must be found. Recall that $I''_{ro}(f_k) = W''_{ro}(f_k)$ for the road being recorded, and is the spectral density per unit roadlength. The spectral density of the sound from each speaker is a function not only of the spectral density of the roadway where the sound was recorded but also of the frequency-dependent attenuation that occurred while the sound was getting from the road to the microphone. That is,

$$W'_{roi}(f_k) \quad \text{is proportional to} \quad I''_{ro}(f_k) \, Y\left[r_s, \alpha(f_k) \right]$$

Let A_{roi} be an amplitude function characteristic of the i^{th} speaker; A_{roi} is defined in such a way that the intensity at a distance r_{oi} from the i^{th} speaker is

$$dBF_{ro\ell} = 10 \log \left\{ g r_o^2 \int_0^\infty 2A_{ro\ell} I''_{ro}(f) Y[r_s, \alpha(f)] e^{-2\alpha(f) r_{o\ell}} df \right\};$$

that is, so that

$$W'_{rci} = 2A_{rc\ell} r_{o\ell}^2 I''_{ro}(f) Y[r_s, \alpha(f)] \cdot \qquad (15)$$

Thus, the intensity at any distance r_2 from the ℓ^{th} speaker is (from Eqs. 15 and 5)

$$dBF_{r2} = 10 \log \left\{ 2 g r_o^2 A_{ro\ell} \left(\frac{r_{o\ell}}{r_2} \right)^2 \int_0^\infty I''_{ro}(f) e^{-2\alpha(f) r_2} Y[r_s, \alpha(f)] df \right\} \qquad (16)$$

The intensity from an array of N speakers is then

$$dBF_N = \mathcal{L}_N = 10 \log \left\{ 2 g r_o^2 \sum_{i=1}^{N} A_{rci} \left(\frac{r_{oi}}{r_i} \right)^2 \int_0^\infty I''_{ro}(f) e^{-2\alpha(f) r_i} Y[r_s, \alpha(f)] df \right\} \qquad (17)$$

where every speaker is playing back the same sound recorded at a distance r_s from the real road. Each r_i is the distance from the speaker at point i to the place where the intensity is being measured.

D. Comparison of Intensities -

At a point in space at a distance r_r from the proposed roadway, and at distances r_i from N speakers, the difference between the intensity of the sound from all the speakers and the intensity from the proposed road is

$$\mathcal{L}_N - \mathcal{L}_1 = 10 \log \left\{ \frac{2 g r_o^2 \sum_{i=1}^{N} A_{roi} \left(\frac{r_{oi}}{r_i} \right)^2 \int_0^\infty I''_{ro}(f) e^{-2\alpha(f) r_i} Y[r_s, \alpha(f)] df}{2 g r_o^2 \int_0^\infty I''_{ro}(f) Y[r_r, \alpha(f)] df} \right\} \qquad (18)$$

The magnitude of this quantity is a measure of how good the simulation is. That is, in a perfect simulation $\mathcal{L}_N - \mathcal{L}_1 = 0$; the larger the absolute value of $\mathcal{L}_N - \mathcal{L}_1$, the poorer the simulation. There are several arbitrary variables in Eq. 18: for each speaker, the product $A_{roi} r_{oi}^2$ can be set at will. Also, the distance from the observation point to each speaker can be varied. Thus, there are 2N adjustable parameters to vary to optimize the simulation.

Assume now that the speaker have a fixed configuration; it is reasonable to calibrate the speaker intensity at one point; this will, in essence, determine the values of the N products $A_{roi} r_{oi}^2$. At a distance $r_r = r_{rt}$ from the proposed road, let the difference in total intensities be $\Delta' \ell$:

$$\Delta' \ell = \left(\mathcal{L}_N - \mathcal{L}_1\right)_{r_r = r_{rt}} = \text{(from 18)}$$

$$10 \log \left\{ \frac{\sum_{i=1}^{N} A_{roi} \left(\frac{r_{oi}}{r_i}\right)^2 \int_0^\infty I''_{ro}(f)\, e^{-2\alpha(f) r_i}\, Y[r_s, \alpha(f)]\, df}{\int_0^\infty I''_{ro}(f)\, Y[r_{rt}, \alpha(f)]\, df} \right\} \tag{19}$$

In principle this expression relating the A_{roi}'s, the r_{oi}'s, and $\Delta' \ell$ could be substituted into (18) to solve for $\mathcal{L}_N - \mathcal{L}_1$. Equations (18) and (19) fully describe the model in its most general case. All further steps are only to make the model more useful in practical cases.

Consider now the case where all of the speakers are on the same straight line, and where this line is parallel to the proposed road, as in Figure RP8. Let r_t be the value of r at which the intensities are calibrated; i.e., when $r_r = r_{rt}$. Furthermore, let $r_{oi} = r_{ol}$ for all i. This means that all of the speaker amplitudes are to be compared at a standard distance, r_{ol}, from each speaker. New parameters D, R_i are defined in such a way that

$$r_{oi}^2 A_{roi} = R_i r_t^2 D \quad , \quad \text{for} \quad i \neq 1 ,$$

and $r_{o1}^2 A_{ro1} = r_t^2 D$

$(\text{i.e., } R_1 = 1)$.

This relates the amplitude of all the speakers to the amplitude of the "first" speaker.

Using the above notation, we obtain

$$\Delta' \ell = 10 \log \left\{ \frac{D \sum_{i=1}^{N} \frac{R_i}{(r_i / r_t)^2} \int_0^{\infty} I''_{ro}(f)\, e^{-2\alpha(f) r_t \sqrt{(r_i/r_t)^2}}\, Y[r_s, \alpha(f)]\, df}{\int_0^{\infty} I''_{ro}(f)\, Y[r_{rt}, \alpha(f)]\, df} \right\} \tag{20}$$

As seen in Figure RP8,

$$r_i^2 = r^2 + d_i^2 - 2 r d_i \cos\theta \tag{21}$$

Also, let

$$\Delta'_\ell = 10 \log R_I \quad , \tag{22}$$

where

$$R_I = \frac{I_s(r_t)}{I_r(r_{rt})} \quad ; \tag{23}$$

I_s is the intensity from the speakers at r_t, I_r is the intensity from the proposed road at r_{rt}; these quantities are actual intensities in acoustical power per unit area, not their decibel equivalents.

