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EVALUATION OF THE TILT AND ABSORBING NOISE BARRIERS ON I-78 SECTIONS 5M, 5BW, AND 5BY IN UNION COUNTY, N. J.

By

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16. Abstract

In 1986 New Jersey completed an eight-mile section of I-78 in Union County, which included the construction of two innovative traffic noise barriers. Both barriers were concrete post-and-panel structures, designed ostensibly to reduce the assumed interaction between parallel barriers which was considered to degrade barrier effectiveness. One barrier was tilted 10 degrees away from the roadway and had a standard hard concrete grapestake finish, the opposite barrier being of the same type. The second type of barrier was vertical and the panels were covered with a proprietary absorbing finish. Some of the opposite barriers had the same finish, while others had a non-absorbing finish. Both innovative barriers were evaluated for their effectiveness in reducing farside noise levels and increasing nearside insertion loss vis-a-vis a standard barrier with a reflective finish. This evaluation was carried out in two phases. Data collection for Phase I was completed in 1986 before the road was opened to traffic, using a portable generator as a point noise source. Data collection for Phase II was completed in 1989, using traffic as the noise source. The results of the project showed that the additional insertion loss and reduction of farside noise provided by these new barriers was .6 dB or less. Although innovative in design and materials, they exhibited no real advantage over a standard barrier at the locations studied and were therefore not worth the considerably higher cost.

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SUMMARY AND CONCLUSIONS

Summary

In 1986 New Jersey completed a seven-mile section of I-78 in Union County which incorporated two types of traffic noise barriers not previously used in the state. One of these had a proprietary sound-absorbing finish; the other was tilted 10 degrees away from the road and had a grapestake finish. Both were concrete post-and-panel design.

The effectiveness of these barriers was evaluated in two phases using two different noise sources, and using different sites for each phase. During both phases noise data was collected from the barrier under evaluation and a barrier at a corresponding control site, in order to make comparisons between the standard and special barriers.

Phase I

Phase I data collection was carried out during the final months of highway construction and finished the day before the highway was opened. For this phase the noise source was a portable generator with the muffler removed, the effects of which were recorded for different distances from the test and control site barriers. (See Figures 1, 2, and 3, pages 11, 12 and 13.) At each site the reference microphones were placed 75 feet from the barrier, this distance remaining constant throughout the data collection process. The noise source was between the reference microphones and the field microphones and 15 feet from the field microphones. After each series of observations the noise source and the field microphones were moved 15 feet closer to the barrier, so that four sets of observations were obtained for each site. Because of the location of both the test and control sites, it was not possible to place microphones behind the barrier to compare insertion losses. Details of the data collection operation are in DATA COLLECTION - Phase I, pages 19-21, and in Appendix I, pages 62 and 63.

Analysis of the data showed that the absorbing barrier did not cause a reduction in levels at the reference microphones, 75 feet away, when compared to the levels at the standard barrier control site. We inferred from this that either the test barrier did not absorb to a degree which acted to reduce farside noise levels, or that if it did absorb sound as claimed, the effects of fully reflected sound (as at the control site) were negligible at that distance. In either case the obvious conclusion was that there was no advantage in having the absorbing barrier.

For the tilt barrier, the data showed that it did indeed reflect more sound vertically into the air than the standard barrier when the noise source was in the slow or middle lanes, but that it did not when the source was in the fast lane. It also showed that the level 5 feet directly above the tilt barrier top was higher than that at the vertical barrier, when the source was in the middle and slow lanes. This seemed to be a result of the sound being deflected upward by the tilt of the barrier, but this could not be proven on the basis of the study. However, it did raise the question as to whether or not the insertion loss was adversely affected by this higher level.

The data analysis and conclusions for both barriers were discussed with the NJDOT Bureau of Environmental Analysis, the client unit for this project. These discussions resulted in our undertaking a second phase of the project, using traffic as the noise source once the road had been open long enough for a regular pattern of use to develop. Subsequently new test and control sites were chosen and data collection for Phase II was carried out in 1988 and 1989.

Phase II

During Phase II the absorbing barrier was again tested to determine whether or not it was in fact absorbing sound, and if so to what degree the levels at the top of the barrier were reduced, in order to have an indication of its insertion loss as compared to that of a standard reflecting barrier. Because of site constraints and other considerations, it was not possible to test for the relative insertion loss between the two types of barriers directly.

The absorbing barrier test and control sites in this phase were on I-78 westbound and had been constructed subsequent to the completion of Phase I. They were part of the same barrier which was continuous for 2100 feet, and had the same height, panel size and spacing, and panel surface configuration throughout. The only change along the barrier was that the eastern half had panels with the proprietary absorbing finish, and the western half had a standard hard concrete finish. Two sets of 3 microphones each were set up, one set in front of each section. Two microphones in each set were placed within 6 inches of the panel faces, and the third was placed 2 feet above the barrier top and directly over it. See Figures 4 and 7, pages 16 and 65, for diagrams of the microphone locations and sites. Details of the data collection operation are in DATA COLLECTION - Phase II, pages 22-24, and in APPENDIX II.

There were two purposes in reexamining the tilt barrier. The first was to determine if the higher levels at the top of the barrier (as found in Phase I) resulted in correspondingly higher levels at receiver locations; the second was to determine insertion loss vis-a-vis a standard barrier.

The test and control sites for the tilt barrier were located 4300 feet apart and had essentially the same placement and configuration, except for the tilt. In this instance we were able to obtain measurements not only from the tops of the two barriers, via reference microphones placed 5 feet above the tops, but also from receiver microphones placed 4 feet below the tops, at distances of 25 and 50 feet behind the barriers. Figures 5, 6, and 8, pages 17, 18 and 69 show the microphone locations and the configurations of the test and control sites. Details of the data collection method are in DATA COLLECTION - Phase II, and in Appendix II.

Conclusions

Absorbing Barrier: The data for this barrier was utilized to examine the barrier performance from two aspects. First, it was used to determine if there was a difference in levels at the tops of the test and control site barriers and if there was, did the difference indicate that the absorbing barrier offered an advantage over the standard barrier. The result of this analysis showed that the median level at the top of the absorbing barrier was .3 dB less than at the top of the control site barrier, indicating that the absorbing barrier offered essentially no increased protection.

Second, the data was used to examine the effect of the absorbing barrier versus the standard barrier on farside noise levels for the four different possible configurations of the two types. Using the data from this study, and certain assumptions based on engineering judgement and experience gained in prior noise barrier studies, we determined that the absorbing barrier would reduce farside noise levels by .3 dB at best, even for a roadway only 75 feet wide. (See Appendix XI, pages 95-97.)

A third analysis using octave center frequencies was also performed. This was done to determine if the barrier did in fact absorb noise at specific frequencies and to what degree, since the results of the ASTM test for absorption had been a major selling point for this barrier. The results of this analysis showed that the barrier did indeed absorb sound, and that for two of the four frequencies tested it performed as well or better in the field than it did in the laboratory tests.

Based on the findings of both phases of this study, it was concluded that 1) the absorbing barrier does in fact absorb sound - but because of the distance between barriers on most New Jersey roadways, the attenuation of traffic noise over distance, and perhaps because of undefined characteristics of the absorbing barrier itself - it is not effective in reducing either nearside or farside noise; 2) the fact that the barrier exhibited absorption in the ASTM laboratory test is not indicative of its providing better protection in the field than a standard barrier. This failure of measured absorption to relate to barrier effectiveness is also apparent from the field data analysis for absorption, which shows that even though the barrier is absorptive, it provides essentially the same protection as a non-absorptive barrier.

Tilt Barrier: The data for this barrier also required a considerable amount of analysis. Two facts were immediately evident from the initial analysis: the median level at the test site reference microphone was 2.1 dB higher than that at the control site - a significant difference; and the median levels from corresponding field microphones were not significantly different. (See Table VII, page 39.) Therefore it was first necessary to determine whether or not the noise level from the traffic at the test site was higher than at the control site. The effect of the (probable) difference in speeds at the two sites was investigated, experience having shown that traffic always moves at a speed very close to the legal limit when radar is present (as at the control site), only to return to a higher speed as drivers perceive themselves to be out of range (at the test site, 4000 feet downstream). It was also our experience that the usual speed of most traffic on this section of I-78 was 65+ mph, at the time of day during which we took our measurements.

This information was used in STAMINA 2.0 in the first attempt to explain the difference in reference levels between the two sites. (See RESULTS AND DISCUSSION , pages 43-59.) Unfortunately this model did not predict either the absolute or the relative levels accurately enough to provide any insight, so that this investigation proved fruitless with regard to explaining the difference in reference levels at the two sites.

Next, the physical characteristics of both sites were examined in detail, and slight differences between sites were used in another set of STAMINA 2.0 inputs. The results served to compare changes within the predictions for each site, since these results were in no way dependent on either the absolute or relative levels at each site, or on comparisons between sites. The outcome of these predictions was that the changes in characteristics resulted in changes of .5 dB or less at each site, which certainly did not explain the 2.1 dB difference between reference microphone levels.

The final step was to investigate the validity of the hypothesis that the higher level at the test site was due to the reflection of traffic noise "vertically" because of the tilt of the barrier. If this were the case, the reference microphone would be directly in line to receive any "vertical" reflections from the barrier, unlike the situation for the standard barrier where the 5-foot height would place the microphone above the area affected by the barrier top. The results of this investigation, coupled with the findings in Phase I led to the conclusion that this hypothesis offered the only realistic explanation of the higher levels at the tilt barrier reference microphone. The analysis of the data for the tilt barrier is detailed in <u>RESULTS AND DISCUSSION</u> - Phase II.

RECOMMENDATIONS

The following recommendations concerning the two types of barriers are the result of considering the findings of both phases of this study; the fact that virtually all mainline parallel barrier installations in New Jersey would be more 75 feet apart; and information on traffic noise attenuation from previous studies, literature searches, and engineering judgement. These recommendations are as follows:

1. The absorbing barrier should not be used on future noise abatement projects, except where parallel barriers are to be constructed less than 75 feet apart. Although it cannot be shown by this study, it is likely that some benefit would be derived from the absorbing quality of the barrier faces on such an installation. However, cost-benefit should be a major consideration because of the much higher price of an absorbing barrier.
2. The tilt barrier evaluated in this study should not be used on future noise abatement projects. This barrier had a 10-degree tilt. It is unknown whether or not a different angle of tilt would provide an advantage over a vertical barrier, but even if it did cost-benefit would have to be carefully determined, because of the premium price of this type of barrier.

INTRODUCTION

Two innovative noise barriers were used on two sections of I-78 in Union County, N. J. in the area of the Watchung Reservation, a county park. I-78 Section 5BW passed through the park itself. On part of this section a tilted concrete post-and-panel barrier was used. The tilt was 10 degrees, away from the roadway; the panel finish was grapestake. The purpose of the tilt was to reflect noise into the air where it would dissipate, as opposed to reflecting it across the road to (supposedly) add to the traffic noise on the opposite side, as a vertical barrier was assumed to do. A total of 6600 linear feet of this barrier were installed, at a cost of $1,005,705. Figure 1, page 11 shows a cross section of the tilt barrier test site.

Immediately to the east of the park area on I-78 Section 5M, a vertical concrete post-and-panel barrier with a proprietary absorbing finish 2 5/8" thick was used, in and around the Rt. 24 interchange. A cross section of the site is shown in Figure 2, page 12. As with the tilt barrier, the purpose was to prevent reflections from adding to the noise levels on the opposite side of the highway. The cost of this barrier was $2,279,328 for 7065 linear feet. Each of these special barriers cost about 15% more than standard barriers of the same dimensions.

A single control site was used for both barriers. This site had a vertical, concrete post-and-panel barrier, with a grapestake finish. See Figure 3, page 13 for a cross section of this site.

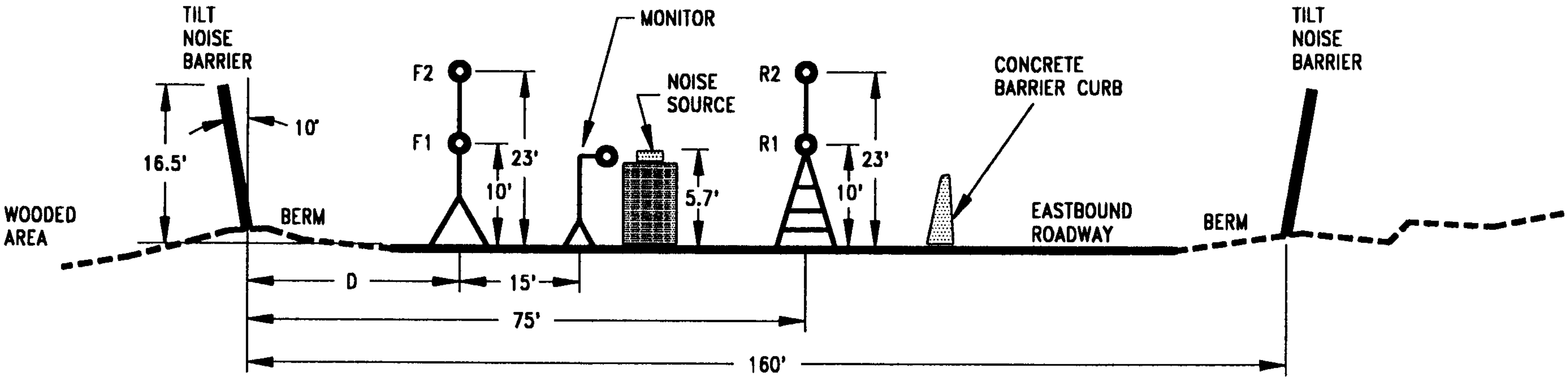
FHWA approved the use of the absorbing barrier in the design

FIGURE 1

TILT BARRIER TEST SITE - PHASE I

STATION 256+25 WESTBOUND ROADWAY

D: Variable in 15-foot increments
F1, F2 Field microphones, moveable in 15-foot increments
R1, R2 Reference microphones, position fixed



NOT TO SCALE

FIGURE 2

ABSORBING BARRIER TEST SITE – PHASE I

STATION 348+00 EASTBOUND OUTER ROADWAY

D: Variable in 15-foot increments
F1, F2 Field microphones, moveable in 15-foot increments
R1, R2 Reference microphones, position fixed

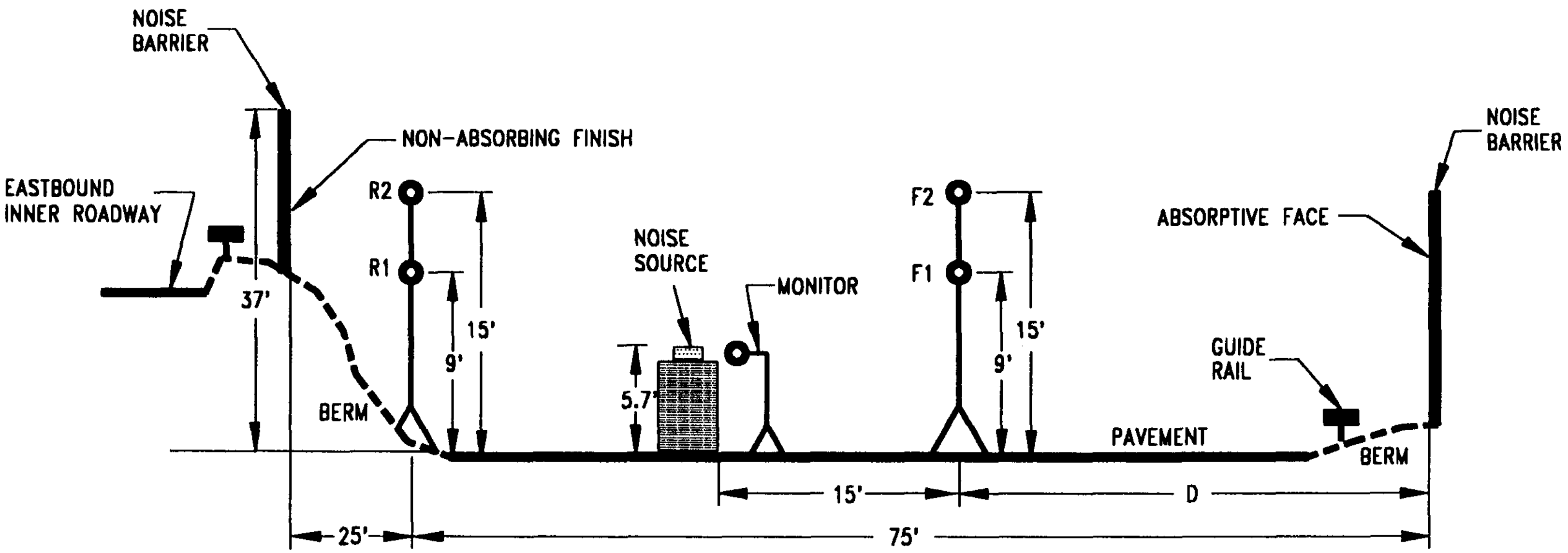


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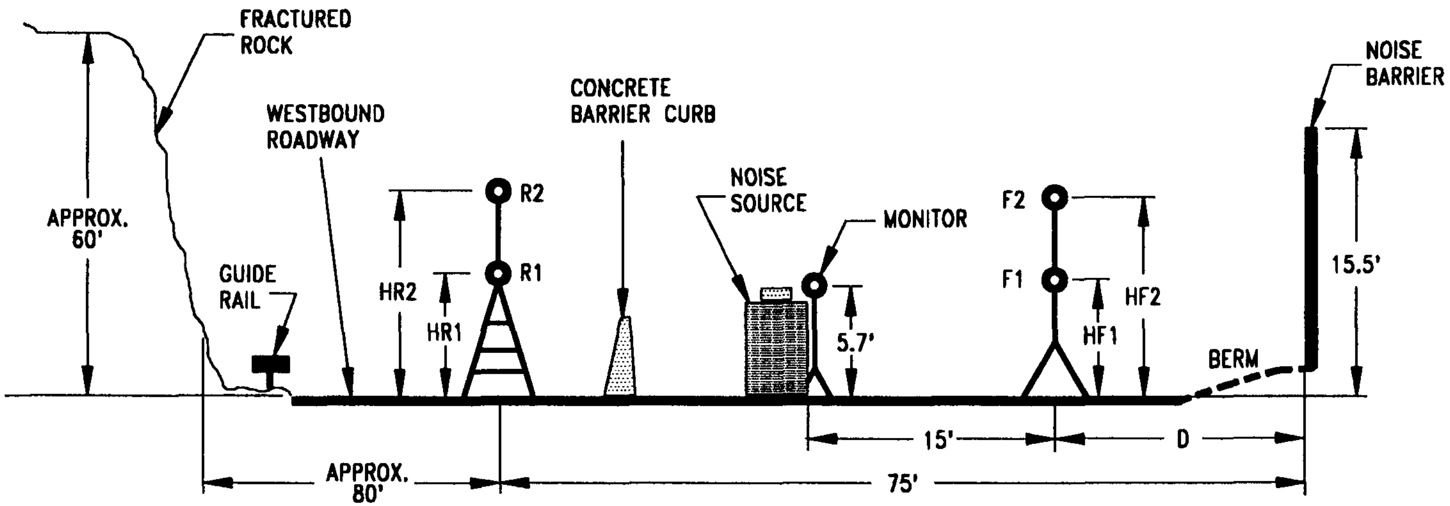
FIGURE 3