Thus, since $r = r_t$,

$$0 = 10 \log \left\{ \frac{D \sum_{i=1}^{N} \frac{R_i}{1 + (d_i/r_t)^2 - 2(d_i/r_t)\cos\theta} \times \int_0^{\infty} I''_{ro}(f)\, e^{-2\alpha(f) r_t \sqrt{1 + (d_i/r_t)^2 - 2(d_i/r_t)\cos\theta}}\, Y[r_s, \alpha(f)]\, df}{R_I \int_0^{\infty} I''_{ro}(f)\, Y[r_{rt}, \alpha(f)]\, df} \right\} \tag{24}$$

From Equation (18),

$$\mathcal{L}_N - \mathcal{L}_1 = 10 \log \left\{ D \sum_{i=1}^{N} \frac{R_i}{(r/r_t)^2 + (d_i/r_t)^2 - 2\frac{rd_i}{r_t^2}\cos\theta} \times \right.$$

$$\left. \frac{\int_0^\infty I''_{ro}(f)\, e^{-2\alpha(f) r_t \sqrt{(r/r_t)^2 + (d_i/r_t)^2 - 2\frac{rd_i}{r_t^2}\cos\theta}}\, Y[r_s, \alpha(f)]\, df}{\int_0^\infty I''_{ro}(f)\, Y[r_r, \alpha(f)]\, df} \right\} \quad (25)$$

From Figures RP8 and RP9, r_r (and r_{rt}) can be given in terms of r (and r_t) and p, the distance between the proposed road and the line of speakers;

$$r_r = \sqrt{p^2 + r^2 \sin^2\theta - 2pr\sin\theta\cos\phi} \quad (26)$$

r_{rt} = the value of r_r when $r = r_t$

ϕ is the angle of elevation from the horizontal plane containing the line of speakers and the median of the proposed road to P, the point of observation. When $r = r_t$, $\phi = \phi_m$.

As before Equation (24) can be used to find a relationship for D in terms of the R_i's and this relation substituted into Equation 25 to solve for $\mathcal{L}_N - \mathcal{L}_1$ as a function of distance from the speakers. However, if $I''_{ro}(f)$, the spectral power density per unit length, is not known, the calculation can not be performed. An analogous calculation can be made over a narrow frequency band:

Let $\Delta'\ell$ be the known intensity difference at $r = r_t$, $f = f_i$. Again, $\Delta'\ell = 10 \log R_I$ Equation (24) becomes

$$0 = 10 \log \left\{ D(f_1) \sum_{i=1}^{N} \frac{R_i}{1 + (d_i/r_t)^2 - 2(d_i/r_t)\cos\theta} \times \frac{\int_{f_1}^{f_1+\Delta f} I''_{ro}(f_1)\, e^{-2\alpha(f_1) r_t \sqrt{1+(d_i/r_t)^2 - 2(d_i/r_t)\cos\theta}}\, Y[r_s, \alpha(f_1)]\, df}{R_I \int_{f_1}^{f_1+\Delta f} I''_{ro}(f_1)\, Y[r_{rt}, \alpha(f_1)]\, df} \right\} \quad (27$$

$$= 10 \log \left\{ D(f_1) \sum_{i=1}^{N} \frac{R_i}{1 + (d_i/r_t)^2 - 2(d_i/r_t)\cos\theta} \times \frac{I''_{ro}(f_1)\, e^{-2\alpha(f_1) r_t \sqrt{1+(d_i/r_t)^2 - 2(d_i/r_t)\cos\theta}}\, Y[r_s, \alpha(f_1)] \int_{f_1}^{f_1+\Delta f} df}{R_I I''_{ro}(f_1)\, Y[r_{rt}, \alpha(f_1)] \int_{f_1}^{f_1+\Delta f} df} \right\} \quad (28$$

$$= 10 \log \left\{ D(f_1) \sum_{i=1}^{N} \frac{R_i\, e^{-2\alpha(f_1) r_t \sqrt{1+(d_i/r_t)^2 - 2(d_i/r_t)\cos\theta}}\, Y[r_s, \alpha(f_1)]}{\left[1 + (d_i/r_t)^2 - 2(d_i/r_t)\cos\theta\right] R_I\, Y[r_{rt}, \alpha(f_1)]} \right\} \quad (29$$

Since 0 = 10 log 1, the calibration condition becomes

$$D(f_1)\sum_{i=1}^{N}\frac{R_i\, e^{-2\alpha(f_1) r_t\sqrt{1+(d_i/r_t)^2-2(d_i/r_t)\cos\theta}}}{1+(d_i/r_t)^2-2(d_i/r_t)\cos\theta} = R_I\,\frac{Y\left[r_{rt}, \alpha(f_1)\right]}{Y\left[r_s, \alpha(f_1)\right]} \qquad (30)$$

When the intensity calibration is made, what is done is to set the difference between the sound level at which the tape recording was made at the real road and the sound level from the speakers at r_t, to a known value. That is, if $I_r(r_s)$ is the actual intensity of the recorded sound, and if $I_s(r_{rt})$ is the intensity from the speakers, at r_s and r_{rt} respectively, then

$$\Delta\ell = 10 \log \frac{I_r(r_s)}{I_s(r_{rt})} \qquad (31)$$

is set to a known value. If r_s and r_{rt} and not too different in magnitude, we can set

$$\frac{I_r(r_s)}{I_r(r_{rt})} \approx \frac{r_{rt}}{r_s}, \qquad (32)$$

since both roads are approximately straight line sources. If r_{rt} and r_s were very different, a correction for exponential attenuation would have to be made for equation (32). From (23 and (31),

$$R_I = \frac{I_s(r_t)}{I_r(r_{rt})} = \frac{I_s(r_t)}{I_r(r_s)}\,\frac{r_{rt}}{r_s}$$

$$R_I = \frac{r_{rt}}{r_s}\, 10^{-\Delta\ell/10} \qquad (33)$$

The "best" value for R_I is unity; for this case,

$$\Delta \ell = 10 \log \frac{r_{rt}}{r_s} \qquad (34)$$

and if $r_{rt} = r_s$, $\Delta \ell = 0$.

The computer code, ROAD, solves for $D(f_1)$ in equation (30), given all the length and angle parameters, $\Delta \ell$, and the attenuation coefficients for frequency f_1 (Ref. RP3). It solves this equation under the asumption that there are four speakers, that all the speakers have the same amplitude, that point O (Fig. RP8) is at the midpoint of the speakers, and that the speakers are symmetrically placed about O. That is, $N = 4$, $R_1 = R_2 = R_3 = R_4 = 1$, $d_3 = -d_1$, $d_4 = -d_2$.

Then the code solves equation (25) for $\mathcal{L}_N - \mathcal{L}_1$, which is termed the "deviation from match". This equation could be solved over the whole frequency band if $I''_{ro}(f)$ were known. However, ROAD solves it at a discrete frequency f, for which the form is $L_N - L_1$ = deviation from match at a frequency f for a system calibrated at frequency f_1 =

$$10 \log \left\{ D(f_1) \sum_{i=1}^{4} \frac{e^{-2\alpha(f) r_t \sqrt{(r/r_t)^2 + (d_i/r_t)^2 - 2\frac{r d_i}{r_t^2}\cos\theta}}}{(r/r_t)^2 + (d_i/r_t)^2 - 2\frac{r d_i}{r_t^2}\cos\theta} \; \frac{Y[r_s, \alpha(f)]}{Y[r_r, \alpha(f)]} \right\} \qquad (34$$

Of course, the same assumptions for d_3, d_4 hold as above.

Figure RP10 is a sketch of a simulation site that could be evaluated by use of the ROAD code.

E. Factors not Included in the Mathematical model -

- Spatial intensity distribution from loudspeakers:

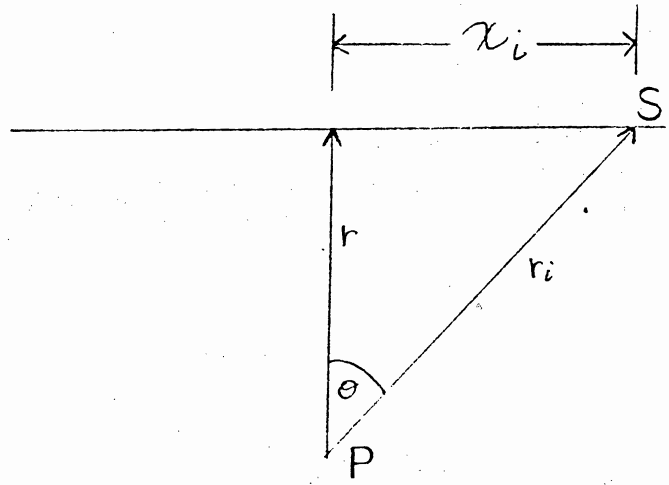
The mathematical model assumes that the speakers are point sources of sound, or at least that at P (Figure RP9) the sound waves from each speaker have spherical wave fronts. The directionality of the actual speakers used in the simulation test were not known; however, the speakers were aimed halfway up the wall of the building which subtended, at O, an angle of about 27°. This is significantly less than the opening angles of the speaker used; therefore, it is expected that the assumption of spherical waves is a very good approximation at the places where our measurements were made.

- Finite width of roadways -

The model assumes each road is a geometrical line, and does not consider the fact that the recorded sound is from traffic moving in both directions in separated traffic lanes, nor the fact that the new road has finite width. The noise level due to the near lane of the proposed road will be higher than the noise actually played back, but the noise from the far lane will be less; the effect is to average out the difference. A calculation made to estimate the actual change in sound level indicates that the maximum error expected for the dormitory site is -0.2 db. This error becomes less as 1) the distance between the real road and the point where the playback tape was made increases; 2) the distance between the proposed road and the calibration point increases; 3) the distance between the proposed road and the observation point increases.

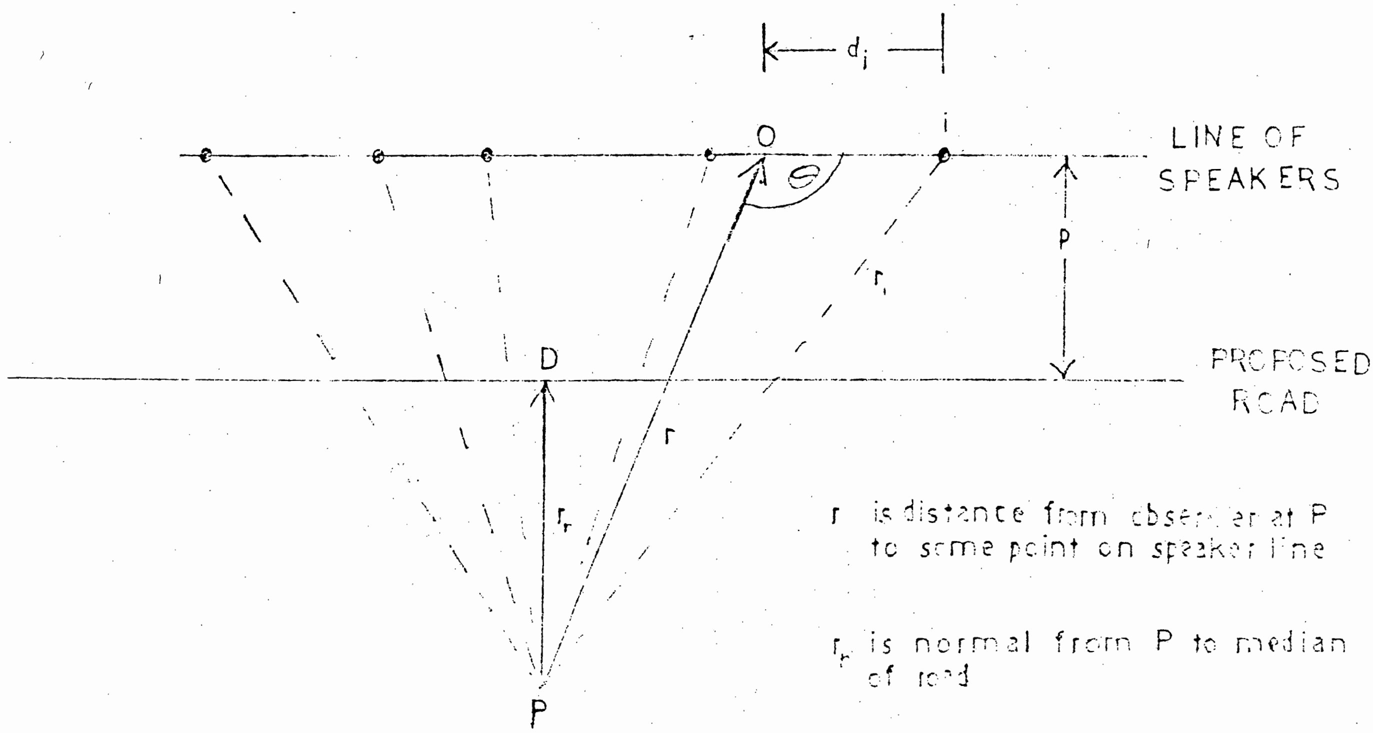
- Effect of Obstacles in the Sound Field -

The contour of the land, the presence of buildings or other structures, etc., will perturb the sound field. In a correctly designed simulation, the calibration point will be away from such obstacles. The presence of perturbing features at observation points is a necessary part of the simulation, and the measurement of sound levels at such points is the purpose of doing the simulation.