TILT AND ABSORBING BARRIER CONTROL SITE – PHASE I

STATION 126+75 EASTBOUND OUTER ROADWAY

D: Variable in 15–foot increments
F1, F2 Field microphones, moveable in 15–foot increments
R1, R2 Reference microphones, position fixed
HF1, HF2: Heights correspond to those at test sites
HR1, HR2: Heights correspond to those at test sites



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stage with the stipulation that it be evaluated once in place. They therefore approved a research project designed to carry out this evaluation, and the evaluation of the tilt barrier as well. The original intent was that the data be collected prior to the road being opened to traffic, so that a controlled noise source could be used. Accordingly, data collection was carried out in June, July, and August of 1986. Barrier construction had been completed at that time and the final construction phases for the projects were nearing completion so that construction noise was almost nonexistent late in the afternoon. An attempt was made to obtain data prior to the construction of the tilt barrier, in order to have before-and-after data for an insertion loss determination, but this was unsuccessful because of equipment problems and weather conditions.

Data analysis for both barriers was completed in 1987, and the results discussed with representatives of the Bureau of Environmental Analysis (BEA). As a result, a second evaluation of the absorbing barrier and a further study of the tilt barrier was undertaken, using traffic as the noise source.

Microphone placement for this second phase was completely different, so that new test and control sites had to be selected. Two of these, the test and control sites for the absorbing barrier, were on I-78 Section 5BY, which is immediately to the east of Section 5M. A section of absorbing barrier 1400 feet long had been installed contiguous with 700 feet of standard barrier on Section 5BY (which had been open for several years without barriers) subsequent to the completion and opening of Sections 5M and 5BW. The barrier on Section 5BY was almost ideal for data collection, so both the test and control sites for the absorbing barrier were located on this section. Panel configuration and surface were the same as used on the Section 5M barriers. The new tilt barrier test and control sites were located on Section 5BW as previously, since the tilt barrier was not used anywhere else.

Both the tilt barrier test and control site barriers for Phase II (after road opening) were the vertical concrete post-and-panel type, with a grapestake finish. The control site barrier for the Phase II absorbing barrier data collection had the same configuration as the absorbing barrier, except for the absorbing surface treatment.

Figures 4, 5, and 6, pages 16, 17 and 18, show the positions of the microphones at the test and control sites for Phase II.

Data collection for Phase II took place during June, September, and October of 1988, and July and August of 1989.

FIGURE 4

ROADWAY CROSS SECTION AND MICROPHONE POSITIONS ABSORBING BARRIER TEST AND CONTROL SITES – PHASE II

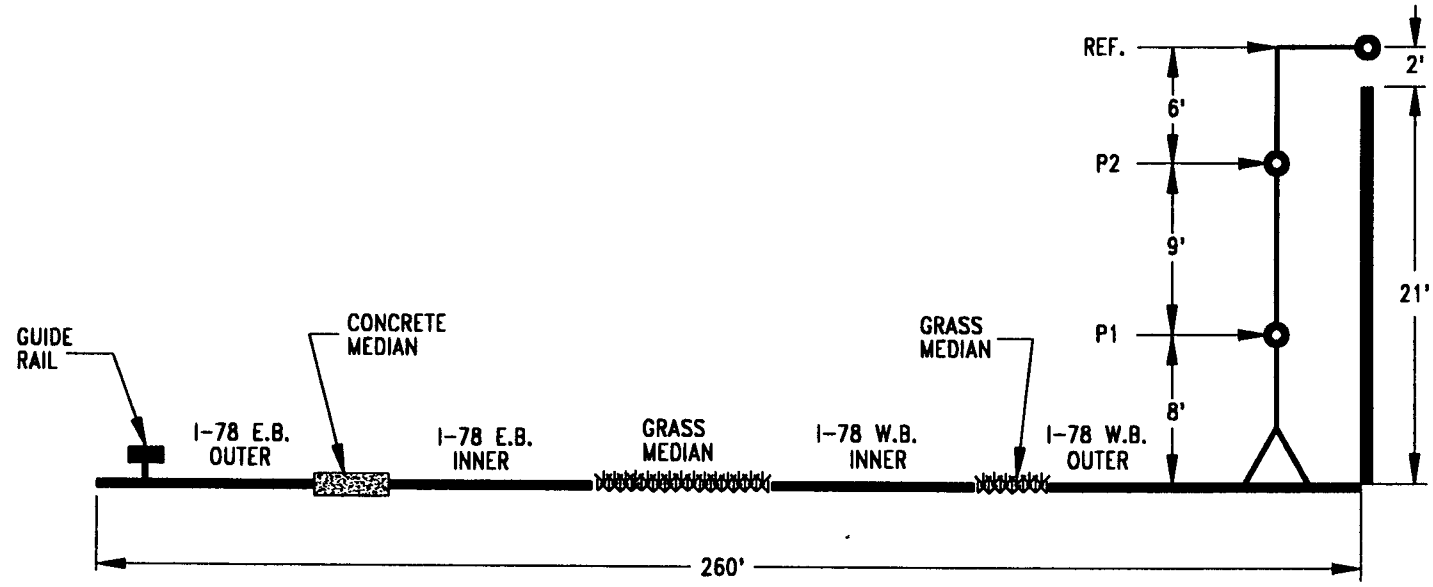

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FIGURE 5

ROADWAY CROSS SECTION & MICROPHONE POSITIONS

TILT BARRIER TEST SITE - PHASE II

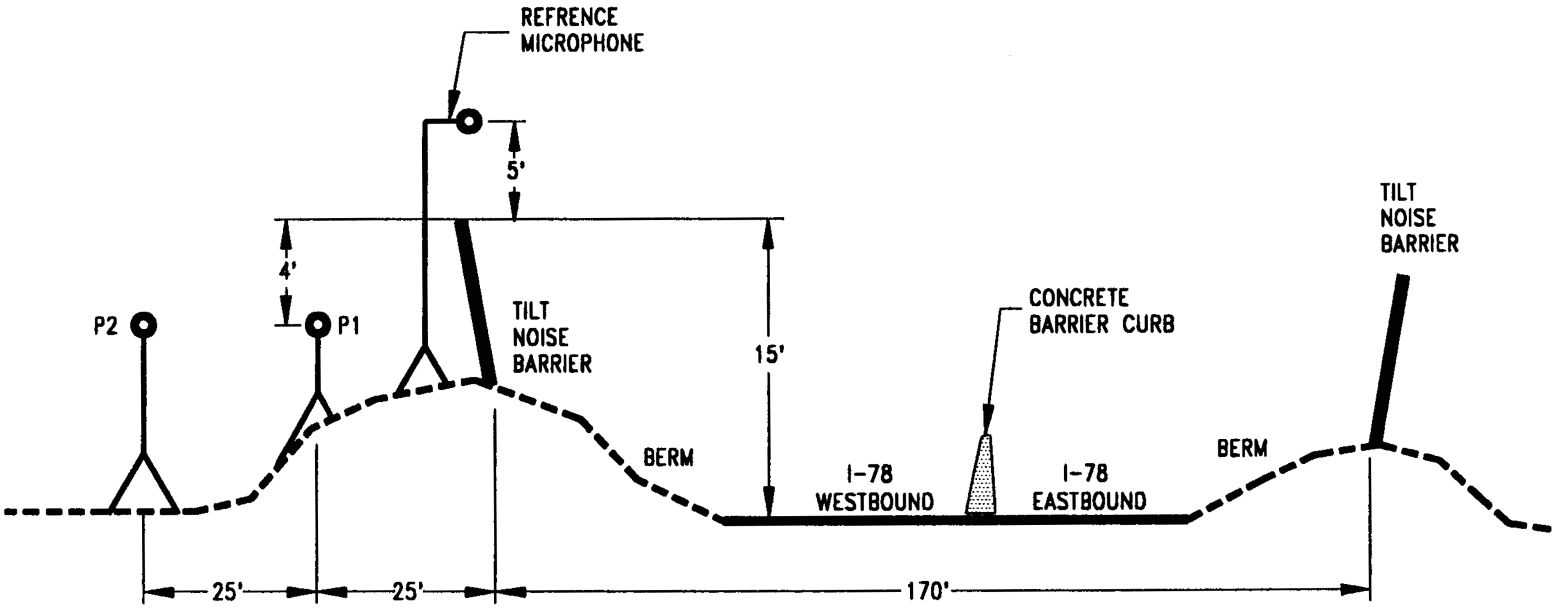

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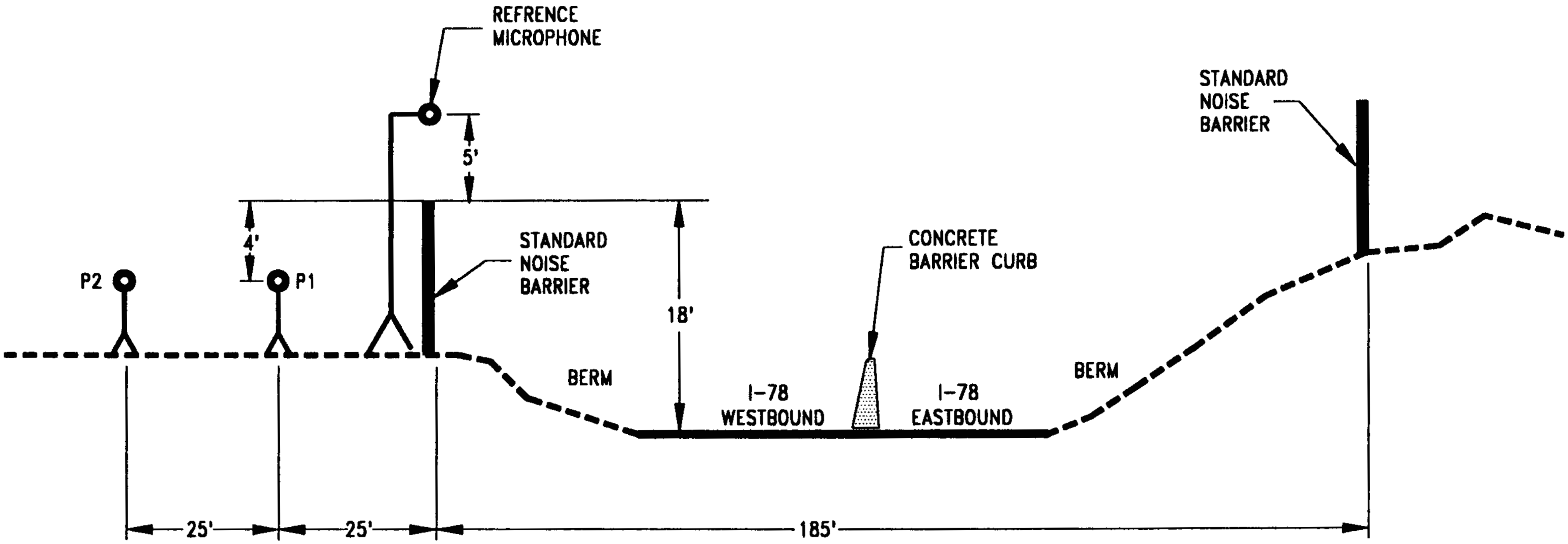
FIGURE 6

ROADWAY CROSS SECTION & MICROPHONE POSITIONS

TILT BARRIER CONTROL SITE – PHASE II



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DATA COLLECTION

Phase I

Data collection for Phase I took place at three sites: a test site for the absorbing barrier; a test site for the tilt barrier; a control site which served for both the absorbing and tilt barriers. The control site (vertical) barrier and the tilt barrier were concrete post-and-panel construction with a grapestake finish on the panels. With regard to data collection, the major difference between the tilt and absorbing test sites was the difference in microphone heights. This allowed us to use one control site, since all that was required was that the microphone heights be changed to correspond to those used at each test site. Figures 1, 2, and 3, pages 11, 12 and 13, show the microphone heights and initial placement at each site.

The sites as selected were the best available, but it was not possible to find control sites which exactly duplicated the topography of the tilt and absorbing barrier sites. However, the control site chosen did in fact present a "best case" for the absorbing barrier especially. The site was along the south side of the Second Watchung Mountain, the roadbed being cut into it to the extent that there was a 60-foot rock wall opposite the control site. If reflections from this farside wall were at high enough levels to add to the levels from the primary source (as assumed when the absorbing barrier recommended for installation), then nearside levels at the control site should have been noticeably higher than those at the test site, which had 19-foot grass-covered berm supporting a 10-foot-high concrete barrier.

The noise source was a 1500-watt Kohler portable generator driven by a 2 hp air-cooled engine on which the muffler had been replaced with a short piece of 1" iron pipe. The unit was placed on a platform with the exhaust outlet facing the barrier, with a microphone next to it to monitor the output. This microphone (4145 Bruel & Kjaer with random incidence corrector) was positioned 1.5 feet to one side (which was as close as possible to the exhaust outlet), and at 5.7 feet above the pavement - the height of the outlet. The field microphones (4166 B & K) were placed 15 feet from the exhaust outlet, between the generator and the barrier. The reference microphones (4166 B & K) remained at 75 feet from the barrier throughout data collection at the particular site. The generator and microphones were along a straight line perpendicular to the barrier. Both the upper reference microphone and the upper field microphone (R2 and F2) were connected to the same tape recorder. Similarly, R1 and F1 were connected to the same recorder. This minimized any equipment differences between corresponding microphones, thus effectively eliminating this as a factor in making comparisons between the data sets obtained from each pair.

A series of 45-minute observations were recorded simultaneously for all reference and field microphones, tape length being nominally 45 minutes. In addition, a direct readout of the 2-minute Leq's of the exhaust noise level was obtained during the taping. For the initial taping at the absorbing barrier test site, the reference microphones were placed at 75 feet from the barrier; the exhaust outlet was at 60 feet from the barrier; and the field microphones were at 45 feet from the barrier. (See Figure 7, page 65) With the generator running and being monitored every two minutes for an Leq, we recorded the noise for 45 minutes. At the end of this time the field microphones were moved to 30 feet from the barrier, the generator to 45 feet, and the reference microphones remained at 75 feet. The taping and monitoring were repeated for this configuration, and at the end of 45 minutes the generator and field microphones were moved 15 feet closer to the barrier for another 45 minutes. In the last position the field microphones were at 2 feet from the barrier, and the generator at 15 feet. This process was repeated at all sites, the only difference being the microphone heights in each case.

All sound level meters, tape recorders, and ancillary equipment were housed in a van, which was parked about 200 feet from the source-microphone area so that it could not affect the either the output or the readings. Wind speed and direction were recorded continuously during taping and checked frequently if the wind speed was close to 10 mph. No data was collected if wind speed exceeded 10 mph, or during periods of precipitation.
Extensive field notes were kept on observation times, meter settings, equipment operation and malfunctions, and the occurrence of extraneous noise from planes, construction operations, etc.

A complete description of the data collection routine and the equipment used for Phase I can be found in Appendix I, page 62.

Phase II

As in Phase I, the test and control sites were chosen to be as alike as possible. In this instance however, it was also necessary to choose sites which had no interchanges between test and control locations, so that the changes in traffic between the two were minimized.