INTENSITY AT P FROM SOURCE AT S

FIGURE RP 7



r is distance from observer at P to some point on speaker line

r_r is normal from P to median of road

r_i is distance to i^{th} speaker

FIGURE RP 8 Definition of length parameters

Figure RP9

Elevation view -

L is on line of speakers,
D is on proposed road,
P is observation point,
A is below P, on line LD.
p is distance between line of speakers and median strip of proposed road.

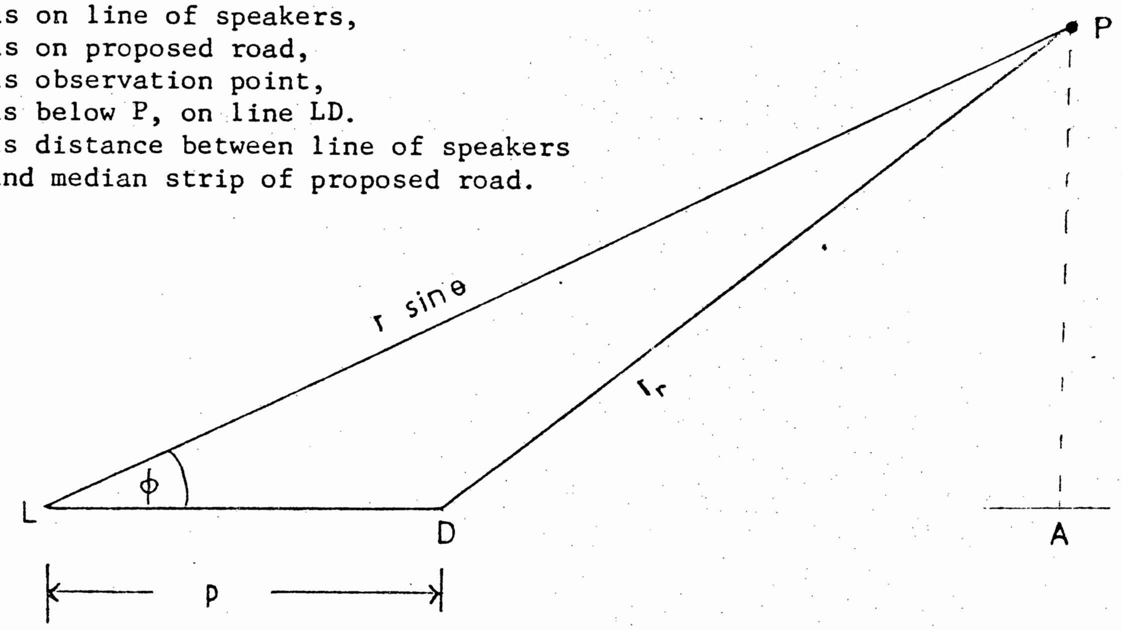


FIGURE RP9

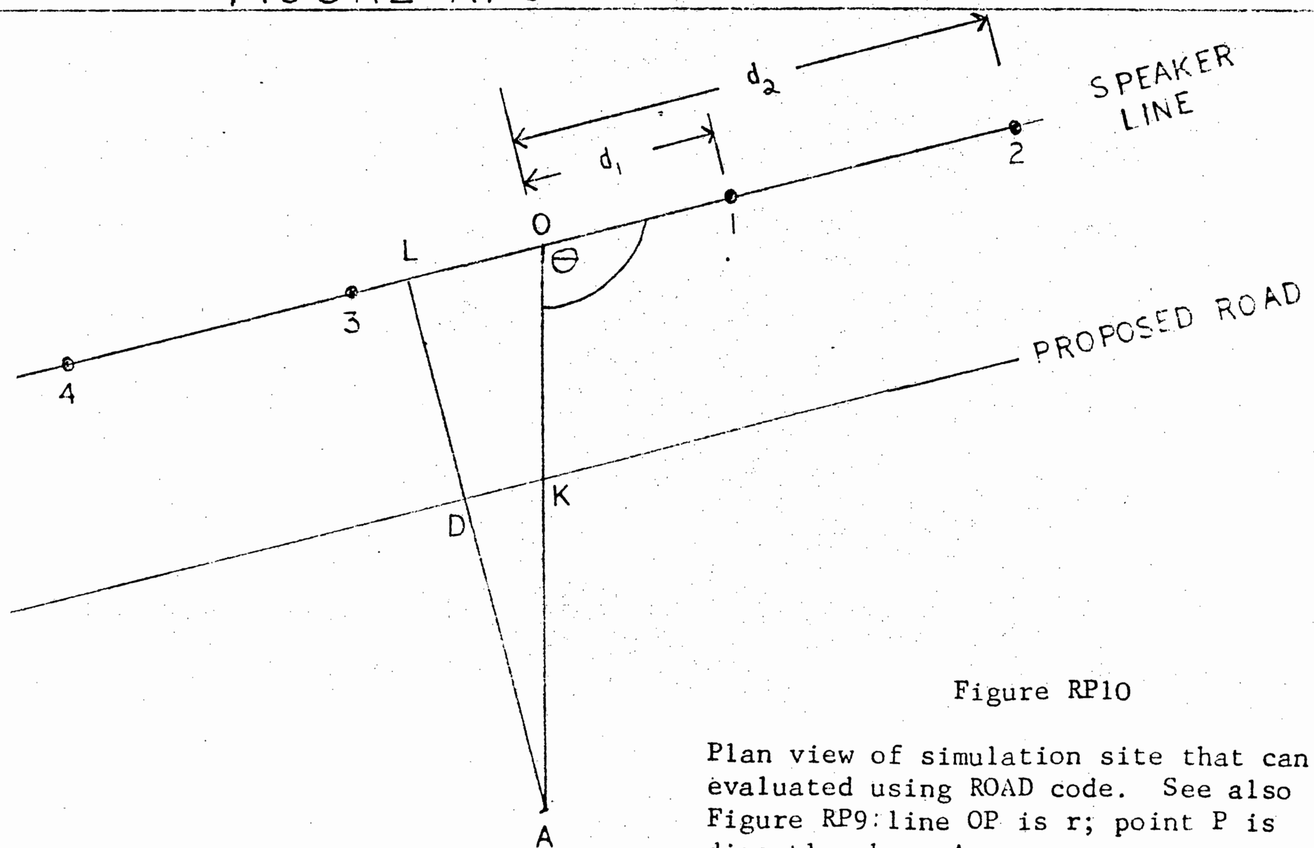


Figure RP10

Plan view of simulation site that can be evaluated using ROAD code. See also Figure RP9: line OP is r; point P is directly above A.

Reference RP3

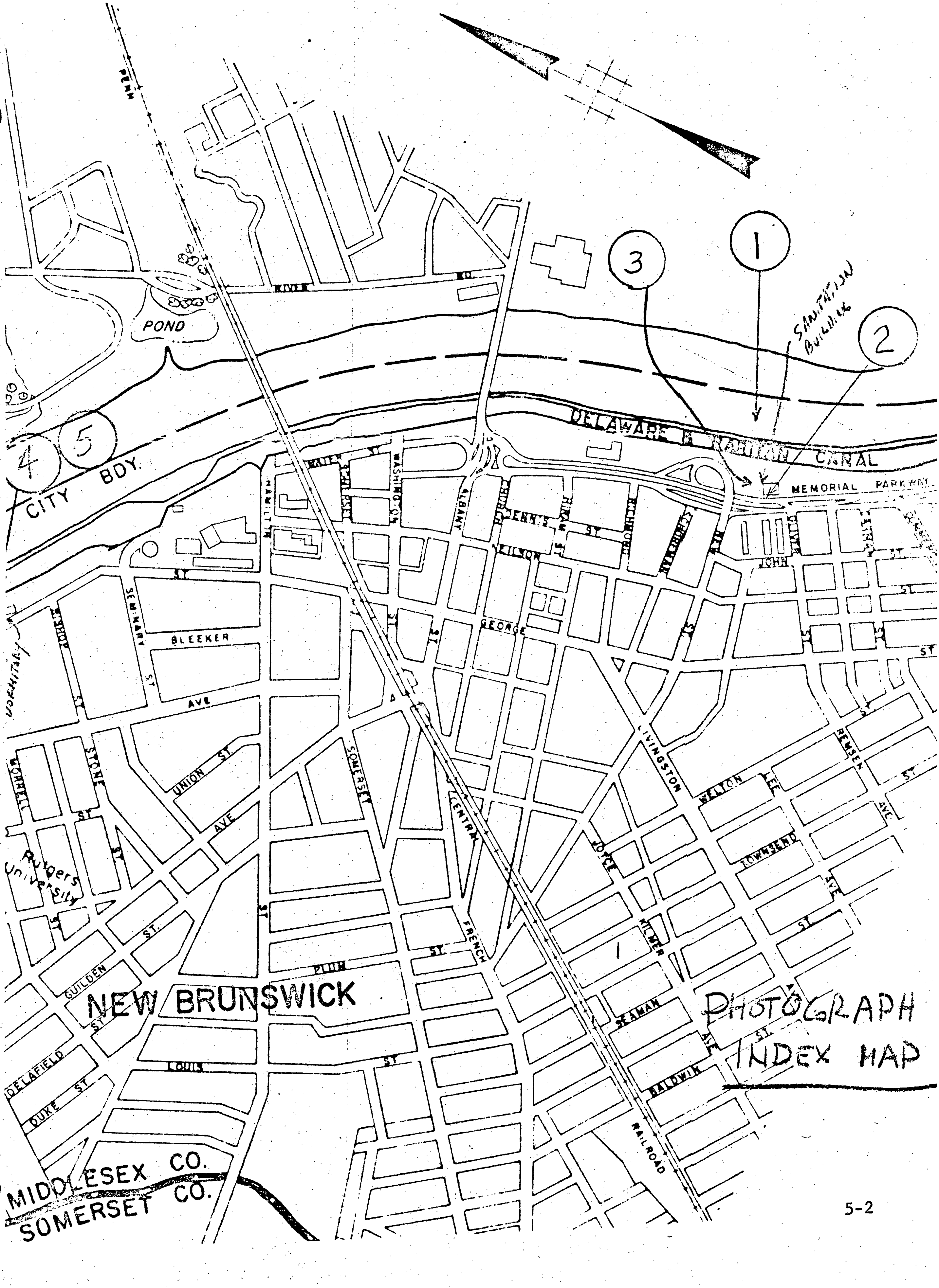
Appendix C, "Development of a Simulation Method for Determining the Noise from Highway Traffic", in Highway Noise Measurement, Simulation and Mixed Reactions, National Cooperative Highway Research Program Report 78, Highway Research Board, NRC, NAS, NAE; pp. 43-45

5.0 PHOTOGRAPHS

Photographs were taken of the three test sites in New Brunswick, N.J. involved in the Route 18 Freeway Extension Study. The photograph index map showing the relative location of these sites follows, along with a description of the photographs. The photographs pertinent to this Noise Impact Study are included here:

1. Aerial view of New Street Area taken 2/24/72. Site of traffic noise recording.
2. New Street traffic noise recording site taken 3/29/72. From roof of Sanitation Building lower left microphone set up on tripod of Route 18 center mall (Figure 3.2-1 Location 1). Right center microphone on roof of Sanitation Building (Figure 3.2-1 Location 2).
3. New Street traffic noise recording site taken 3/29/72 looking south at Sanitation Building. Microphone set up at Location 3 (Figure 3.2-1).

Photographs of the United Nations Site, an index map of that site and a description of the photographs is also included.


PHOTOGRAPH
INDEX MAP
NEW BRUNSWICK
MIDDLESEX CO.
SOMERSET CO.
CITY BDY.
DELAWARE & RARITAN CANAL
MEMORIAL PARKWAY
SANITATION BUILDING
POND
RIVER RD.
PENN
RAILROAD
Rutgers University
GEORGE ST
LIVINGSTON
FRENCH
SOMERSET
ALBANY
BLEEKER
SEMINARY ST
UNION ST
PLUM
LOUIS
DUKE ST
DELAFIELD
GUILDEN
SEAMAN
BALDWIN
WELTON
TOWNSEND
REMSEN
JOYCE
MILMER
WASHINGTON
HAMILTON
NEILSON
SCHUREMAN
RICHMOND
HIRAM
DENNIS ST
STONE
JOHN
1
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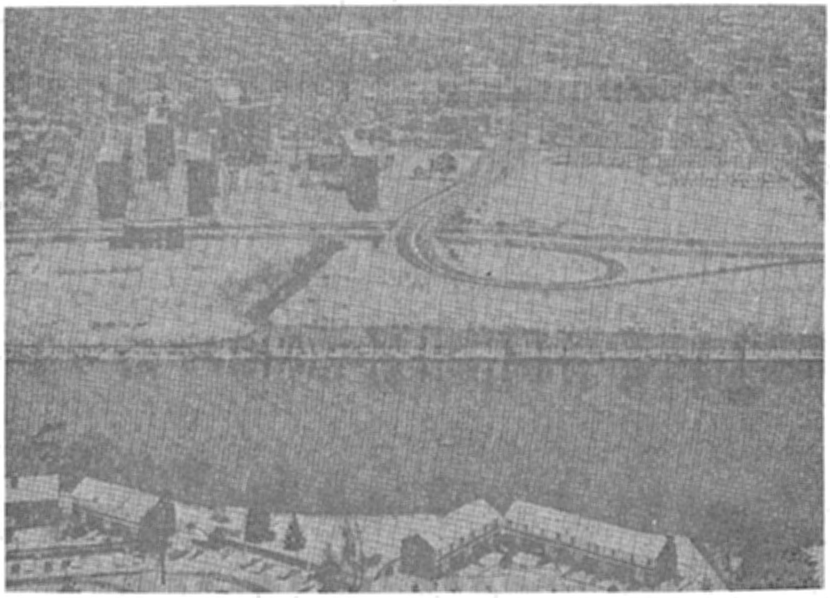