In the case of the absorbing barrier, several thousand feet of barrier had been constructed on I-78 Section BY (westbound) subsequent to the completion of Phase I. About half of this barrier had the absorbing face, made of the same material and having the same configuration as the absorbing barrier on Section 5M. Both the absorbing and reflecting standard barrier on Section 5Y had the same surface configuration, height, placement with regard to the roadway, and the same farside topography. Best of all the two barriers were contiguous, making the sites nearly ideal for comparison purposes. See Figure 4, page 16 for a diagram of the microphone positions at these sites.

Both the sites for the tilt barrier were on I-78 Section 5BW, westbound. While certainly acceptable, they were not nearly as well matched as those for the absorbing barrier. There were small differences in height and placement, and more pronounced differences in roadway configuration. The roadway at the control site curved toward the site and was near the top of an upgrade on an almost flat section of highway; the roadway at the test site curved away from the site, and was at the bottom of a downgrade which extended about 1500 feet in either direction. A discussion and analysis of the effect of these differences can be found in the <u>DATA ANALYSIS</u> and <u>RESULTS AND DISCUSSION</u> sections of this report. Possibly the worst feature of the two sites was that they were 4300 feet apart (but with no interchanges in between) which provided opportunity for changes in traffic patterns, and allowed for a considerable change in speed after the traffic had passed the radar at the control site, which was the upstream site. Similarly, farside (eastbound) traffic patterns and speeds could have changed after passing the test site to the west. See Figures 5 and 6, pages 17 and 18 show the microphone positions at these sites.

Data collection for Phase II began on June 21, 1988 and was completed on August 2, 1989. A series of two-minute noise observations were recorded from all microphones at each site. In addition to traffic noise samples, nearside and farside traffic counts were recorded by vehicle type, and at least five radar speed readings for nearside traffic made during each noise observation. Air temperature, wind speed, and wind direction were also recorded at various times during the sampling. Appendix II, page 64 gives a detailed description of data collection for both types of barriers.

<u>Absorbing Barrier</u>: Microphone heights at both the test and control sites were 8, 17, and 23 feet above the pavement, the highest microphone being two feet above the top of the barrier and directly over it. The reference microphone (23 feet) was placed in this position so that it would be affected by the barrier and therefore give some indication of how the absorbing and reflective faces of the barriers affected the levels at the barrier top. (See Figure 4, page 16) The lower microphones were

set on the source side of the barriers at no more than six inches from the panel faces, centered between posts, and away from the horizontal joints between panels. The two sites were 336 feet apart, so that a three-second delay was required in the starting times for the downstream recorders. Noise observations were two minutes long, recorded on tapes which were nominally 45 minutes long. About 65 observations had to be obtained initially, in order to have approximately 50 after those contaminated by non-traffic noise were discarded.

Tilt Barrier: The tilt barrier and control site microphones were set on the receiver side, with the reference microphone set 5 feet above the barrier and directly over the top. This positioning of the reference microphone eliminated reflections from the control site barrier top, so that direct comparisons could be made between the samples from the two reference microphones. Two field microphones were used at each site, one at 25 feet and the other at 50 feet from the barrier, and 4 feet below the top. The observation length and sample size were as described for the absorbing barrier, with a 45-second delay in starting at the test site, which was downstream of the control site. Radar readings and traffic counts were made at the control site only.

The sound level meters, tape recorders, and ancillary equipment were all operated from a van which was kept at least 200 feet from the microphone line so as not to affect the sound levels.

DATA REDUCTION

Phase I

Data reduction for this phase was straightforward, since the noise was generated by a steady-state point source. Outside interference was relatively easy to determine since it could only come from construction noise, construction vehicles, lawn mowers, and aircraft - all of which produced noise distinctly different from the noise source. Most of the occurrences of outside noise were indicated by time and type in the field notes, which simplified locating them during playback. Data reduction consisted of obtaining Leqs for as many "clean" 2-minute segments of each tape as possible. Since the noise was steady state, as determined from the 2-minute Leq direct readouts from the monitor microphone, it was immaterial whether or not each segment corresponded to those from other microphones at the site as long as all were free of outside noise.

Table I, page 26 shows the number of usable 2-minute observations obtained through data reduction, for each microphone. Appendices III-VI, pages 71-86 show the Leqs obtained for each observation from each microphone, including the source monitor microphone. Microphone positions are shown in Figures 1, 2, and 3, pages 11, 12 and 13.

TABLE I

PHASE I

NUMBER OF 2-MINUTE OBSERVATIONS FROM EACH MICROPHONE - BY SITE

MICROPHONE POSITION

Site	D	S	R1	R2	F1	F2
Absorbing Test	60	22	25	20	20	21
	45	23	21	22	21	23
	30	20	17	21	17	22
	17	22	20	21	22	22
Absorbing Control	60	23	22	21	22	21
	45	23	20	17	22	22
	30	22	18	18	22	21
	17	23	19	19	22	22
Tilt Test	60	23	23	22	22	23
	45	23	19	19	19	21
	30	23	16	11	22	18
	17	22	18	19	21	22
Tilt Control	60	23	22	22	21	20
	45	23	18	19	22	22
	30	23	17	18	22	21
	17	23	19	19	22	21

D: Distance in feet from source to barrier.

S: Microphone at source.

R1: Microphone at 75 ft. from barrier, 9 ft. above pavement for absorbing barrier, 10 ft. for tilt barrier.

R2: Microphone at 75 ft. from barrier, 15 ft. above pavement for absorbing barrier, 23 ft. for tilt barrier.

F1: Microphone at 15 ft. from source, between source and barrier, same heights as R1.

F2: Microphone at 15 ft. from source, between source and barrier, same heights as R2.

Phase II

Outside noise sources during Phase II included aircraft, lawn mowers, vehicles stopped and idling or restarting at the sites, and dogs. The dogs presented an unusual (but minor) problem in that the tilt barrier test site was located adjacent to the Union County Police K-9 detachment. Fortunately our microphones were far enough away so that the noise from the dogs affected only a few observations. All non-highway noise was noted on the field sheets by time and type.

While the noise from the dogs clearly stood out from the traffic noise in those instances where it was loud enough, noise from the other sources tended to blend with it until becoming loud enough to stand out from the traffic noise background, during playback. Thus it was difficult to determine which observations were usable until each had been listened to on playback. Since the observations were discrete 2-minute recordings initially rather than being derived from a continuous tape in the laboratory (as in Phase I), any observation which was contaminated by outside noise was discarded so that the entire two minutes was lost. Nevertheless, it was possible to obtain fairly large samples from each microphone, as shown in Table II, page 28. A complete list of Leqs from each microphone at each site can be found in Appendix VII, page 89 and Appendix IX, pages 91 and 92.

TABLE II

PHASE II

NUMBER OF 2- MINUTE OBSERVATIONS

FROM EACH MICROPHONE - BY SITE

	Site			
Microphone Position	Absorbing		Tilt	
	Test	Control	Test	Control
PR	45	45	58	71
P1	47	47	61	73
P2	47	47	69	73

PR: Reference microphone set 2 feet higher than the top of the barrier and directly over the barrier top.

P1: Microphone set at 8 feet above the pavement and 6 inches from the barrier face.

P2: Microphone set at 17 feet above the pavement and 6 inches from the barrier face.

See Figures 4, 5, and 6, pages 16, 17 and 18 for diagrams of microphone positions.

In addition to the reduction of the noise data, an average speed was determined from the five speed readings made during each observation. Traffic counts and average speed for each reduced observation are listed in Appendix VII, page 90 and Appendix X, pages 93 and 94.

DATA ANALYSIS

Phase I

The effectiveness of each of the innovative barriers was determined by comparing the data obtained at each with the data obtained from the control site for that barrier. Because of the steady-state noise source used, the data from any one microphone was uniformly distributed over a very narrow range of sound pressure levels, which varied only a few tenths of a decibel from lowest to highest. (See Appendix III, page 71.) Thus for any of the four microphones (R1, R2, F1, F2) at any site, there was virtually no overlap among the data sets from any two microphones, which gave an unusually clear indication of variations in levels due to height and distance from the noise source. This was true for all source - barrier distances at all sites. There was also no overlap between levels at corresponding microphones at the test and control sites so that changes in levels due to site were easily seen.

Up to this point we have been discussing the raw data, as obtained from the data reduction process. Since it was not possible to perform a meaningful statistical analysis with the data in this form, it was decided to examine the feasibility of standardizing the noise source output to 100 dB and raising or lowering the reference and field microphone data accordingly. The first step in this operation was to determine the relationship between the source level and each microphone level for every microphone and every distance, for each site.

By selecting as many different (x,y) pairs as possible for each source-microphone combination (x = source Leq, y = field or reference Leq) it was possible to find the highest degree equation necessary to describe the relationship between the source and each microphone, which was a quadratic.(10) Using the general quadratic

$$y = a + bx + cx^2,$$

and substituting the pairs of Leqs for each two-minute observation into the equation, we obtained 17 to 24 equations for each source-microphone combination, depending upon the number of usable observations. Each set of equations was solved by the method of least squares, using a SAS program. In every case the quadratic coefficient dropped out, leaving a linear relationship. Not only were the relationships linear, but they were all parallel, having a slope of 1.0 and differing only in the constant. Thus it was possible to justify standardizing all output Leqs to 100 dBA, and adjusting all reference and field microphone Leqs by the same constant used to standardize the output in each case.

Because of the clear differences between the data sets from each microphone, there was no way to make statistical comparisons to determine if the data sets from corresponding microphones at the test and control sites were from the same population. In actuality, it was not necessary to do so because it was obvious that they were from different populations. Therefore any test or measure of change between test and control data had to be made by other means. Since the range of levels from any microphone was very narrow (usually less than 1 dB), the average of these levels provided an useful representation of the entire range. These averages (shown in Tables III-VI, pages 32-35) were used to make the comparisons between the test and control sites for both new barriers.

TABLE III

ABSORBING BARRIER

AVERAGE Leq AT EACH MICROPHONE POSITION - PHASE I

Microphone Position

Source Distance To Barrier	S	R1	R2	F1	F2
60 ft.	100.0	83.1	80.8	84.9	82.3
45 ft.	100.0	78.5	76.7	85.0	83.0
30 ft.	100.0	72.5	71.3	80.1	83.6
17 ft.	100.0	71.4	72.1	85.1	82.7

S: Microphone at source.

R1: Microphone at 75 ft. from barrier, 9 ft. above pavement.

R2: Microphone at 75 ft. from barrier, 15 ft. above pavement.

F1: Microphone at 15 ft. from source, between source and barrier, 9 ft. above pavement.

F2: Microphone at 15 ft. from source, between source and barrier, 15 ft. above pavement.

TABLE IV

ABSORBING BARRIER CONTROL SITE

AVERAGE Leq AT EACH MICROPHONE POSITION - PHASE I

Microphone Position

Source distance To Barrier	S	R1	R2	F1	F2
60 ft.	100.0	82.6	77.3	83.2	81.3
45 ft.	100.0	74.9	73.6	84.6	81.2
30 ft.	100.0	73.7	71.8	84.8	79.4
17 ft.	100.0	72.9	70.7	85.1	80.8

S: Microphone at source.

R1: Microphone at 75 ft. from barrier, 9 ft. above pavement.

R2: Microphone at 75 ft. from barrier, 15 ft. above pavement.

F1: Microphone at 15 ft. from source, between source and barrier, 9 ft. above pavement.

F2: Microphone at 15 ft. from source, between source and barrier, 15 ft. above pavement.

TABLE V

TILT BARRIER

AVERAGE LEQ AT EACH MICROPHONE POSITION - PHASE I

	Microphone Position				
Source Distance To Barrier	S	R1	R2	F1	F2
60 ft.	100.0	83.3	75.5	83.7	78.2
45 ft.	100.0	74.9	72.4	84.6	79.5
30 ft.	100.0	73.0	70.9	87.0	80.9
17 ft.	100.0	70.7	68.7	86.4	80.0

S: Microphone at source.

R1: Microphone at 75 ft. from barrier, 10 ft. above pavement.

R2: Microphone at 75 ft. from barrier, 23 ft. above pavement.

F1: Microphone at 15 ft. from source, between source and barrier, 10 ft. above pavement.

F2: Microphone at 15 ft. from barrier, between source and barrier, 23 ft. above pavement.

TABLE VI

TILT BARRIER CONTROL SITE

AVERAGE Leq AT EACH MICROPHONE POSITION - PHASE I

Microphone Position

Source Distance To Barrier	S	R1	R2	F1	F2
60 ft.	100.0	83.9	76.6	84.6	79.2
45 ft.	100.0	76.2	77.2	85.7	77.3
30 ft.	100.0	73.8	74.2	85.1	77.0
17 ft.	100.0	71.8	69.8	84.1	75.7

S: Microphone at source.

R1: Microphone at 75 ft. from barrier, 10 ft. above pavement.

R2: Microphone at 75 ft. from barrier, 23 ft. above pavement.

F1: Microphone at 15 ft. from source, between source and barrier, 10 ft. above pavement.

F2: Microphone at 15 ft. from source, between source and barrier, 23 ft. above pavement.

Phase II

The approach used in Phase II was to compare the data obtained from each of the innovative barriers with the data obtained from the control site for each, the objective being 1) to determine whether or not there was any difference between the special and standard barriers, and 2) to determine if any difference found was or was not an actual advantage in terms of noise reduction. This was done statistically, for each corresponding pair of microphones. As with previous studies, traffic noise samples proved to have skewed and bimodal, as well as normal, distributions so that a nonparametric method was needed for comparisons. Specifically, the Wilcoxon rank-sum test was used to determine homogeneity of population, applied at the 95% confidence level.

As an example, the P1 data from the tilt site was compared to the P1 data from the control site, using the Wilcoxon test. There is a .3 dB difference between the medians from the two sets of observations (samples), but this difference is not statistically significant because the two samples tested as being from the same population at the 95% confidence level. No confidence limits were developed for any of the medians. The samples were large and their ranges rather narrow, so that these limits would also be narrow and contribute no useful information. Tables VII and VIII, pages 38 and 39 show the medians and differences for each test-control site microphone combination.

Absorbing Barrier: Data analysis for this test-control site combination comprised three distinct parts. The first was the comparison of the samples from the two reference microphones, set at 2 feet above the tops of the barriers. Table VII, page 38 shows that the median level at the absorbing barrier microphone is .3 dB less than that from the control site barrier. The two samples were tested to see if they were from the same population; i. e., to see if the .3 dB difference had any statistical significance.

Second, the 1.4 dB difference between the corresponding field microphones (Table VII) was examined to determine its effect on farside noise. See Appendix XI, page 95 for details.

Third, because one of the major selling points of the absorbing barrier had been the results of ASTM C-423-66, which is designed to determine absorption at discrete frequencies under laboratory conditions, the absorption at those frequencies under field conditions was examined. This of course was not considered the field equivalent of the laboratory test, since that test depends on reaching a steady-state level and measuring decay time. However, it was felt that the results would indicate whether or not the laboratory test was a valid test to apply to traffic noise barrier panels. More generally, it was also felt that this would show whether or not the absorption at discrete frequencies was a valid test to apply with regard to barrier performance throughout the traffic noise spectrum and to the reduction of the overall level of both nearside and farside noise.

TABLE VII

ABSORBING BARRIER AND CONTROL SITE

MEDIAN Leqs FOR ALL MICROPHONE POSITIONS - PHASE II

CONTROL SITE(STD. BARRIER)		TEST SITE(ABS. BARRIER)		DIFFERENCE
PRC	79.7	PRA	79.4	0.3
P2C	82.9	P2A	81.5	1.4
P1C	83.2	P1A	81.8	1.4

PRC, PRA: Reference microphones set at 23 ft. above pavement, 2 ft. above top of barrier.

P2C, P2A: Microphones set at 17 ft. above roadway, less than 6 inches from barrier face.

P1C, P1A: Microphones set at 8 ft. above roadway, less than 6 inches from barrier face.

TABLE VIII

TILT BARRIER AND CONTROL SITE

MEDIAN Leqs FOR ALL MICROPHONE POSITIONS - PHASE II

TEST SITE(TILT BARRIER)		CONTROL SITE(STD. BARRIER)		DIFFERENCE
PRT	79.1	PRC	77.0	2.1
P1T	63.9	P1C	64.2	-0.3
P2T	62.6	P2C	63.2	-0.6

PRT, PRC: Reference microphones set 5 ft. higher than the top of the barrier and directly over the barrier top.

P1T, P1C: Field microphones set 25 ft. behind barrier and 4 ft. lower than barrier top.

P2T, P1C: Field microphones set 50 ft. behind barrier and 4 ft. lower than barrier top.

The measured levels (from the data reduction process) at both the test and control sites for 250, 500, 1000, and 4000 Hz are shown in Table IX, page 42. In determining the absorption at these frequencies it was assumed that the standard barrier was fully reflective. Therefore the input median levels at P1 and P2 (see Figure 4, page 16) at the standard barrier were 3 dB less than the median levels recorded for these microphones. Since the barriers at both sites were identical except for the surface treatment and the traffic was the same at both, the input at the absorbing barrier was assumed to be the same as at the standard barrier. Using the (assumed) known input and the recorded median levels at P1 and P2 for the absorbing barrier, it was possible to calculate the absorption at each frequency.

Tilt Barrier: The median level at the tilt barrier reference microphone is 2.1 dB higher than the corresponding level at the control site, but the levels at P1 and P2 are .3 dB and .6 dB lower respectively than the corresponding levels at the control site. (See Table VIII, page 39.) One part of the data analysis for the tilt barrier was to determine whether or not these differences were statistically significant; i.e., are corresponding samples from the same population. This was accomplished using the Wilcoxon rank-sum test.

A second part of the data analysis for this barrier was concerned with why higher levels occurred at the tilt barrier reference microphone. For a portion of this analysis STAMINA 2.0 was used to predict levels for all microphones at both the control and test sites using the average speeds from our radar readings, and also for 65 mph at the test site only. This increased speed was based on field experience which has clearly indicated that average speed at "constant-on" radar sites is substantially less than at locales not having this radar. The particular speed - 65 mph - was selected on the basis of extensive driving experience in the immediate area of the sites.

A third part of the analysis used the reference microphone data obtained in Phase I and Phase II, relating the findings and using both the measured and predicted data from Phase II to explain the higher levels at the test site reference microphone.

TABLE IX

ABSORBING BARRIER AND CONTROL SITE

MEDIAN LEVELS FROM FIELD DATA IN dB LINEAR

FOR SELECTED CENTER FREQUENCIES

FREQUENCY IN HZ	P1C	P1A
250	91.3	90.4
500	90.7	87.1
1000	91.1	90.1
4000	81.9	81.2
FREQUENCY IN HZ	P2C	P2A
250	91.3	89.6
500	91.4	87.0
1000	91.7	91.1
4000	82.1	80.5

P1C, P1A: Microphones set at 8 ft. above roadway, less than 6 inches from barrier face.

P2C, P2A: Microphones set at 17 ft. above roadway, less than 6 inches from barrier face.

RESULTS AND DISCUSSION

Phase I

Absorbing Barrier: From Tables III and IV, pages 32 and 33 it is clear that 12 of the 16 averages from the absorbing barrier data are greater than or equal to the corresponding averages from the control site data. In 8 instances the average levels are 1.0 - 4.2 dB higher. This is not reasonable in that experience indicates 1) that the porous surface of the absorbing barrier cannot be more reflective than the hard closed surface of the standard barrier, and 2) that for practical purposes the hard surface of the control site barrier was fully reflecting. Since the absorbing barrier cannot reflect more than the control site barrier, some other factor(s) must have caused the levels at the test site to be higher.

In examining the test and control sites (Figures 2 and 3, pages 12 and 13) it is obvious that there is considerable difference in the topography of the two. The control site is open and flat across a distance of approximately 155 feet, from the barrier to the cut on the opposite side. By contrast, the test site is in a narrow "valley", which is 100 feet wide at the absorbing barrier top and about 60 feet wide at the base. It is possible, but not demonstrable from the available data, that the steady-state noise not only prevented any decay but in addition provided for continuous reflections from both the pavement (which covered most of the valley floor) and the barrier, to whatever degree it was reflective. These reflections may have contributed to some degree to the higher levels found at the test site.

Since the control site barrier was fully reflecting, the average levels there include an increase of up to 3 dB due to this reflection. Using the level from the source at the control site for F2 at the 17-foot source distance as an example, we see that the input would have been 77.8 dB. Subtracting this from 82.7 dB (the corresponding level at the test site) we have 4.9 dB, which is more than can be attributed to the effect of reflection from any single surface. Since the reflecting surfaces are the horizontal berm-roadway combination, and the vertical barrier, we will assume a best case for the absorbing barrier by allowing 3.0 dB reflection from horizontal sources, and only 1.9 dB from the barrier. This is 1.1 dB less than if the barrier had been fully reflecting, a reduction of 22 %. This is a simplistic hypothesized and unprovable best case, for this source - microphone combination.

It is clear that the best case for the absorbing barrier (excluding the anomalous average at F1 - 30 ft.) is at F1 - 17 ft. The input level at the control site is 82.1 dB after subtracting the 3 dB reflected from the barrier, and the input at the test site is also 82.1 dB after subtracting the assumed 3 dB reflection from the roadway. We have assumed that the barrier reflected nothing - that it was 100% absorptive - which is certainly a best case for the barrier. However, even if our assumptions are correct and the barrier does not reflect, we are unable to demonstrate in the context of this study that it offers any real advantage over the standard barrier if we consider the following facts.

1. The levels at F2, which is 15 feet above the roadway at both sites, are always higher at the test site than at the control site by 1.0 - 4.2 dB.
2. The levels at R2 at the test site are higher in 3 out of 4 instances than those at the control site by 1.4 - 3.5 dB. In the one instance where the test site level is lower, it is only .5 dB lower.

Even though we have ignored the fact that the roadway at the control site is just as reflective as the one at the test site, it is not possible to make a case for the absorbing barrier. Furthermore, the data indicates that it does not perform as well as a standard barrier. As cited above, the levels at F2 and R2, which are 1 foot below the barrier tops at both sites, are generally higher at the test site. Essentially this means that more noise would reach both nearside and farside barrier tops when the absorbing barrier is used. At the time Phase 1 was completed we could offer no explanation as to why this should occur, other than the one that site configuration could have contributed (but was not the only cause of) to this unexpected result. Since there was no apparent advantage to this barrier, we recommended against its use on future projects. However, when the findings were reported to BEA, it was emphasized that the noise source was a point source with a spectrum somewhat different from that found in automobile and truck noise. We therefore agreed with BEA that it would be useful to conduct a second phase of the study using traffic noise as the source, since the roadway had been opened to traffic by that time.

<u>Tilt barrier</u>: Tables V and VI, pages 34 and 35, show that in

general the standard barrier reflected more noise back toward the center of the roadway than the tilt barrier did, since the reference microphones (always 75 feet from the barrier) at the control site have higher average levels than those at the test site. This is also true for the field microphones at the farthest point from the barrier (source at 60 feet; microphones at 45 feet). It is therefore reasonable to conclude that for these source-microphone positions the tilt barrier reflects more sound upward that the standard vertical barrier does. This becomes certain as the source and the field microphones approach the barrier, because the field microphone levels at the tilt barrier become substantially higher than those at the standard barrier. Thus there is no question that the tilt barrier does reflect more sound into the air non-horizontally than the vertical barrier does.

Even though the tilt barrier performs as designed, the analysis of the data obtained from this test resulted in an unanswered question pertaining to the effectiveness of the barrier. With the source at the 17-foot position, F1 was less than one foot from the barrier at 10 feet above the pavement and F2 was at 23 feet above the pavement, 7 feet higher than the barrier top and approximately over it. In examining the average of the levels between F1 and F2, we see that it is 83.2 dB at the test site and 79.9 dB at the control site. Assuming that this average would occur about halfway between F1 and F2, which is at the top of the barrier in each case, we conclude that the level at this top of the tilt barrier is 3.3 dB higher than at the top of the standard barrier.

While it might have been argued that this higher level was inconsequential since the direction of the sound is upward at the barrier top, there was no way to ascertain this on the basis of Phase I of this study. The major concern was whether or not this higher level resulted in higher levels for the receivers, even though the tilt barrier performed as expected and reflected more sound into the air than the standard barrier did. Therefore, in discussing the results with BEA we stated we believed the study to be inconclusive and that a second phase should be undertaken to determine the effect on receiver locations.

<u>Phase II</u>

<u>Absorbing Barrier</u>: From Table VII, page 38 we see that there is only a .3 dB difference between the median levels at the tops of the absorbing and control site barriers. This certainly cannot be considered as demonstrating any advantage of the absorbing barrier over the standard barrier. Furthermore, from an inspection of the ranges of Leqs for each reference microphone (77.3 - 81.4 for the absorbing barrier; 77.1 - 81.7 for the standard barrier), from the histograms of these samples (not included in this report), and from applying the Wilcoxon rank-sum test, it is clear that there is not even a statistical difference between the two samples. Thus, given the same barrier placement, height, configuration, and noise input - the absorbing barrier offers no more protection than a reflecting barrier for nearside receivers.

From the analysis detailed in Appendix XI, pages 95-97 it can again be concluded that the absorbing barrier provides no advantage. While a 10 dB attenuation over a 75-foot distance is used in order to the simplify calculations in Appendix XI, most sections of state, U. S., and interstate highways in New Jersey are much wider. Certainly this is true of those sections of I-78 where the absorbing barriers were used and especially true at the location used for Phase II of the study, where the roadway was over 250 feet wide. Therefore the attenuation of the nearside level would be much greater than the 10 dB used in the calculations, so that even fully-reflected noise would be attenuated to the point were it would add almost nothing to the farside level. Thus there is no advantage to using an absorbing barrier to reduce farside noise at locations having roadways of "normal" width.

The last conclusion regarding the absorbing barrier pertains to the laboratory and field testing done to determine absorption at 250, 500, 1000, and 4000 Hz. The results from field data are shown in Table X, page 50. We again state that there is no attempt to present the field data analysis as the "field equivalent" of ASTM C-423-66, since it is impossible to duplicate the laboratory conditions in the field. Furthermore, the thickness of the absorptive material actually used was 2 5/8", rather than the 2" or 3" material cited in the ASTM test results. As far as we know, the manufacturer did not supply NJDOT with test results for this material, and the material appears to be different from that used for the laboratory test. In the absence of any other information, the test results for the 2" and 3" material are included and shown in Table X, page 50.

In determining the field absorption it was assumed (as stated in Appendix XI, page 95) that the control site barrier was fully reflecting and we subtracted 3 dB from the P1 and P2 median levels shown in Table VII, page 38 for this barrier. This yielded the (assumed) input level at each microphone directly from traffic noise, without any increase due to reflection from the barrier. Since these input levels at the control site are lower than the levels at the test site, there must have been some reflection from the absorbing barrier. The difference between the assumed median input level and the median level at the absorbing barrier for each microphone pair was used to calculate the levels that were reflected to each microphone at the absorbing barrier site. From this we calculated the percentage of absorption for each of the four center frequencies.

TABLE X

ABSORPTION LOSSES FROM FIELD DATA FOR SPECIFIC FREQUENCIES

FREQUENCY IN HZ	ABSORPTION LOSS P1A	ABSORPTION LOSS P2A
250	.37	.65
500	1.0 (assumed)	1.0 (assumed)
1000	.41	.29
4000	.28	.61

Results are rounded to the nearest .01.

See Page of text for explanation of 500 Hz entry.

TABLE XI

SOUND ABSORPTION COEFFICIENTS VS. FREQUENCY FOR SOUND-LOK

FREQUENCY IN HZ	2" THICKNESS	3" THICKNESS
250	.28	.58
500	.68	1.00
1000	.90	.79
4000	.65	.83

Data obtained in accordance with ASTM C-423-66.

Reprinted from Smith-Midland brochure for Sound-Lok.

In examining Table X it is obvious that the levels at 500 Hz for both P1A and P2A are anomalous. When 3 dB is subtracted from the levels at the control site for these two cases to obtain the (assumed) input level due to traffic noise minus reflection, the lower level at the corresponding absorbing barrier microphone is lower than the assumed input level. Various explanations for this phenomenon have been considered, and the test site was reexamined for physical characteristics which might act to block the path of this particular frequency. The only explanation we can offer is that some undetected characteristic of the site either partially blocks this frequency, or that reflections are partially cancelling this frequency, or both.

This anomaly aside, the fact that both the laboratory and the field tests to verify absorption show that the materials do in fact absorb (and to what degree) does not in any way guarantee that the barrier will be more effective than a standard (reflecting) barrier in reducing either farside or nearside noise.

In summary, we have found that 1) the absorbing barrier does not provide a usefully greater insertion loss than a standard barrier of the same height, placement, length, and configuration - given the same initial noise level; 2) the absorbing barrier does in fact absorb traffic noise, but that because of the distances between barriers at the test sites and for the vast majority of cases for which barriers are constructed, the absorbency does not act to effectively reduce noise at nearside or farside receiver locations; 3) neither laboratory nor field tests to indicate absorbency have any validity in determining the usefulness of a barrier in situ.

Considering the results of this phase and of Phase I of this study, we recommend against using absorbing barriers on future noise abatement projects where the barriers would be placed more that 75 feet apart.

Tilt Barrier: The .3 dB difference between P1 test and control median levels and the .6 dB difference between P2 test and control median levels shown in Table VIII, page 39 are not statistically significant. The corresponding data sets are from the same populations in each case. However, the 2.1 dB difference between the test and control median levels at the reference microphones is statistically significant, indicating that the samples are from different populations. One of the following cases correctly describes why these conditions occurred.

1. The traffic noise levels reaching the reference microphone at the tilt barrier are higher than those at the control site. Therefore the tilt barrier provides a greater insertion loss than the standard barrier, since the levels at the receiver microphones (P1 and P2) are (statistically) the same for both sites.
2. The traffic noise levels reaching the reference microphone at the tilt barrier are lower than those at the control site. Therefore the higher levels at the reference microphone must be due to some characteristic of the barrier, and not due to traffic. Since the input levels are (assumed to be) lower, the levels at the receiver microphones should also be lower, if the barrier

were not causing an increase in level over and above the input level. However, the receiver microphone levels are (statiscally) the same as those at the control site. Therefore the barrier is not only causing an increase at the reference microphone, but at the receiver microphones as well and is providing a "negative insertion loss."

3. The traffic noise level reaching the reference microphone at the tilt barrier is the <u>same</u> as that at the control site. As before, the increased reference level is therefore due to some characteristic of the barrier. Since the input level at the reference microphone is (assumed to be) the same for both barriers, the levels at the receiver microphones should be the same for both barriers, unless the barrier characteristic which caused the increased reference level also affects the receiver levels. This is not the case; the receiver levels are (statistically) the same for both barriers. Based on the assumption of equal traffic noise levels at both barriers, we conclude that the tilt barrier does not provide greater insertion loss than the standard barrier.

In order for the traffic noise levels to be significantly higher or lower at the test site the traffic composition and/or speed would have had to change substantially during the 45 seconds it took to go from the control site to the test site. Furthermore, this would have had to occur for 20 or more consecutive 2-minute observations, on three separate days over a period of four weeks. Although it is unlikely that traffic <u>composition</u> changed under these conditions, the effect of increased speed was considered, as discussed below.

In investigating the reason for the higher median levels at the tilt barrier reference microphones, we used STAMINA 2.0 to predict levels for all microphones at both sites for the average speeds determined from the radar readings, and for the assumed speed of 65 mph at the test site. (See discussion on page 57.) We hoped to obtain sets of data which preserved the relationships between the median levels at the various microphones, even if the absolute predicted levels were different from those measured. This would at least partially support the view that the higher level at the tilt barrier reference microphone was "horizontal" in direction; i.e., it was directly from traffic, just as it would be for a vertical barrier. This, in turn, would indicate that the tilt barrier was providing greater insertion loss. However, this effort was not successful, as explained below.

Referring to Table XII, page 56, we note the following:

1. When the average speeds from the field measurements were used in the predictions, the levels for corresponding microphones at each site were in close agreement. They were in fact from the same population, including the reference levels, which is not what was found from field measurements. Thus STAMINA 2.0 predicted the relative difference for the field microphones correctly, but did not predict the relative difference for the reference microphones correctly. It also did not predict absolute levels correctly for any of the microphones at either site.

2. When the 65 mph speed was used to predict levels at the tilt barrier site, the <u>reference</u> levels were in close agreement with those from field measurements; they were from the same population. However, the field microphone levels were even higher than they were in the first case, and they were no longer from the same population as the corresponding predicted levels from the control site. Thus using the 65 mph speed gave the correct absolute levels for the tilt barrier reference microphone, but the relative difference between the tilt and control site reference microphones was not preserved, nor were the relative differences between the corresponding tilt and control site field microphones.

TABLE XII

AVERAGE LEVELS FOR SMALL SAMPLES

MEASURED AND PREDICTED DATA

	TILT SITE		
	M	P	P65
REF	79.3	78.1	79.2
P1	63.9	67.4	68.4
P2	63.3	67.0	68.0

	CONTROL SITE	
	M	P
REF	76.9	78.1
P1	64.0	67.6
P2	62.6	67.0

M: Averaged from measured data.

P: Averaged from predicted data using average speeds as determined by radar at the control site.

P65: Averaged from predicted data using 65 mph as the speed of all vehicles.

A further argument against using the 65 mph speed to explain the higher level at the tilt barrier reference is that the site was at the lowest point of the roadway for at least 1500 feet in either direction. Therefore both nearside and farside traffic would be relatively quiet when approaching and for a few hundred feet after leaving the site. This would tend to negate to some (unknown) extent any increase in noise level due to the higher speed. Furthermore, the control site was approximately 200 feet downstream of the highest point of the roadway. Thus upstream and downstream traffic travelling upgrade would tend to raise the level to some (unknown) extent at this site, even though the speed was (assumed) lower than at the test site.

There was also thorough investigation of the effects of the slight differences in sites using STAMINA 2.0. By changing barrier heights and locations in 1-foot increments and increasing or decreasing roadway widths to correspond to those at the other site, it was possible to find slight changes for the predicted levels at each barrier. These changes were independent of the accuracy of both the absolute and relative measured levels for the two sites. It was therefore hypothesized that if some combination of changes at one of the sites resulted in a change on the order of 2 dB at the reference microphone, the differences in levels could be explained as being the result of differences in the two sites. However, these changes were .5 dB or less, which certainly did not provide the desired explanation.