PHOTO 1

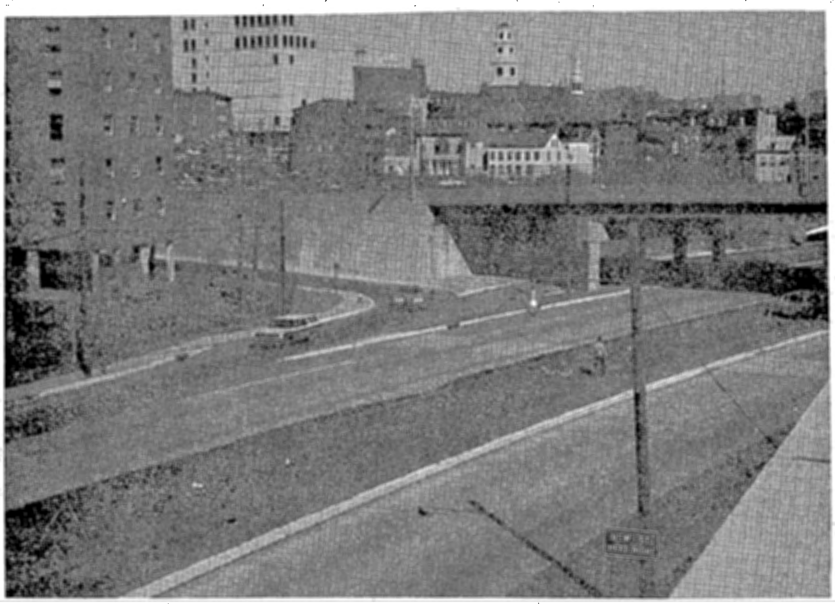

PHOTO 2

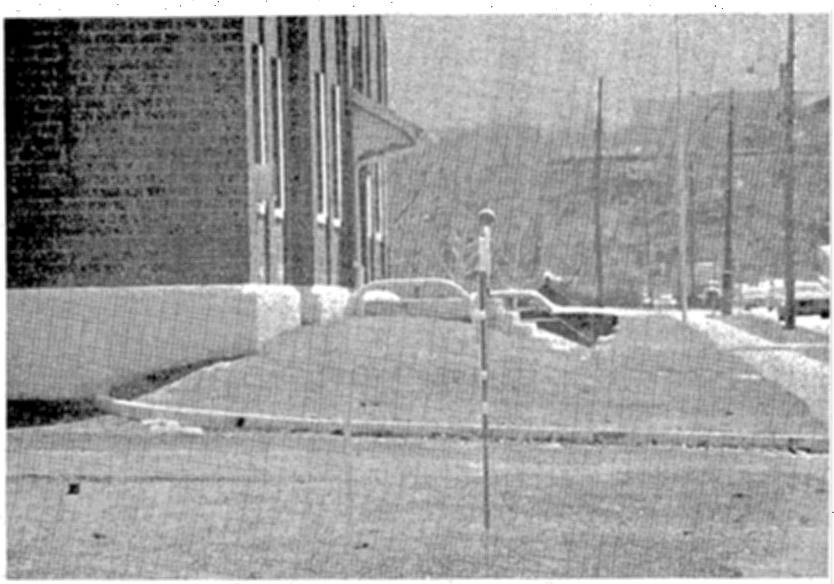

PHOTO 3

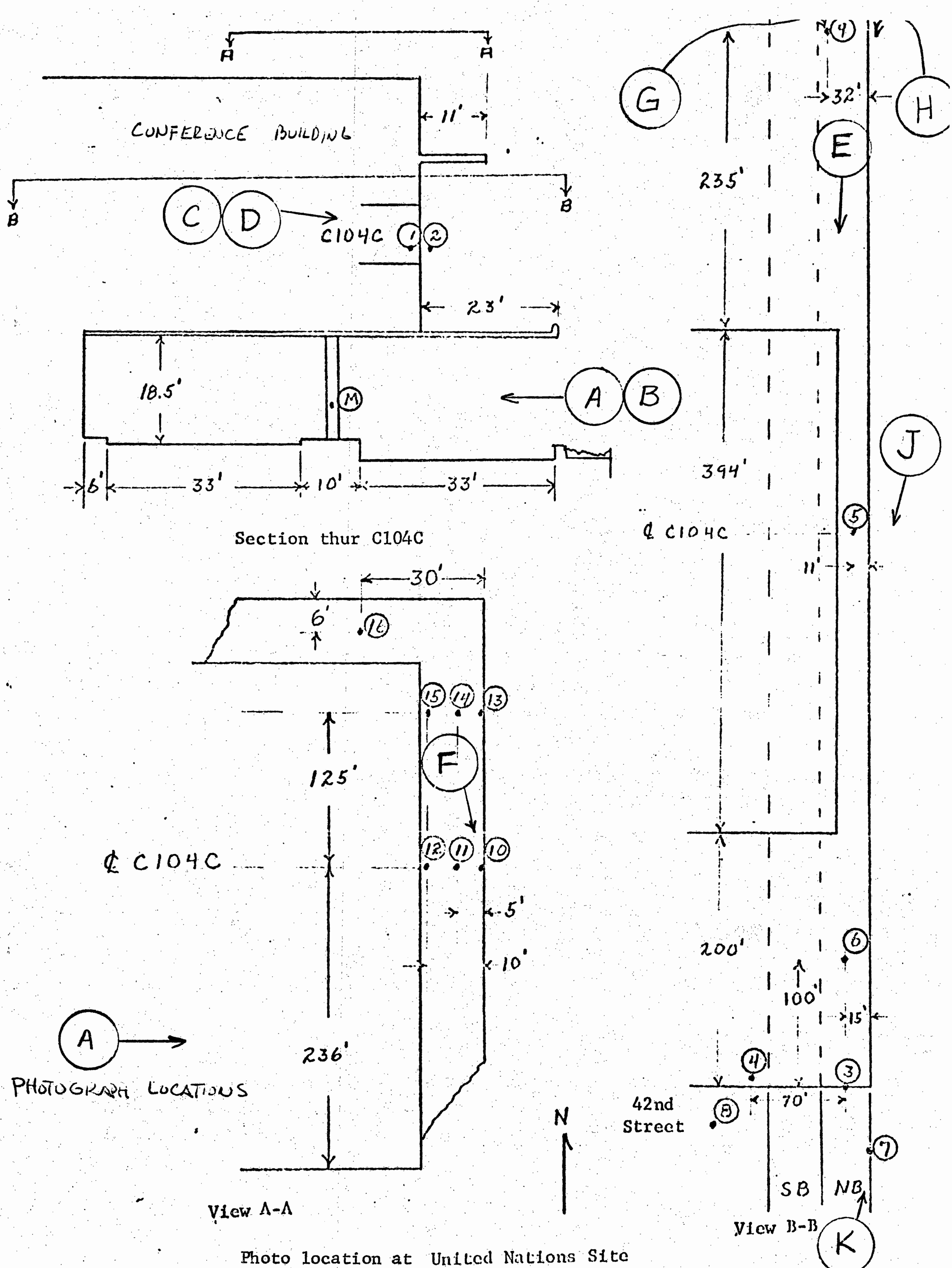

Photo location at United Nations Site

DESCRIPTION OF PHOTOGRAPHS AT U.N. SITE

A & B	N.Y.C. Dept. of Traffic truck placing microphone on center Mall of FDR Drive below United Nation deck in vicinity of Conference Building Room C104-C. (Figure 3.1-1 Location M)
C & D	Graphic noise level recorders in Room C104-C United Nations Conference Building. (Figure 3.1-1 Location 1)
E	View of deck over FDR Drive at United Nations Conference Building.
F	View of Conference Building 3rd floor deck measuring noise level with portable sound level meter at Location 10 (Figure 3.1-1)
G	View of microphone on United Nations deck over FDR Drive north of Conference Building at Location 9 (Figure 3.1-1)
H	North end of United Nations deck over FDR Drive with radar unit attached to vehicle on center mall in foreground.
J	View of United Nations deck over FDR Drive looking south from vicinity of Room C104-C Conference Building.
K	South end of United Nations deck over FDR Drive with microphone at Location 7 (Figure 3.1-1).