Since these investigations did not identify the cause(s) of the higher levels at the test site reference microphone, it seems reasonable to explain them on the basis of the findings from

Phase I of this study. Specifically, the average levels at the tilt barrier reference microphone were about 3 dB higher than those at the control site reference microphone, when the (point) noise source was in the nearside slow lane. This was apparently the result of more sound being reflected vertically because of the tilt of the barrier. Our traffic counts for Phase II show from 10% - 33% heavy trucks on the nearside roadway. All of these were necessarily in the slow and middle lanes, and it is likely that at least a third of them were in the slow lane at both sites. This would account for the higher overall reference level at the tilt barrier site, since there was a greater vertical reflection than at the control site.

To support this explanation of the higher reference level at the tilt site, we refer to the data in Table XII, page 56. At the control site the differences between the median measured reference level and the median measured P1 level is 12.9 dB, and for the predicted levels it is 10.5 dB. Therefore the model predicts an insertion loss which is lower than measured by 2.4 dB. At the tilt barrier the corresponding measured difference is 15.4 dB and the predicted difference is 10.8 dB, using 65 mph as the speed. Since the model predicts for a vertical rather than a tilt barrier, we are justified in using the 2.4 dB from the control site to add to the 10.8 dB at the tilt site, to obtain 13.2 dB. This is the theoretical difference between the the reference and P1 levels at the tilt site, which is 2.2 dB higher than if it were a vertical barrier. Considering that this figure results from computation using small samples (to avoid the tedious and time-consuming work of predicting for 58 - 73 observations) it is acceptably close to the 2.1 dB difference listed in Table VIII, page 39 which is the result of using full samples.

From our attempts to determine the reason for the higher level at the tilt barrier reference microphone which occurred in both phases of this study, we conclude that it is not an artifact of the data collection process or the result of higher traffic noise levels due to a change in speed and/or traffic mix. Rather we believe it to be the result of the tilt barrier reflecting part of the noise from slow lane sources vertically upward. There is no evidence that this higher level at the barrier top results in higher levels at receiver locations, and therefore people on the receiver side of the barrier would not be subjected to higher levels than they would at corresponding locations behind a vertical barrier. However, this cannot be interpreted as an indication that the tilt barrier offers greater protection, since the direction of the sound is vertically upward rather than "horizontal", as it would be with a vertical barrier.

There is statistically no difference between the median measured levels at the <u>field</u> microphones behind either barrier, and the slightly lower median levels at the tilt barrier field microphones (.3 dB, .6 dB) would not be discernible to people at those locations. Thus the tilt barrier, although more expensive than the standard vertical barrier, offers no advantage and it is therefore recommended that it not be used future noise abatement projects.

IMPLEMENTATION

As the data analysis was completed for each section of each phase of the project, the information was summarized in a memorandum to BEA, the client unit. These summaries included recommendations against using either of the barriers in future noise abatement projects. Both the findings and the recommendations were discussed fully at subsequent meetings, and in the case of Phase I these discussions led to the initiating of Phase II.

Although Phase I and Phase II data collection used different noise sources and different sites, the Phase II results also indicated that neither the tilt nor the absorbing barriers offered a useful increase in insertion loss over that produced by a standard barrier. Consequently BEA has accepted the findings and has ceased to recommend the use of either of these barriers.

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APPENDIX I

DATA COLLECTION ROUTINE - PHASE I

Data collection proceeded as described below. At each site the initial setup was: 1) The reference microphones were placed at 75 feet from the barrier face. They remained at this distance throughout the data collection at all sites; 2) The noise source was placed at 60 feet from the barrier face; 3) The field microphones were placed at 45 feet from the barrier face. Microphone height was set as appropriate for the particular site, heights at the control site duplicating those at the test site for each barrier. Refer to Figures 1, 2, and 3, pages 11-13.

Data collection proceeded as follows:

1. A voice announcement was made at the beginning of each tape on each channel. This announcement included the tape number, date, location, type of barrier, etc.
2. Microphones R1, R2, F1, and F2 were calibrated and the calibration signal recorded on the tape immediately after each voice announcement. All channels were then played back to insure that the announcement and calibration signal had been properly recorded.
3. The monitor microphone was calibrated and the 2218 B & K sound level meter set to record for 2 minutes.
4. The generator was started and recording on all four channels and the 2218 SLM was started simultaneously.
5. Every two minutes the Leq from the SLM was read and recorded. The meter was then reset for another two

minutes, at the end of which the Leq was read and recorded again. This continued for the duration of the tapes, which ran continuously until 22 2-minute Leqs had been obtained. Wind speed was monitored during the taping, especially when it appeared to be near 10 mph. Also, the occurrence of extraneous noises was noted on the field sheets, indicating the time, type, and duration in each case.

6. A second voice announcement was made to indicate the end of each tape on each channel, followed by a second calibration signal. The monitor microphone was also calibrated.
7. The generator was stopped.
8. New tapes and the 2218 SLM were set up as in Steps 1 and 2.
9. The generator was moved 15 feet closer to the barrier, as were the field microphones, the 15-foot separation between the two being maintained. The reference microphones remained at 75 feet from the barrier.
10. The generator was refueled and started.
11. Recording proceeded as described in Steps 4, 5, and 6.

Four sets of recordings were made at each site, one each for the generator at 60, 45, 30, and 17 feet from the barrier, with the field microphones being placed correspondingly at 45, 30, 15, and 2 feet from the barrier. The configuration of the microphone support gear and the berm adjacent to the barrier in each case prevented our placing the microphone closer to the barrier in the final step.

APPENDIX II

DATA COLLECTION ROUTINE - PHASE II

Absorbing Barrier Test and Control Sites

The microphone setup for these sites is shown in Figure 4, page 16, and descriptions of the sites are in the section DATA COLLECTION - Phase II. All recording equipment was housed in a van, which was parked on the right shoulder of the westbound outer roadway, about halfway between the two microphone masts (see Figure 7, page 65). There was one equipment operator for each set of microphones, and two traffic counters, one for each set of roadways. The traffic counters were also in the equipment van to eliminate the need for radio communication between the van and another vehicle.

The two reference microphones were each connected to a Nagra SJ IV tape recorder, via a 2204 or 2209 B & K sound level meter. The P1 microphones were connected to 2231 sound level meters and the P2 microphones to 2218 meters, both being connected to Sony TC-D5 PRO II cassette recorders.

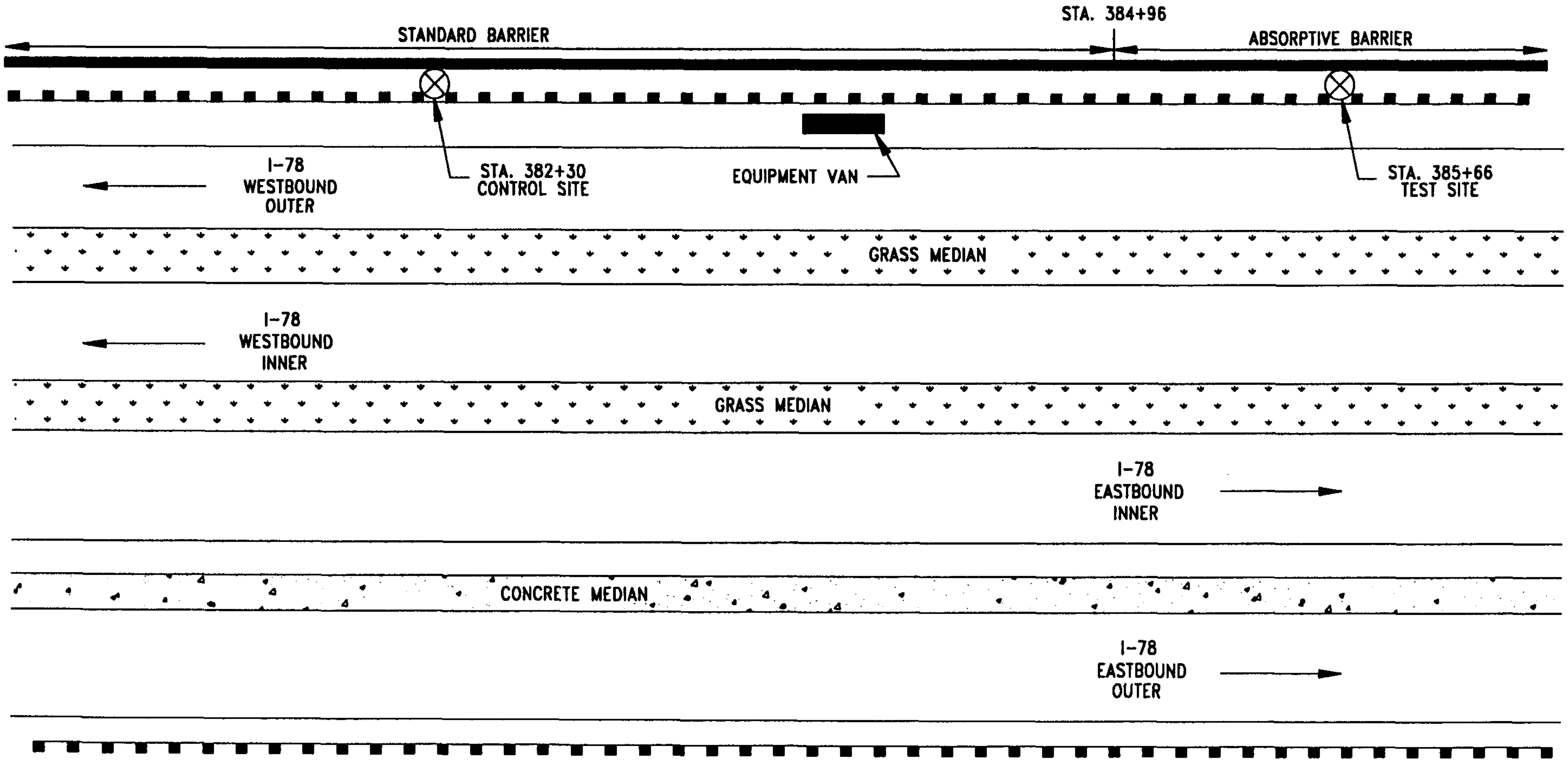
Data collection proceeded as described below.

1. A voice announcement was made at the beginning of each tape giving the tape number, date, location, type of barrier, etc.
2. All microphones were calibrated using a 4220 B & K pistonphone, and the signal recorded on the tapes. The tapes were then played back to insure that the voice announcements and the calibration signals had been

FIGURE 7

ABSORPTIVE BARRIER

TEST AND CONTROL SITES – PHASE II



NOT TO SCALE

properly recorded. A voice announcement indicating the start of data recording was then made on each tape.

3. The sound level meters connected to the P1 and P2 microphones were set to record for two minutes.
4. Wind speed and direction and temperature were recorded on the field sheets, along with all meter settings, tape numbers, date, time, etc.
5. The operator of the upstream equipment (absorbing barrier) verbally indicated the start of recording, at which time the counters began to record traffic counts and radar speed observations.
6. The operator of the downstream equipment started to record 3 seconds later, to compensate for the distance between microphone masts.
7. At the end of two minutes the upstream operator gave a "stop counting" signal to the traffic counters and simultaneously stopped recording. The downstream operator stopped recording 3 seconds later.
8. All direct readouts and traffic counts were recorded on the field sheets, and the tapes advanced through 5 seconds of no input to provide a break between observations.
9. Steps 5 - 8 were repeated until 21 2-minute observations had been recorded.
10. At the end of the tapes all microphones were again calibrated. The equipment was then readied for another series of observations and Steps 1 - 9 repeated.

At various times during the 2-minute observations one of the equipment operators took wind and temperature readings, which were recorded on the field data sheets. Also, the occurrence of non-highway noise was noted as to time and source (e. g., planes, vehicles stopping and starting).

Tilt Barrier Test and Control Sites

The microphone setup for these sites is shown in Figure 5 and 6, pages 17 and 18, and descriptions of the sites are in the section DATA COLLECTION - Phase II. Since the two sites were 4300 feet apart, the equipment was housed in two vans - one at each site. (See Figure 8, page 69.) The traffic counters were stationed in the upstream van, at the control (standard barrier) site. Operations for both sites were controlled from this van.

The reference microphone at each site was connected to a Sony TC-D5 PRO II cassette recorder via a 2204 or 2209 B & K sound level meter. The P1 and P2 microphones were connected to 2218 and 2231 meters and were read directly.

Data collection was essentially the same as for the absorbing barrier sites, with the exceptions listed below.

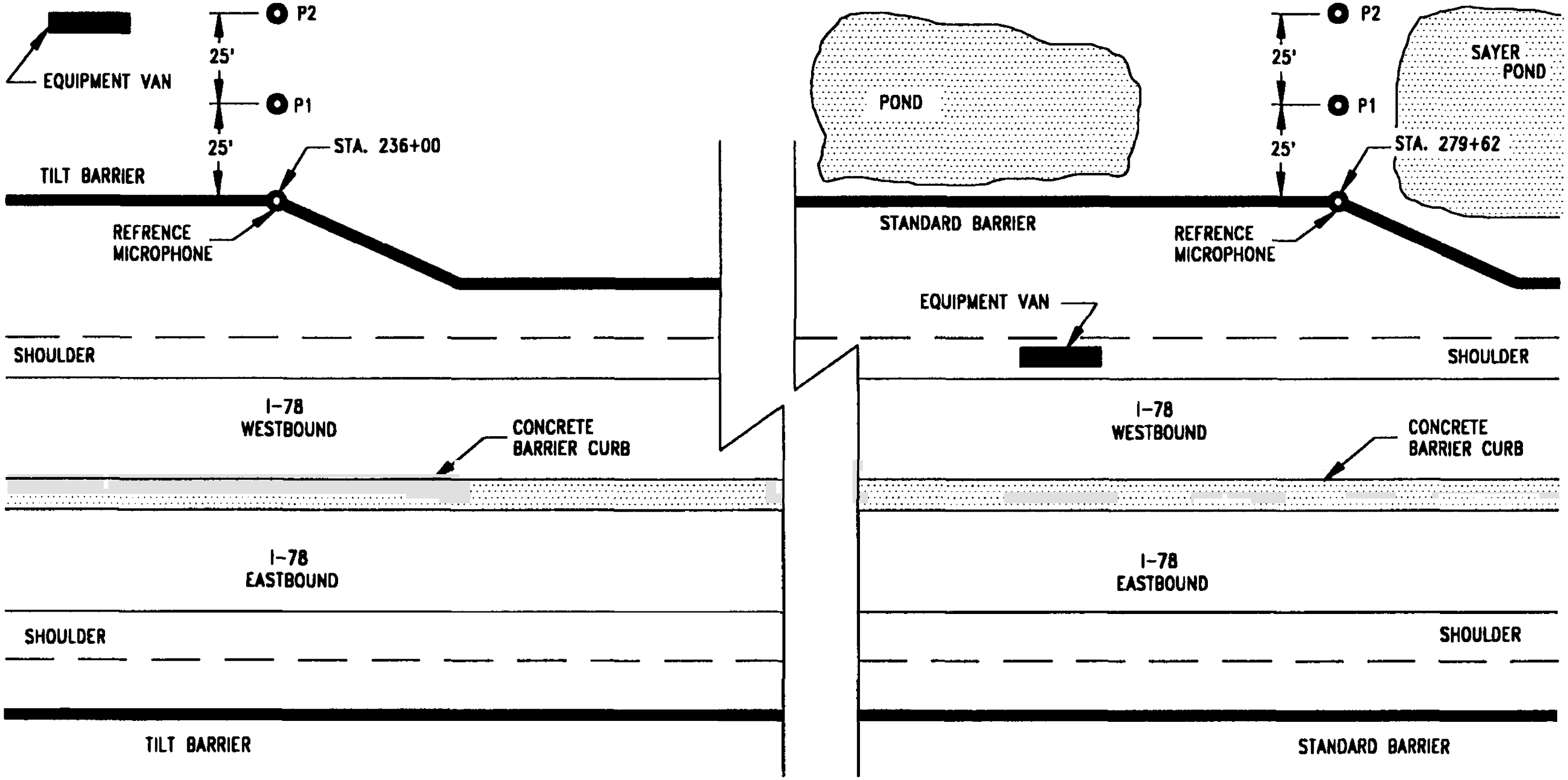
1. The meters for the P1 and P2 microphones were set to record for two minutes, at the end of which the operators obtained a direct readouts of the Leqs.
2. The operator of the downstream equipment (at the tilt barrier) started to record 45 seconds after the start of the upstream recording.

3. The operator of the downstream equipment stopped recording 45 seconds after the upstream recording was stopped.

FIGURE 8

TILT BARRIER

TEST AND CONTROL SITES – PHASE II



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NOTES ON APPENDICES III - VI

The entries in Appendices III - VI are raw data, not corrected for a uniform noise source of 100 dB. This correction process is discussed on pages 29 and 30 of the text. All entries are 2-minute Leqs.

The abbreviations used in these appendices are as follows:

S: Level at source monitor microphone. See Figures 1, 2, and 3, pages 11, 12 and 13, and text, page 20.

R1: Level at lower reference microphone, placed 75 feet from barrier, height being specific to particular site. See figures and text cited above.