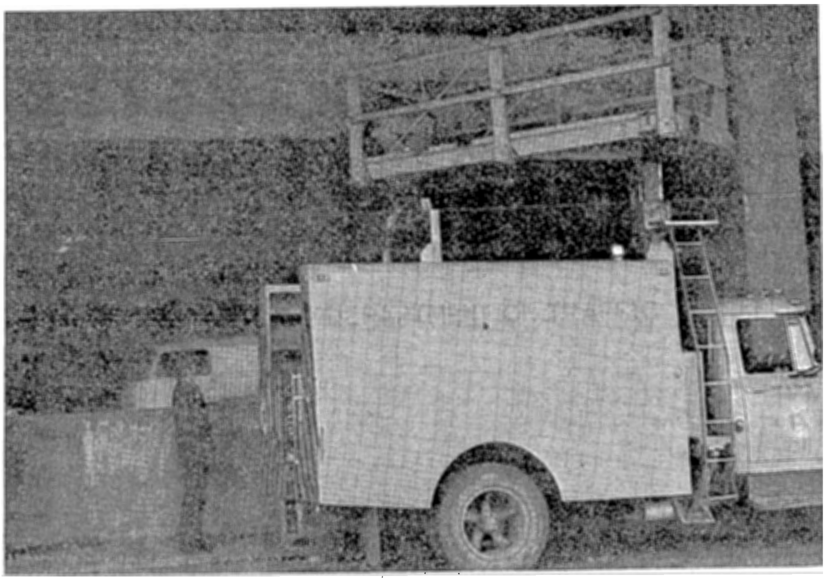

PHOTO A

PHOTO B

PHOTO C

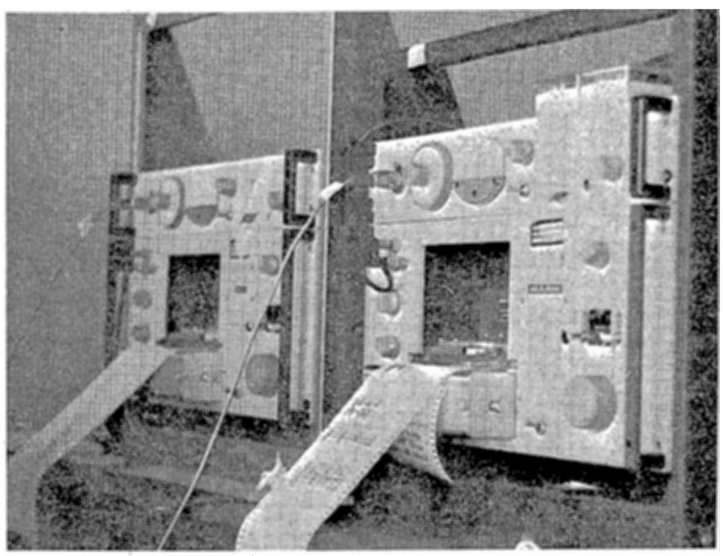

PHOTO D

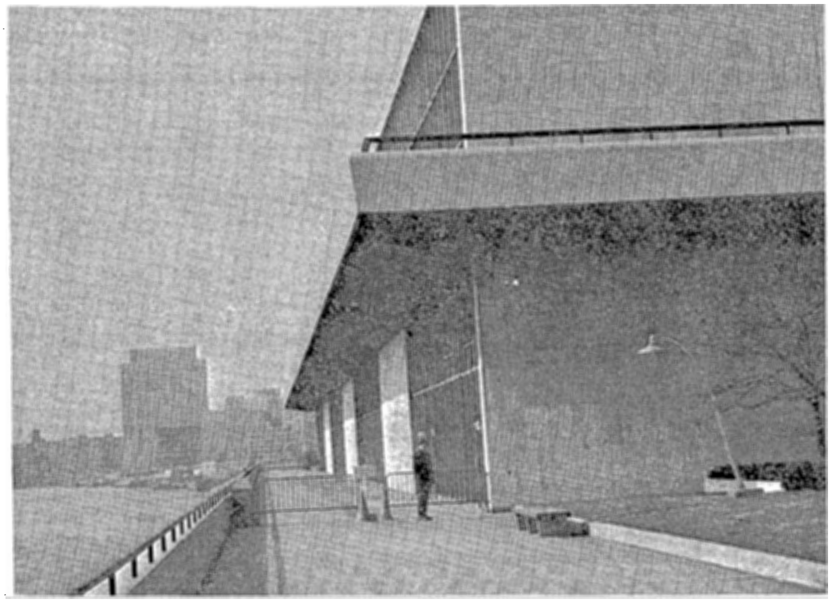

PHOTO E

PHOTO F