R2: Level at the upper reference microphone. See remarks for R1.

F1: Level at lower field microphone, placed 15 feet from source between barrier and source. See figures and text cited above.

F2: Level at upper field microphone. See remarks for F1.

APPENDIX III

ABSORBING BARRIER TEST SITE LEQS

SOURCE 60 FEET FROM BARRIER

OBS	DATE	S	R1	R2	F1	F2
1	7/22/86	99.3	82.3	81.1	85.7	82.6
2	7/22/86	99.3	82.7	80.6	85.6	82.4
3	7/22/86	99.4	83.0	80.6	85.4	82.6
4	7/22/86	99.4	83.0	80.6	85.4	82.4
5	7/22/86	99.9	82.9	80.7	85.0	82.0
6	7/22/86	100.0	82.9	80.6	84.5	82.1
7	7/22/86	100.0	83.0	80.6	84.6	82.1
8	7/22/86	99.9	83.0	80.5	84.6	82.1
9	7/22/86	100.0	83.0	80.5	84.5	81.9
10	7/22/86	99.9	83.0	80.6	84.6	82.1
11	7/22/86	99.9	83.0	80.6	84.5	81.9
12	7/22/86	100.0	83.0	80.5	84.5	81.9
13	7/22/86	100.0	83.0	80.4	84.4	81.9
14	7/22/86	99.9	82.9	80.4	84.3	82.0
15	7/22/86	99.9	82.9	80.5	84.6	82.1
16	7/22/86	99.9	82.9	80.5	84.5	81.9
17	7/22/86	99.9	82.7	80.5	84.4	81.9
18	7/22/86	99.9	82.8	80.6	84.2	81.8
19	7/22/86	99.9	83.0	80.6	84.2	81.9
20	7/22/86	99.8	82.9	80.4	84.3	81.9
21	7/22/86	99.6	82.7	.	.	82.5
22	7/22/86	99.9	82.8	.	.	.
23	7/22/86	.	82.9	.	.	.
24	7/22/86	.	83.0	.	.	.
25	7/22/86	.	82.9	.	.	.

APPENDIX III

ABSORBING BARRIER TEST SITE LEQS

SOURCE 45 FEET FROM BARRIER

OBS	DATE	S	R1	R2	F1	F2
1	7/22/86	99.8	79.1	77.7	84.8	83.7
2	7/22/86	100.3	78.8	77.5	85.1	83.8
3	7/22/86	100.5	78.8	77.2	85.3	83.9
4	7/22/86	100.3	78.9	77.1	85.2	83.8
5	7/22/86	100.4	78.9	77.6	85.3	83.5
6	7/22/86	100.3	78.8	77.2	85.4	83.6
7	7/22/86	100.2	78.9	76.8	85.2	83.7
8	7/22/86	100.2	78.8	76.8	85.3	83.2
9	7/22/86	100.2	78.8	76.8	85.6	83.0
10	7/22/86	100.2	78.7	76.9	85.7	83.2
11	7/22/86	100.0	78.7	76.9	85.5	83.4
12	7/22/86	100.1	78.8	76.8	85.4	83.4
13	7/22/86	100.3	78.8	76.7	85.1	83.0
14	7/22/86	100.3	78.8	76.6	85.4	82.7
15	7/22/86	100.2	78.9	76.7	85.1	82.8
16	7/22/86	100.2	78.6	76.6	84.9	82.6
17	7/22/86	100.1	78.5	76.6	84.9	82.6
18	7/22/86	100.1	78.4	76.5	84.8	82.6
19	7/22/86	99.9	78.3	76.6	84.9	82.5
20	7/22/86	100.0	78.4	76.7	84.9	82.6
21	7/22/86	100.0	78.9	76.6	85.2	82.7
22	7/22/86	100.3	.	77.1	.	83.1
23	7/22/86	100.2	.	.	.	.

APPENDIX III

ABSORBING BARRIER TEST SITE LEQS

SOURCE 30 FEET FROM BARRIER

OBS	DATE	S	R1	R2	F1	F2
1	7/23/86	102.7	75.4	74.5	82.9	86.7
2	7/23/86	102.5	75.4	74.1	82.9	86.6
3	7/23/86	102.7	75.1	74.5	83.2	86.7
4	7/23/86	102.8	74.9	74.4	83.1	86.6
5	7/23/86	103.0	74.9	74.3	83.1	86.4
6	7/23/86	102.6	75.0	74.0	83.2	86.7
7	7/23/86	103.1	75.2	74.0	83.3	86.8
8	7/23/86	103.0	75.4	74.1	83.3	86.7
9	7/23/86	103.0	75.9	74.6	83.2	86.7
10	7/23/86	103.2	75.5	74.3	83.0	86.4
11	7/23/86	103.1	75.6	74.3	83.0	86.5
12	7/23/86	103.1	75.5	74.2	83.1	86.6
13	7/23/86	103.5	75.7	74.2	83.1	86.6
14	7/23/86	103.3	75.8	74.3	83.1	86.5
15	7/23/86	103.2	76.1	74.4	83.1	86.4
16	7/23/86	103.0	76.2	74.4	83.2	86.7
17	7/23/86	103.0	75.9	74.3	83.2	86.7
18	7/23/86	102.7	.	74.1	.	86.6
19	7/23/86	103.3	.	74.3	.	86.6
20	7/23/86	102.8	.	74.4	.	86.7
21	7/23/86	.	.	74.5	.	86.7
22	7/23/86	.	.	.	.	86.4

APPENDIX III

ABSORBING BARRIER TEST SITE LEQS

SOURCE 17 FEET FROM BARRIER

OBS	DATE	S	R1	R2	F1	F2
1	7/23/86	100.1	71.6	71.6	85.2	81.8
2	7/23/86	100.3	71.7	72.4	85.2	82.3
3	7/23/86	100.2	71.8	72.4	85.3	82.2
4	7/23/86	100.3	72.1	72.5	85.5	82.4
5	7/23/86	100.7	72.2	72.9	85.6	82.3
6	7/23/86	100.7	71.9	72.8	85.4	82.7
7	7/23/86	100.4	71.9	73.7	85.5	82.8
8	7/23/86	100.5	72.6	73.6	86.3	84.1
9	7/23/86	100.8	72.8	73.4	86.3	83.8
10	7/23/86	101.2	72.6	73.4	86.2	84.1
11	7/23/86	101.8	72.4	73.5	86.4	84.3
12	7/23/86	101.7	72.3	73.5	86.5	84.1
13	7/23/86	101.3	72.2	73.7	86.7	84.4
14	7/23/86	101.5	72.5	73.2	87.2	84.7
15	7/23/86	101.4	72.6	73.3	86.8	84.7
16	7/23/86	101.3	72.6	73.3	86.6	84.7
17	7/23/86	101.1	72.5	73.1	86.1	84.4
18	7/23/86	101.1	72.5	72.1	86.0	84.6
19	7/23/86	101.1	72.6	72.7	85.9	84.7
20	7/23/86	101.1	72.2	72.1	85.3	82.6
21	7/23/86	101.3	.	72.7	85.1	82.6
22	7/23/86	101.4	.	.	87.1	84.0

APPENDIX IV

TILT BARRIER TEST SITE LEQS

SOURCE 60 FEET FROM BARRIER

OBS	DATE	S	R1	R2	F1	F2
1	8/4/86	98.2	81.4	73.5	81.9	76.4
2	8/4/86	98.2	81.4	73.4	81.9	76.4
3	8/4/86	98.2	81.4	73.4	82.0	76.4
4	8/4/86	98.1	81.4	73.4	81.9	76.4
5	8/4/86	98.1	81.3	73.5	81.9	76.3
6	8/4/86	98.1	81.3	73.5	81.9	76.5
7	8/4/86	98.2	81.4	73.5	82.0	76.4
8	8/4/86	98.2	81.4	73.6	82.0	76.3
9	8/4/86	98.1	81.3	73.6	81.9	76.4
10	8/4/86	98.2	81.4	73.6	81.9	76.3
11	8/4/86	98.1	81.4	73.7	81.8	76.3
12	8/4/86	98.1	81.4	73.7	81.8	76.3
13	8/4/86	98.1	81.4	73.8	81.9	76.4
14	8/4/86	98.2	81.5	73.8	81.9	76.6
15	8/4/86	98.3	81.6	73.8	81.9	76.5
16	8/4/86	98.3	81.6	73.9	81.9	76.6
17	8/4/86	98.4	81.7	73.9	81.9	76.6
18	8/4/86	98.4	81.7	73.9	81.9	76.6
19	8/4/86	98.4	81.6	73.9	82.0	76.5
20	8/4/86	98.4	81.6	73.9	82.0	76.6
21	8/4/86	98.4	81.6	74.0	81.9	76.5
22	8/4/86	98.4	81.6	73.9	81.9	76.6
23	8/4/86	98.1	81.4	.	.	76.4

APPENDIX IV

TILT BARRIER TEST SITE LEQS

SOURCE 45 FEET FROM BARRIER

OBS	DATE	S	R1	R2	F1	F2
1	8/4/86	99.9	74.0	72.2	84.1	79.2
2	8/4/86	99.7	74.0	71.9	84.1	78.9
3	8/4/86	99.7	74.3	72.0	84.1	79.2
4	8/4/86	99.7	74.3	72.0	84.1	79.2
5	8/4/86	99.6	74.3	71.9	84.1	79.2
6	8/4/86	99.6	74.5	71.9	84.1	79.1
7	8/4/86	99.5	74.4	71.8	84.1	79.0
8	8/4/86	99.4	74.4	71.8	84.2	78.9
9	8/4/86	99.4	74.3	71.7	84.0	78.9
10	8/4/86	99.4	74.6	71.7	83.9	78.7
11	8/4/86	99.3	74.4	71.8	83.8	78.9
12	8/4/86	99.3	74.4	71.9	83.9	78.8
13	8/4/86	99.3	74.6	71.9	83.8	78.8
14	8/4/86	99.1	74.3	71.9	83.8	78.9
15	8/4/86	99.1	74.0	71.7	84.0	78.8
16	8/4/86	99.1	74.1	71.6	83.7	78.8
17	8/4/86	99.2	74.4	71.6	83.7	78.7
18	8/4/86	99.3	74.4	71.8	83.7	78.9
19	8/4/86	99.3	74.3	71.7	83.9	78.8
20	8/4/86	99.9	.	.	.	78.9
21	8/4/86	99.5	.	.	.	78.9
22	8/4/86	99.6	.	.	.	.
23	8/4/86	99.4	.	.	.	.

APPENDIX IV

TILT BARRIER TEST SITE LEQS

SOURCE 30 FEET FROM BARRIER

OBS	DATE	S	R1	R2	F1	F2
1	8/4/86	97.2	70.0	67.8	84.0	78.6
2	8/4/86	97.4	70.4	68.0	84.2	78.7
3	8/4/86	97.5	70.4	68.1	84.5	78.4
4	8/4/86	97.6	70.7	68.4	84.6	78.4
5	8/4/86	97.4	70.1	68.3	84.3	78.4
6	8/4/86	97.4	70.5	68.2	84.5	78.2
7	8/4/86	97.6	70.6	68.7	84.8	78.0
8	8/4/86	97.4	70.5	68.5	84.7	78.3
9	8/4/86	97.4	70.3	68.4	84.5	78.3
10	8/4/86	97.4	70.4	68.5	84.5	77.8
11	8/4/86	97.3	70.3	68.4	84.4	78.1
12	8/4/86	97.3	70.3	.	82.9	78.6
13	8/4/86	97.4	70.5	.	84.3	78.4
14	8/4/86	97.4	70.4	.	84.2	78.2
15	8/4/86	97.6	70.6	.	84.6	78.4
16	8/4/86	97.3	70.4	.	84.3	78.4
17	8/4/86	97.3	.	.	84.2	77.7
18	8/4/86	97.5	.	.	84.5	77.9
19	8/4/86	97.5	.	.	84.6	.
20	8/4/86	97.7	.	.	84.6	.
21	8/4/86	97.6	.	.	84.3	.
22	8/4/86	97.4	.	.	84.3	.
23	8/4/86	97.5	.	.	.	.

APPENDIX IV

TILT BARRIER TEST SITE LEQS

SOURCE 17 FEET FROM BARRIER

OBS	DATE	S	R1	R2	F1	F2
1	8/4/86	97.9	67.9	66.2	84.4	77.8
2	8/4/86	98.1	68.4	66.1	84.5	77.9
3	8/4/86	98.2	68.4	66.7	84.5	78.0
4	8/4/86	98.3	68.4	66.7	84.7	78.0
5	8/4/86	98.3	68.4	66.7	84.7	78.3
6	8/4/86	98.2	68.3	66.9	84.6	78.0
7	8/4/86	98.2	68.3	66.8	84.6	77.9
8	8/4/86	98.1	68.6	66.9	84.4	78.0
9	8/4/86	98.1	69.4	66.8	84.5	78.1
10	8/4/86	98.0	69.2	66.7	84.3	78.2
11	8/4/86	98.1	69.4	66.9	84.6	78.7
12	8/4/86	98.1	69.2	67.0	84.5	78.4
13	8/4/86	98.0	69.0	66.7	84.4	78.3
14	8/4/86	98.0	69.1	67.2	84.5	78.2
15	8/4/86	97.9	69.1	66.9	84.4	78.2
16	8/4/86	97.9	69.1	67.1	84.6	78.1
17	8/4/86	98.0	69.2	66.7	84.3	78.2
18	8/4/86	97.9	69.1	67.2	84.4	78.0
19	8/4/86	98.2	.	66.7	84.7	78.0
20	8/4/86	98.1	.	.	84.5	78.0
21	8/4/86	98.1	.	.	84.4	78.0
22	8/4/86	98.0	.	.	.	78.2

APPENDIX V

ABSORBING BARRIER CONTROL SITE LEQS

SOURCE 60 FEET FROM BARRIER

OBS	DATE	S	R1	R2	F1	F2
1	8/6/86	97.9	80.8	76.0	81.3	80.1
2	8/6/86	98.0	80.8	76.3	81.7	79.8
3	8/6/86	98.3	80.5	76.4	81.8	80.1
4	8/6/86	98.2	81.0	75.3	81.8	80.5
5	8/6/86	98.4	81.2	75.3	81.6	80.3
6	8/6/86	98.4	81.2	75.5	81.7	80.3
7	8/6/86	98.5	81.2	75.9	81.4	80.0
8	8/6/86	98.6	81.3	76.7	81.3	79.9
9	8/6/86	98.5	81.3	75.9	81.4	79.8
10	8/6/86	98.7	81.2	76.0	81.2	79.8
11	8/6/86	98.8	81.2	75.9	81.5	79.8
12	8/6/86	99.0	81.2	76.4	81.9	80.0
13	8/6/86	99.1	81.2	75.9	82.1	80.1
14	8/6/86	99.2	81.4	76.0	82.3	80.2
15	8/6/86	99.3	81.6	76.0	82.5	80.3
16	8/6/86	99.3	81.9	76.0	82.8	80.3
17	8/6/86	99.3	82.2	76.6	82.8	80.4
18	8/6/86	99.4	82.2	76.6	82.9	80.0
19	8/6/86	99.5	82.4	76.3	82.9	80.0
20	8/6/86	99.6	82.5	76.4	83.0	80.0
21	8/6/86	99.7	81.2	76.7	83.1	80.0
22	8/6/86	98.2	81.2	.	81.7	.
23	8/6/86	98.6	.	.	.	.

APPENDIX V

ABSORBING BARRIER CONTROL SITE LEQS

SOURCE 45 FEET FROM BARRIER

OBS	DATE	S	R1	R2	F1	F2
1	8/6/86	99.5	74.1	73.2	84.0	80.8
2	8/6/86	99.4	74.2	72.8	84.5	80.4
3	8/6/86	99.4	74.4	73.0	84.4	81.1
4	8/6/86	99.7	74.4	72.7	84.3	81.1
5	8/6/86	99.8	74.3	72.9	84.2	81.3
6	8/6/86	99.7	74.4	73.4	84.4	81.2
7	8/6/86	99.7	74.5	73.1	84.3	80.9
8	8/6/86	99.6	74.2	73.2	84.0	80.7
9	8/6/86	99.5	74.2	73.4	84.0	80.8
10	8/6/86	99.6	74.2	73.4	84.0	80.6
11	8/6/86	99.4	74.3	73.4	84.0	80.9
12	8/6/86	99.5	74.2	73.3	83.9	80.8
13	8/6/86	99.5	74.3	73.3	84.0	80.3
14	8/6/86	99.5	74.6	73.3	84.0	80.6
15	8/6/86	99.4	74.5	73.0	84.0	80.3
16	8/6/86	99.4	74.7	73.0	84.1	80.3
17	8/6/86	99.5	74.8	72.8	84.2	80.2
18	8/6/86	99.5	74.2	.	83.9	81.1
19	8/6/86	99.3	74.3	.	84.1	81.2
20	8/6/86	99.5	74.5	.	84.2	81.2
21	8/6/86	99.9	.	.	84.1	80.7
22	8/6/86	99.6	.	.	84.0	80.7
23	8/6/86	99.5	.	.	.	.