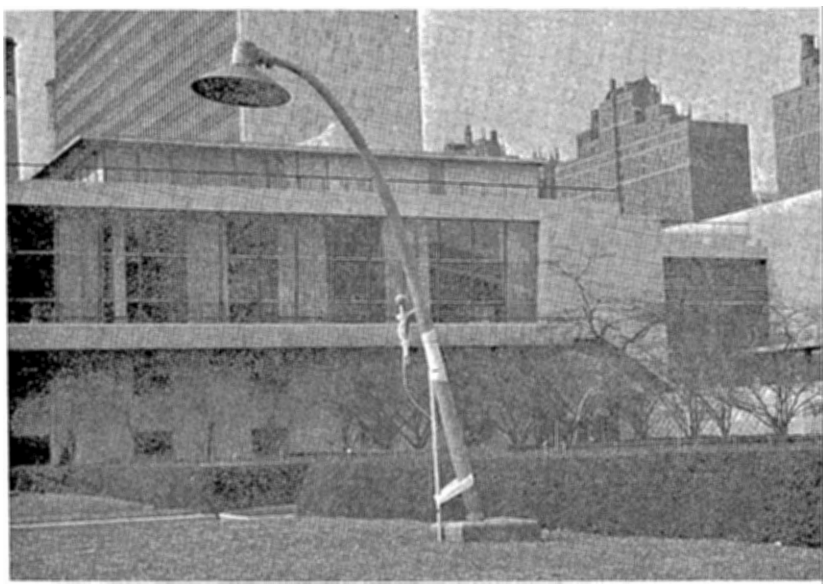

PHOTO G

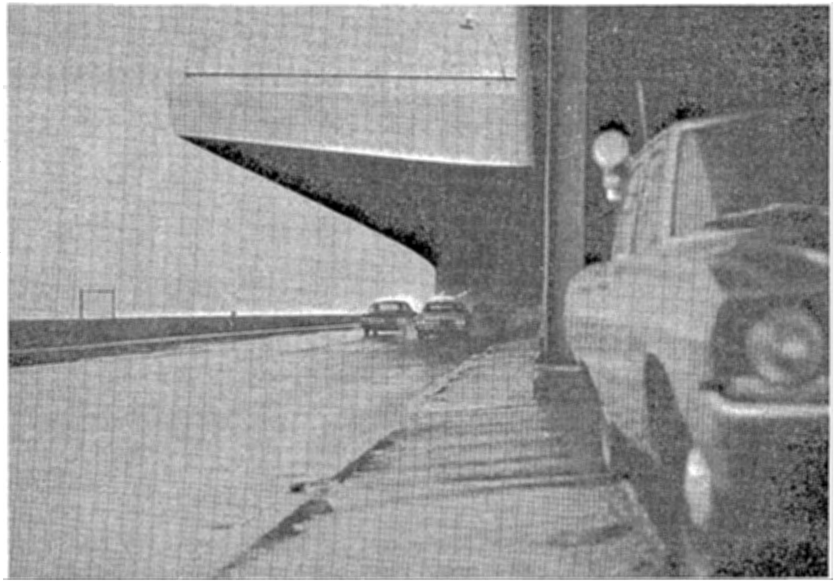

PHOTO H

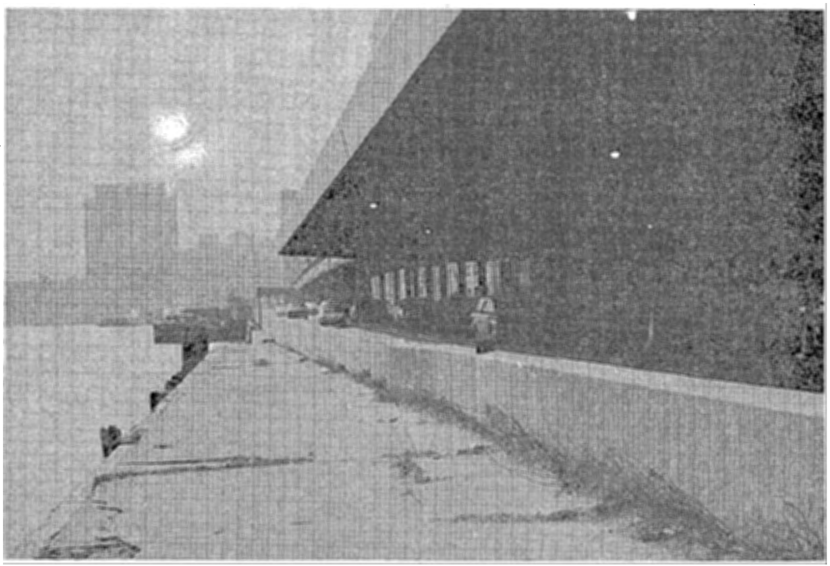

PHOTO J

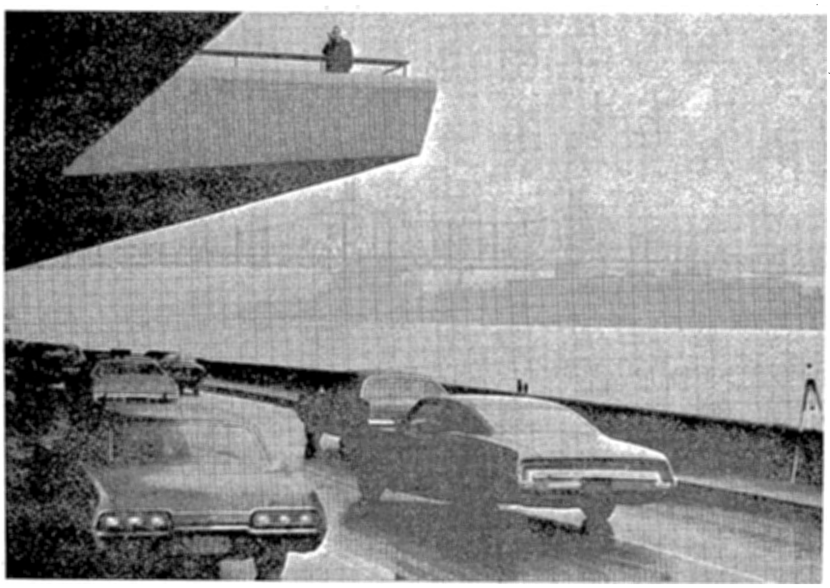

PHOTO K