APPENDIX V

ABSORBING BARRIER CONTROL SITE LEQS

SOURCE 30 FEET FROM BARRIER

OBS	DATE	S	R1	R2	F1	F2
1	8/12/86	99.9	72.9	71.7	84.9	79.7
2	8/12/86	100.0	73.2	71.9	85.2	79.4
3	8/12/86	100.1	73.5	71.9	85.2	79.3
4	8/12/86	100.0	73.8	71.9	85.2	79.5
5	8/12/86	100.2	74.3	72.1	85.2	79.6
6	8/12/86	100.4	73.5	71.8	85.2	79.8
7	8/12/86	100.4	74.2	72.1	85.2	79.7
8	8/12/86	100.5	74.1	71.8	85.2	79.8
9	8/12/86	100.5	74.1	72.3	85.2	79.8
10	8/12/86	100.5	74.2	72.2	85.5	79.8
11	8/12/86	100.5	73.9	71.9	85.4	79.7
12	8/12/86	100.5	74.0	72.2	85.1	79.8
13	8/12/86	100.4	74.1	72.3	84.9	79.7
14	8/12/86	100.4	74.3	72.5	85.1	79.7
15	8/12/86	100.5	74.3	72.5	85.0	79.7
16	8/12/86	100.4	74.2	72.4	85.0	79.7
17	8/12/86	100.5	74.3	72.7	85.0	79.6
18	8/12/86	100.5	74.3	72.4	84.7	79.7
19	8/12/86	100.4	.	.	75.3	79.4
20	8/12/86	100.4	.	.	85.4	79.6
21	8/12/86	100.5	.	.	85.2	79.8
22	8/12/86	100.5	.	.	85.0	.

APPENDIX V

ABSORBING BARRIER CONTROL SITE LEQS

SOURCE 17 FEET FROM BARRIER

OBS	DATE	S	R1	R2	F1	F2
1	8/12/86	100.1	71.0	69.7	85.0	80.5
2	8/12/86	100.0	72.4	70.7	85.3	80.4
3	8/12/86	100.0	73.2	71.1	85.4	80.4
4	8/12/86	100.1	73.7	71.3	85.6	80.8
5	8/12/86	100.2	73.4	71.3	85.6	81.0
6	8/12/86	100.3	73.7	71.3	85.4	81.3
7	8/12/86	100.2	73.2	70.8	85.5	81.3
8	8/12/86	100.3	73.4	70.8	85.4	81.5
9	8/12/86	100.3	73.3	70.9	85.5	81.5
10	8/12/86	100.3	73.4	70.8	85.2	81.2
11	8/12/86	100.3	73.3	70.8	85.1	81.1
12	8/12/86	100.1	73.2	70.7	84.9	80.9
13	8/12/86	100.3	73.7	71.0	85.6	81.3
14	8/12/86	100.3	73.1	71.0	85.3	81.2
15	8/12/86	100.3	72.9	71.0	85.5	81.1
16	8/12/86	100.3	73.3	71.2	85.5	81.1
17	8/12/86	100.2	73.1	71.3	85.3	81.0
18	8/12/86	100.2	73.0	71.0	85.1	81.0
19	8/12/86	100.3	72.9	70.8	84.9	80.6
20	8/12/86	100.3	.	.	85.2	81.2
21	8/12/86	100.2	.	.	85.5	81.2
22	8/12/86	100.1	.	.	85.0	80.7
23	8/12/86	100.3	.	.	.	.

APPENDIX VI

TILT BARRIER CONTROL SITE LEQS

SOURCE 60 FEET FROM BARRIER

OBS	DATE	S	R1	R2	F1	F2
1	8/6/86	97.2	80.5	74.1	81.9	76.6
2	8/6/86	97.2	80.2	73.9	81.8	76.3
3	8/6/86	97.3	80.8	74.3	82.1	76.6
4	8/6/86	98.7	81.5	74.5	82.5	77.2
5	8/6/86	97.7	81.7	74.4	82.5	76.9
6	8/6/86	97.7	81.8	74.3	82.5	76.6
7	8/6/86	97.6	81.8	74.3	82.6	77.3
8	8/6/86	97.8	81.9	74.9	82.6	76.9
9	8/6/86	97.7	81.9	74.3	82.6	76.8
10	8/6/86	97.6	81.9	74.3	82.6	77.1
11	8/6/86	97.9	82.1	74.4	82.3	77.1
12	8/6/86	97.9	82.0	74.6	82.4	77.1
13	8/6/86	97.9	81.9	74.3	82.4	77.0
14	8/6/86	97.9	82.1	74.1	82.5	77.2
15	8/6/86	97.9	82.0	74.1	82.5	77.5
16	8/6/86	97.9	82.1	74.5	82.5	77.2
17	8/6/86	97.9	82.0	74.4	82.5	77.3
18	8/6/86	98.0	81.9	74.5	82.4	77.3
19	8/6/86	98.0	81.9	74.4	82.3	77.2
20	8/6/86	98.0	81.9	74.2	82.3	77.3
21	8/6/86	97.7	81.9	74.5	82.4	.
22	8/6/86	97.7	81.9	74.3	.	.
23	8/6/86	97.9	.	.	.	.

APPENDIX VI

TILT BARRIER CONTROL SITE LEQS

SOURCE 45 FEET FROM BARRIER

OBS	DATE	S	R1	R2	F1	F2
1	8/11/86	98.5	74.8	75.6	84.3	76.0
2	8/11/86	98.8	75.6	75.7	85.0	75.9
3	8/11/86	99.1	75.7	76.2	84.7	75.7
4	8/11/86	99.0	75.5	75.4	84.6	76.1
5	8/11/86	99.0	75.4	76.0	85.0	76.2
6	8/11/86	99.0	75.3	76.4	84.6	76.0
7	8/11/86	99.1	75.3	76.1	84.8	76.4
8	8/11/86	99.1	75.1	76.9	84.8	76.3
9	8/11/86	99.0	75.0	75.8	84.6	76.5
10	8/11/86	99.0	75.0	76.6	84.6	77.4
11	8/11/86	99.0	75.2	75.9	84.6	76.2
12	8/11/86	99.0	75.2	75.9	84.6	76.6
13	8/11/86	99.0	75.0	76.5	84.4	76.6
14	8/11/86	99.0	75.0	76.3	84.5	76.1
15	8/11/86	99.0	75.1	75.8	84.4	76.0
16	8/11/86	99.0	75.0	76.9	84.6	76.3
17	8/11/86	99.1	74.9	76.6	85.0	77.1
18	8/11/86	99.1	75.1	76.6	84.8	76.6
19	8/11/86	99.0	.	76.1	85.1	76.1
20	8/11/86	99.0	.	.	84.6	76.4
21	8/11/86	99.0	.	.	84.8	76.4
22	8/11/86	99.0	.	.	84.7	77.1
23	8/11/86	98.4	.	.	.	.

APPENDIX VI

TILT BARRIER CONTROL SITE LEQS

SOURCE 30 FEET FROM BARRIER

OBS	DATE	S	R1	R2	F1	F2
1	8/12/86	100.1	73.1	74.0	85.2	77.0
2	8/12/86	100.1	73.6	74.4	85.3	77.2
3	8/12/86	100.1	73.9	74.2	85.1	77.2
4	8/12/86	100.0	73.6	74.4	85.0	77.1
5	8/12/86	100.0	73.8	74.3	85.2	77.0
6	8/12/86	100.1	73.5	74.3	85.6	77.3
7	8/12/86	100.2	74.1	74.3	85.6	77.2
8	8/12/86	100.2	74.1	74.5	85.3	77.1
9	8/12/86	100.3	74.2	74.6	85.4	77.1
10	8/12/86	100.3	74.1	74.4	85.4	77.1
11	8/12/86	100.3	73.9	74.9	85.0	77.0
12	8/12/86	100.3	74.5	74.6	85.3	77.2
13	8/12/86	100.3	74.5	74.1	85.2	77.4
14	8/12/86	100.3	74.4	74.4	85.4	77.5
15	8/12/86	100.2	74.6	74.6	85.3	77.5
16	8/12/86	100.2	74.0	74.4	85.6	77.5
17	8/12/86	100.2	74.0	74.6	85.7	77.4
18	8/12/86	100.1	.	74.6	85.0	77.0
19	8/12/86	100.3	.	.	85.2	77.1
20	8/12/86	100.3	.	.	85.5	77.2
21	8/12/86	100.3	.	.	85.5	77.2
22	8/12/86	100.3	.	.	85.6	.
23	8/12/86	100.2	.	.	.	.

APPENDIX VI

TILT BARRIER CONTROL SITE LEQS

SOURCE 17 FEET FROM BARRIER

OBS	DATE	S	R1	R2	F1	F2
1	8/6/86	100.7	71.9	70.4	85.1	76.2
2	8/6/86	100.8	72.9	70.5	85.5	76.4
3	8/6/86	101.1	73.3	70.5	85.5	76.4
4	8/6/86	101.2	73.2	70.6	85.4	77.0
5	8/6/86	101.2	73.3	70.9	85.2	76.9
6	8/6/86	101.3	73.5	71.0	85.5	76.8
7	8/6/86	101.3	73.3	71.0	85.3	76.7
8	8/6/86	101.3	73.3	70.9	85.5	77.0
9	8/6/86	101.3	73.3	70.8	85.4	76.7
10	8/6/86	101.2	73.3	70.8	85.5	76.7
11	8/6/86	101.2	73.4	71.1	85.2	76.9
12	8/6/86	101.2	73.0	71.1	85.3	76.8
13	8/6/86	101.3	72.9	71.3	85.5	76.9
14	8/6/86	101.3	72.7	71.4	85.0	77.1
15	8/6/86	101.4	72.4	71.3	85.2	77.3
16	8/6/86	101.4	72.7	71.3	85.5	77.1
17	8/6/86	101.5	72.9	71.3	85.4	77.3
18	8/6/86	101.6	72.9	71.3	85.2	77.1
19	8/6/86	101.5	72.8	71.2	85.2	77.6
20	8/6/86	101.2	.	.	85.7	76.9
21	8/6/86	101.2	.	.	85.5	77.1
22	8/6/86	101.2	.	.	85.4	.
23	8/6/86	101.3	.	.	.	.

NOTES ON APPENDICES VII - X

For microphone heights and locations, see Figures 4, 5, and 6, pages 16, 17, and 18, and text, pages 23 and 24.

The abbreviations used in these appendices are as follows:

OBSNO: Sequential number of actual field measurement. Missing numbers indicate that observation was discarded during the data reduction process.

PRA: Level at absorbing barrier reference microphone.

P1A: Level at lower microphone in front of absorbing barrier face.

P2A: Level at upper microphone in front of absorbing barrier face.

PRC: Level at control site barrier reference microphone.

P1C: Level at lower microphone in front of control site barrier face.

P2C: Level at upper microphone in front of control site barrier face.

PRT, PRC: Levels corresponding to PRA and PRC above, for tilt barrier and control site.

P1T, P1C: Levels corresponding to P1A and P1C.

P2T, P2C: Levels corresponding to P2A and P2C.

SPD: Vehicle speed in mph. See text, page   for method.

NOL, NOM, NOH: Number of light, medium, and heavy vehicles in nearside outer lanes.

NIL, NIM, NIH: As above, for nearside inner lanes.

FOL, FOM, FOH: As above, for farside outer lanes.

FIL, FIM, FIH: As above, for nearside inner lanes.

NL, NM, NH: Number of light, medium, and heavy vehicles in nearside lanes.

FL, FM, FH: As above, for farside lanes.

APPENDIX VII

Leqs FOR ABSORBING BARRIER TEST AND CONTROL SITES

DATE	OBSNO	PRA	P1A	P2A	PRC	P1C	P2C
06/21/88	1	79.4	81.1	80.1	80.1	83.2	82.7
06/21/88	2	78.3	79.3	78.7	78.4	81.0	80.9
06/21/88	3	78.0	78.6	77.9	78.0	80.2	80.1
06/21/88	6	78.1	78.8	78.1	78.2	80.4	80.1
06/21/88	8	77.3	78.2	77.3	77.1	79.9	79.5
06/21/88	9	77.7	78.9	78.0	77.7	80.5	80.0
06/21/88	10	.	79.6	79.0	.	83.4	81.3
06/21/88	11	.	78.5	77.4	.	80.2	79.8
09/30/88	1	78.8	81.2	81.8	79.1	82.8	82.2
09/30/88	2	80.2	82.7	83.1	80.6	84.7	83.5
09/30/88	3	78.7	80.9	81.4	79.5	82.7	82.2
09/30/88	4	79.3	81.6	82.4	79.7	83.8	82.9
09/30/88	5	79.5	82.0	82.6	80.0	83.7	82.7
09/30/88	6	80.3	83.3	83.1	80.8	85.2	84.1
09/30/88	7	79.8	82.5	83.0	80.2	84.1	83.3
09/30/88	8	79.0	82.4	82.2	79.3	82.9	82.3
09/30/88	9	77.8	80.3	80.9	78.5	81.9	81.3
09/30/88	10	81.4	84.3	83.8	81.7	85.8	84.7
09/30/88	11	79.8	82.4	82.8	79.9	84.0	83.4
09/30/88	12	79.7	82.4	82.3	80.2	84.4	83.6
09/30/88	13	80.1	82.4	83.0	80.4	84.0	83.5
09/30/88	14	79.9	82.1	82.8	81.5	85.4	84.5
09/30/88	15	79.8	81.4	82.5	79.9	82.7	82.8
09/30/88	16	79.4	82.4	82.0	80.0	84.5	83.6
09/30/88	17	78.2	80.2	81.0	78.6	81.8	81.6
09/30/88	18	78.7	81.1	81.8	79.2	83.2	82.3
09/30/88	19	79.5	81.8	82.1	80.2	84.4	83.3
09/30/88	20	78.5	80.6	81.4	79.1	82.4	81.6
10/14/88	2	80.7	83.3	82.6	81.1	84.8	84.8
10/14/88	3	79.8	82.3	81.7	80.0	83.7	83.4
10/14/88	4	79.1	81.8	81.1	79.7	83.4	83.3
10/14/88	5	79.1	81.4	81.1	79.0	82.9	82.8
10/14/88	6	77.3	80.8	79.9	78.2	82.3	81.9
10/14/88	7	79.7	82.0	81.8	79.6	83.2	83.2
10/14/88	8	78.9	81.3	80.7	78.7	82.2	82.2
10/14/88	9	78.0	80.2	80.0	78.2	81.3	81.3
10/14/88	10	78.6	81.0	80.3	78.5	82.2	82.2
10/14/88	11	79.6	82.0	81.3	79.6	83.2	83.1
10/14/88	12	79.7	82.5	81.5	80.3	84.1	83.7
10/14/88	13	78.9	81.2	80.6	79.2	82.4	82.6
10/14/88	14	80.0	82.6	81.7	80.4	83.9	83.9
10/14/88	15	79.9	82.8	81.5	80.1	83.5	83.5
10/14/88	16	79.5	82.3	81.3	80.0	83.7	83.5
10/14/88	18	80.2	82.6	82.2	80.3	83.5	83.6
10/14/88	19	79.8	83.2	82.1	80.3	85.0	84.0
10/14/88	20	80.2	82.9	82.3	80.5	83.9	84.1
10/14/88	21	79.5	81.8	81.4	79.7	82.7	83.2

APPENDIX VIII

TRAFFIC COUNTS AND SPEEDS

ABSORBING BARRIER AND CONTROL SITE

DATE	OBSNO	SPD	NOL	NOM	NOH	NIL	NIM	NIH	FOL	FOM	FOH	FIL	FIM	FIH
06/21/88	1	54.6	53	4	6	19	3	6	50	3	2	33	3	5
06/21/88	2	55.6	57	2	3	16	7	3	45	3	1	27	1	1
06/21/88	3	55.0	56	1	1	27	1	6	56	4	1	33	2	10
06/21/88	6	58.0	59	0	1	15	1	10	50	2	1	38	1	2
06/21/88	8	52.2	69	1	1	20	3	2	47	3	1	30	6	3
06/21/88	9	59.6	73	2	1	23	3	4	36	5	0	27	1	4
06/21/88	10	56.5	69	3	0	22	0	7	46	0	3	32	3	3
06/21/88	11	57.6	61	1	1	25	1	4	42	2	5	30	1	4
09/30/88	1	56.8	56	2	2	34	2	6	66	0	5	15	1	3
09/30/88	2	54.6	62	2	7	22	2	6	60	1	0	24	2	3
09/30/88	3	55.4	74	0	1	28	2	6	47	1	4	29	1	6
09/30/88	4	59.0	62	3	2	29	1	4	55	4	1	29	5	4
09/30/88	5	54.2	67	1	3	16	0	9	58	0	2	27	2	3
09/30/88	6	58.2	68	4	4	30	1	4	70	5	1	18	1	3
09/30/88	7	56.4	74	3	2	26	2	8	55	3	3	42	2	4
09/30/88	8	60.0	68	1	1	20	1	6	59	9	3	41	2	4
09/30/88	9	56.4	63	2	0	17	1	5	54	3	0	32	1	0
09/30/88	10	57.2	63	2	3	26	1	9	49	3	6	.	.	.
09/30/88	11	57.8	59	1	3	38	3	9	54	0	1	25	2	5
09/30/88	12	62.5	64	2	4	29	2	6	59	3	0	39	1	3
09/30/88	13	57.2	74	3	3	23	4	10	74	4	2	36	5	6
09/30/88	14	55.4	70	2	4	34	1	7	65	4	2	34	1	2
09/30/88	15	53.6	63	3	2	51	0	8	59	3	1	18	4	13
09/30/88	16	58.4	60	6	1	32	2	4	66	2	3	35	1	9
09/30/88	17	59.4	62	0	1	37	0	6	52	0	2	34	1	7
09/30/88	18	56.2	65	2	2	30	1	3	68	1	3	29	3	3
09/30/88	19	58.5	69	5	2	26	0	6	61	0	0	43	3	5
09/30/88	20	51.8	77	2	3	30	2	7	47	2	0	31	0	2
10/14/88	2	51.0	71	5	7	11	1	9	38	4	2	23	2	5
10/14/88	3	56.8	78	4	0	26	1	9	55	0	2	32	1	4
10/14/88	4	53.8	69	2	1	25	4	6	51	2	5	33	1	5
10/14/88	5	56.0	50	2	2	34	1	7	43	2	3	27	2	8
10/14/88	6	51.0	70	2	1	20	1	4	44	2	1	32	1	0
10/14/88	7	54.8	87	0	1	22	0	6	44	3	2	25	2	8
10/14/88	8	56.6	57	0	1	20	0	8	70	0	0	42	2	6
10/14/88	9	56.0	67	1	0	28	0	4	60	4	2	47	1	7
10/14/88	10	59.6	58	0	1	38	1	7	43	2	2	31	1	3
10/14/88	11	55.2	67	2	1	15	2	6	60	3	1	28	1	2
10/14/88	12	52.2	78	2	4	19	1	2	58	1	3	38	2	4
10/14/88	13	54.2	78	0	0	28	2	6	65	4	1	34	0	6
10/14/88	14	57.6	81	2	2	31	1	8	71	2	0	48	2	3
10/14/88	15	56.0	76	1	2	35	1	10	57	1	7	41	1	7
10/14/88	16	51.4	69	2	3	22	0	11	73	1	0	35	2	3
10/14/88	18	61.8	81	2	0	24	0	13	68	2	2	39	1	4
10/14/88	19	60.2	73	2	3	24	2	4	61	5	1	27	0	6
10/14/88	20	55.8	51	2	5	34	1	5	56	0	4	42	1	9
10/14/88	21	56.5	70	0	0	40	2	12	60	1	2	40	2	7

APPENDIX IX

Leqs FOR TILT BARRIER TEST AND CONTROL SITES

DATE	OBSNO	PRT	P1T	P2T	PRC	P1C	P2C
07/07/89	1	.	.	64.2	78.0	64.6	63.7
07/07/89	2	79.9	.	61.4	76.9	63.6	61.8
07/07/89	3	.	.	61.8	76.8	63.0	61.2
07/07/89	4	.	.	.	76.5	62.8	60.8
07/07/89	5	80.3	.	62.6	77.3	64.0	62.2
07/07/89	6	.	.	64.5	78.4	65.0	63.3
07/07/89	7	.	.	59.7	75.3	61.6	60.0
07/07/89	8	.	.	64.6	78.4	65.9	63.9
07/07/89	9	80.8	.	63.5	78.1	65.3	63.2
07/07/89	10	80.0	61.4	61.7	76.9	62.9	60.8
07/07/89	11	.	61.4	62.6	78.6	65.7	63.7
07/07/89	12	.	63.8	63.8	77.5	64.4	62.6
07/07/89	13	.	62.1	61.9	77.4	64.4	62.6
07/07/89	14	78.5	60.1	60.2	74.9	62.4	60.7
07/07/89	15	.	62.7	62.9	77.4	63.8	62.1
07/07/89	16	.	62.2	62.0	77.3	62.9	61.0
07/07/89	17	.	61.1	61.3	76.5	64.4	62.6
07/07/89	18	80.3	62.9	62.8	77.2	64.8	62.9
07/07/89	19	.	62.5	62.8	76.7	63.2	61.3
07/07/89	20	79.5	61.7	61.3	76.0	61.5	59.7
07/19/89	1	78.4	64.6	63.2	78.0	65.6	64.4
07/19/89	2	79.1	65.2	64.0	76.0	64.4	63.7
07/19/89	3	77.1	63.1	62.1	74.9	63.1	61.7
07/19/89	5	78.3	64.2	62.9	76.0	63.7	62.3
07/19/89	6	79.9	65.7	64.3	78.5	65.7	64.2
07/19/89	7	78.6	.	.	.	63.9	62.6
07/19/89	8	78.8	64.7	63.4	76.8	63.1	61.7
07/19/89	9	77.7	63.5	62.2	77.0	64.8	63.8
07/19/89	10	78.6	64.1	62.6	77.3	63.5	62.2
07/19/89	11	76.9	62.8	61.2	75.4	62.3	60.9
07/19/89	12	78.5	64.0	62.5	76.5	63.7	62.3
07/19/89	13	78.7	64.3	62.8	77.4	64.2	62.7
07/19/89	14	79.1	65.1	63.6	77.7	65.2	64.1
07/19/89	15	79.1	64.9	63.6	77.6	63.9	62.5
07/19/89	16	80.0	66.3	64.5	77.8	65.5	63.9
07/19/89	17	78.2	63.1	62.0	75.9	62.0	60.7
07/19/89	18	77.7	63.5	61.8	75.5	63.2	61.7
07/19/89	19	79.9	66.1	64.9	77.4	64.9	63.5
07/19/89	20	78.7	64.4	62.9	76.3	63.8	62.4
07/19/89	21	79.4	65.2	63.7	78.2	66.2	65.1
07/19/89	22	79.6	65.1	64.3	77.1	64.6	63.2
07/19/89	23	79.5	64.7	63.9	78.2	65.9	64.6
07/19/89	24	78.0	62.6	61.8	76.2	63.3	61.9
07/19/89	25	.	.	.	78.5	65.6	64.1
07/19/89	26	78.5	63.4	62.3	76.7	63.2	61.9
07/19/89	27	80.4	65.8	65.1	77.3	63.1	61.7
07/19/89	28	80.0	65.4	64.3	77.4	63.3	62.2

Leqs FOR TILT BARRIER TEST AND CONTROL SITES

DATE	OBSNO	PRT	P1T	P2T	PRC	P1C	P2C
07/19/89	29	79.3	64.6	63.6	77.2	63.5	62.3
07/19/89	30	80.7	65.0	64.0	78.1	64.7	63.4
07/19/89	31	79.7	64.2	63.2	76.4	63.4	62.1
07/19/89	32	78.4	63.5	62.4	76.2	62.9	61.8
07/19/89	33	80.4	65.4	64.2	77.3	64.1	62.6
07/19/89	34	81.2	66.1	65.2	78.1	64.7	63.4
07/19/89	35	80.0	65.5	65.2	77.2	65.4	63.8
08/02/89	1	79.1	64.8	64.2	76.4	63.7	62.4
08/02/89	2	79.4	65.2	64.6	77.8	65.4	64.2
08/02/89	3	80.2	65.7	65.4	78.1	65.0	63.6
08/02/89	4	78.9	63.9	63.2	77.8	64.9	63.7
08/02/89	5	78.9	64.9	64.0	76.1	63.7	62.4
08/02/89	6	78.5	63.3	62.7	76.0	63.9	62.7
08/02/89	7	79.5	64.9	65.3	77.0	64.3	63.1
08/02/89	8	79.7	65.2	64.8	77.1	64.6	63.4
08/02/89	9	79.4	65.2	64.6	77.0	64.5	63.2
08/02/89	10	77.4	64.7	64.5	73.9	62.7	61.3
08/02/89	12	77.9	63.1	63.0	75.9	63.2	62.0
08/02/89	13	79.8	65.2	64.6	78.2	65.7	64.9
08/02/89	14	78.5	63.8	63.2	76.9	64.5	63.1
08/02/89	15	79.4	64.7	63.9	76.6	64.0	62.7
08/02/89	16	78.9	63.9	63.3	75.9	63.1	61.9
08/02/89	17	.	.	.	76.4	63.1	61.8
08/02/89	18	78.4	63.7	63.0	.	64.1	62.7
08/02/89	19	78.2	63.6	63.1	76.0	63.9	62.5
08/02/89	20	77.7	63.9	63.5	75.2	62.4	60.8

APPENDIX X

TRAFFIC COUNTS AND SPEEDS

TILT BARRIER AND CONTROL SITE

DATE	OBSNO	SPD	NL	NM	NH	FL	FM	FH
07/07/89	1	56.2	48	3	6	57	5	11
07/07/89	2	61.0	54	0	4	34	0	5
07/07/89	3	56.4	31	2	4	44	0	7
07/07/89	4	56.8	36	0	6	44	4	8
07/07/89	5	54.2	42	2	6	53	3	6
07/07/89	6	54.2	32	0	11	38	3	12
07/07/89	7	56.8	36	0	3	42	2	3
07/07/89	8	59.6	48	2	3	48	2	10
07/07/89	9	57.8	45	2	6	52	4	8
07/07/89	10	59.8	41	4	2	50	3	9
07/07/89	11	53.6	41	2	5	48	0	13
07/07/89	12	63.4	36	1	4	34	0	10
07/07/89	13	62.0	52	0	6	47	6	5
07/07/89	14	55.6	28	2	3	55	1	3
07/07/89	15	59.0	49	2	7	101	1	14
07/07/89	16	58.2	43	3	1	63	0	7
07/07/89	17	56.6	46	0	6	47	0	4
07/07/89	18	54.2	50	0	4	49	1	10
07/07/89	19	57.4	45	0	4	42	3	6
07/07/89	20	56.6	57	1	2	50	2	3
07/19/89	1	54.8	33	3	7	48	2	18
07/19/89	2	59.4	38	3	7	57	0	10
07/19/89	3	58.8	41	5	2	45	4	4
07/19/89	5	57.6	44	2	6	58	1	7
07/19/89	6	55.8	50	2	15	60	3	9
07/19/89	7	56.4	41	3	7	33	1	8
07/19/89	8	59.0	35	0	5	38	2	5
07/19/89	9	57.0	31	1	4	42	2	9
07/19/89	10	58.4	33	0	11	46	2	6
07/19/89	11	58.0	51	1	3	48	1	3
07/19/89	12	59.8	41	2	7	33	1	6
07/19/89	13	57.8	41	3	7	40	1	6
07/19/89	14	59.5	38	2	9	44	1	15
07/19/89	15	57.0	60	3	8	40	3	10
07/19/89	16	61.4	49	4	9	38	1	6
07/19/89	17	53.4	50	2	7	50	1	4
07/19/89	18	58.3	26	0	5	42	4	6
07/19/89	19	58.5	36	4	8	32	0	9
07/19/89	20	60.0	37	1	8	40	3	5
07/19/89	21	60.4	47	1	10	55	1	11
07/19/89	22	59.0	46	0	9	39	0	13
07/19/89	23	56.6	35	1	9	46	1	11
07/19/89	24	57.8	50	1	4	51	0	6
07/19/89	25	57.0	52	2	10	47	1	5
07/19/89	26	56.4	57	2	7	55	1	4
07/19/89	27	55.8	52	2	11	71	1	5
07/19/89	28	61.8	57	3	8	74	1	5

APPENDIX X - continued

TRAFFIC COUNTS AND SPEEDS

TILT BARRIER AND CONTROL SITE

DATE	OBSNO	SPD	NL	NM	NH	FL	FM	FH
07/19/89	29	58.0	61	3	6	64	2	4
07/19/89	30	59.2	66	1	10	57	0	8
07/19/89	31	56.6	56	1	6	47	1	7
07/19/89	32	58.6	77	0	5	68	0	8
07/19/89	33	56.8	82	6	8	46	1	5
07/19/89	34	57.0	75	4	11	53	3	2
07/19/89	35	56.0	91	2	8	72	4	5
08/02/89	1	56.2	26	1	8	29	1	4
08/02/89	2	57.8	35	1	15	45	1	10
08/02/89	3	56.2	44	2	14	35	1	4
08/02/89	4	55.4	40	2	10	41	0	12
08/02/89	5	59.8	26	4	7	34	0	7
08/02/89	6	55.4	33	2	7	27	1	9
08/02/89	7	58.0	31	2	9	49	0	7
08/02/89	8	56.2	37	2	10	34	1	9
08/02/89	9	58.4	35	0	8	42	0	9
08/02/89	10	59.0	36	2	3	41	0	3
08/02/89	12	59.0	41	1	5	31	0	6
08/02/89	13	57.0	29	1	7	38	1	13
08/02/89	14	58.6	32	2	10	35	0	7
08/02/89	15	58.2	37	0	11	34	2	4
08/02/89	16	56.8	31	2	5	39	0	5
08/02/89	17	55.4	43	2	8	39	0	4
08/02/89	18	56.6	29	1	7	37	0	7
08/02/89	19	56.0	34	8	5	27	1	4
08/02/89	20	60.2	38	0	6	43	0	2

APPENDIX XI

ANALYSIS OF ABSORBING VS. STANDARD BARRIER - PHASE II

Referring to Table VII, page 38 we see that there is a 1.4dB difference in median levels between the 8-foot and 17-foot control site (standard barrier) microphone positions and the corresponding positions at the absorbing barrier. These differences are statistically significant, but they present no real advantage to the people behind the barriers.

We will discuss several cases to demonstrate this. For ease of discussion we will assume the following:

1. That the standard barrier is fully reflecting, which means that the actual nearside median traffic noise level is 80.2dBA, based on the reflected level at P1C shown in Table VII (80.2 + 80.2 = 83.2).
2. That farside traffic noise level is also 80.2dBA at the farside barrier.
3. That the <u>reflected</u> level from either type of barrier is reduced by 10dB at a distance of 75 feet from the barrier. This assumption is based on the analysis of data from previous noise studies which showed that there is about a 10 dB attenuation of traffic noise over this distance. Thus (referring to Table VII) the reflected level from the absorbing barrier is 71.8dBA (from P1A), and 73.2dBA from the standard barrier (from P1C) at a distance of 75 feet.

4. That the farside traffic noise source is at 75 feet from the nearside barrier. We also assume that the farside barrier, in those cases where one is present, is somewhat more than 75 feet from the nearside barrier, so that the nearside noise source is 75 feet from the farside barrier. Therefore the level at the farside barrier will be the essentially same as that at the nearside barrier of the same type.

Consider the following cases:

STANDARD BARRIER NEARSIDE AND NO BARRIER FARSIDE

80.2dBA - Farside traffic noise level

73.2dBA - Attenuated nearside reflected noise level

81.0dBA - Farside level

ABSORBING BARRIER NEARSIDE AND NO BARRIER FARSIDE

80.2dBA - Farside traffic noise level

71.8dBA - Attenuated nearside reflected noise level

80.8dBA - Farside level

The absorbing barrier offers only .2dB advantage.

STANDARD BARRIERS BOTH SIDES OF ROADWAY

83.2dBA - Farside traffic noise level

73.2dBA - Attenuated nearside reflected noise level

83.6dBA - Total

-3.5dB - Difference between P1C (8-ft.) and PRC (2 feet above barrier) from Table VII

80.1dBA - Farside level at top of barrier

ABSORBING BARRIERS BOTH SIDES OF ROADWAY

81.8dBA - Farside traffic noise level

71.8dBA - Attenuated nearside reflected noise level

82.2dBA - Total

-2.4dB - Difference between P1A and PRA from Table VII

79.8dBA - Farside level at top of barrier

The parallel absorbing barriers offer only a .3dB advantage.

ABSORBING BARRIER NEARSIDE AND STANDARD BARRIER FARSIDE

83.2dBA - Farside traffic noise level

71.8dBA - Attenuated nearside reflected noise level

83.5dBA - Total farside level

-3.5dB - Difference between P1C and PRC from Table I

80.0dBA - Farside level at top of barrier

STANDARD BARRIER NEARSIDE AND ABSORBING BARRIER FARSIDE

81.8dBA - Farside traffic noise level

73.2dBA - Attenuated nearside reflected noise level

82.4dBA - Total

-2.4dB - Difference between P1A and PRA

80.0dBA - Farside level at top of barrier

The absorbing barrier offers no advantage in either case.

APPENDIX XII

MAJOR ITEMS OF EQUIPMENT USED IN

DATA COLLECTION, REDUCTION, AND ANALYSIS

6052-443 BELFORT WIND INSTRUMENT

566 BENDIX ASPIRATED PSYCHROMETER

2204 BRUEL AND KJAER SOUND LEVEL METER

2209 BRUEL AND KJAER SOUND LEVEL METER

2218 BRUEL AND KJAER SOUND LEVEL METER (2)

2231 BRUEL AND KJAER SOUND LEVEL METER (2)

2305 BRUEL AND KJAER GRAPHIC LEVEL RECORDER (2)

2619 BRUEL AND KJAER PREAMPLIFIER (5)

4134 BRUEL AND KJAER 1/2" MICROPHONE (3)

4166 BRUEL AND KJAER 1/2" MICROPHONE (4)

4220 BRUEL AND KJAER PISTONPHONE (2)

WM-III 540 CLIMATRONICS WIND MEASURING SYSTEM

IV-SJ NAGRA TAPE RECORDER (2)

TC-D5 PROII SONY CASSETTE RECORDER (2)

SD312-22 SPECTRAL DYNAMICS 1/3 OCTAVE ANALYZER