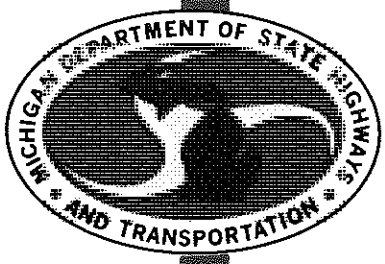
EFFECTIVENESS OF THE EXPERIMENTAL WOODEN NOISE WALL, INTERSTATE HIGHWAY I 75, CITY OF ALLEN PARK, MICHIGAN



TESTING AND RESEARCH DIVISION
RESEARCH LABORATORY SECTION

EFFECTIVENESS OF THE EXPERIMENTAL WOODEN NOISE WALL, INTERSTATE HIGHWAY I 75, CITY OF ALLEN PARK, MICHIGAN

G. H. Grove

Research Laboratory Section
Testing and Research Division
Research Project 71 TI-36
Research Report No. R-1045

Michigan State Highway Commission
Peter B. Fletcher, Chairman; Carl V. Pellonpaa,
Vice-Chairman, Hannes Meyers, Jr., Weston E. Vivian
John P. Woodford, Director
Lansing, February 1977

ACKNOWLEDGEMENT

The author wishes to thank L. Lintner of the Research Laboratory's Statistical Analysis Group for her contribution to the Subjective Questionnaire design and analysis.

INTRODUCTION

The Michigan Department of State Highways and Transportation selected the segment of I 75 described herein as the site for an experimental traffic noise abatement project. This segment of I 75 is located in Allen Park along the southern edge of the metropolitan Detroit area (Fig. 1). The area on the northwest side of the freeway is occupied by a group of high density, single family dwellings. The freeway is composed of three lanes in each direction, separated by a 26-ft median, and has a grade which changes from depressed under Moore Rd to elevated over Goddard Rd.

This segment was selected because of a serious traffic noise problem in the adjacent residential area which was brought to the Department's attention by objections and protests from area residents and requests from city, state, and Federal officials and legislators.

Construction of a Wooden Barrier

In the spring of 1974, a wooden noise barrier wall was constructed of full thickness 2 by 8-in. tongue and groove fir planks to a uniform height of 13-1/2 ft above the pavement at a total cost of $181,000. The length of the barrier is 2,735 lin ft, running from Sta. 745+15 to Sta. 772+50.

The roadway elevation varies from 2 ft depressed at the northern end of the site to 16 ft elevated at the southern end on the Goddard Rd bridge. The distance from the barrier wall to the center of the near lane varies from 18 to 30 ft. The nearest residential property is 140 ft from the center of the near lane and 110 ft from the barrier wall.

An existing 3 to 4-ft high earth berm was incorporated into the required 13-1/2 ft height for approximately 1,000 ft on the northern end. A barrier consisting entirely of an earth berm was not feasible due to the lack of right-of-way, varied elevation, and a nearby parallel railway line.

The reader is referred to actual construction plans, Control Section M82191, Job Number 06464A, Sheets 1 through 12 for details. Post construction aerial photographs (Fig. 2) depict the final structure, while Figure 3 depicts various details associated with barrier construction.

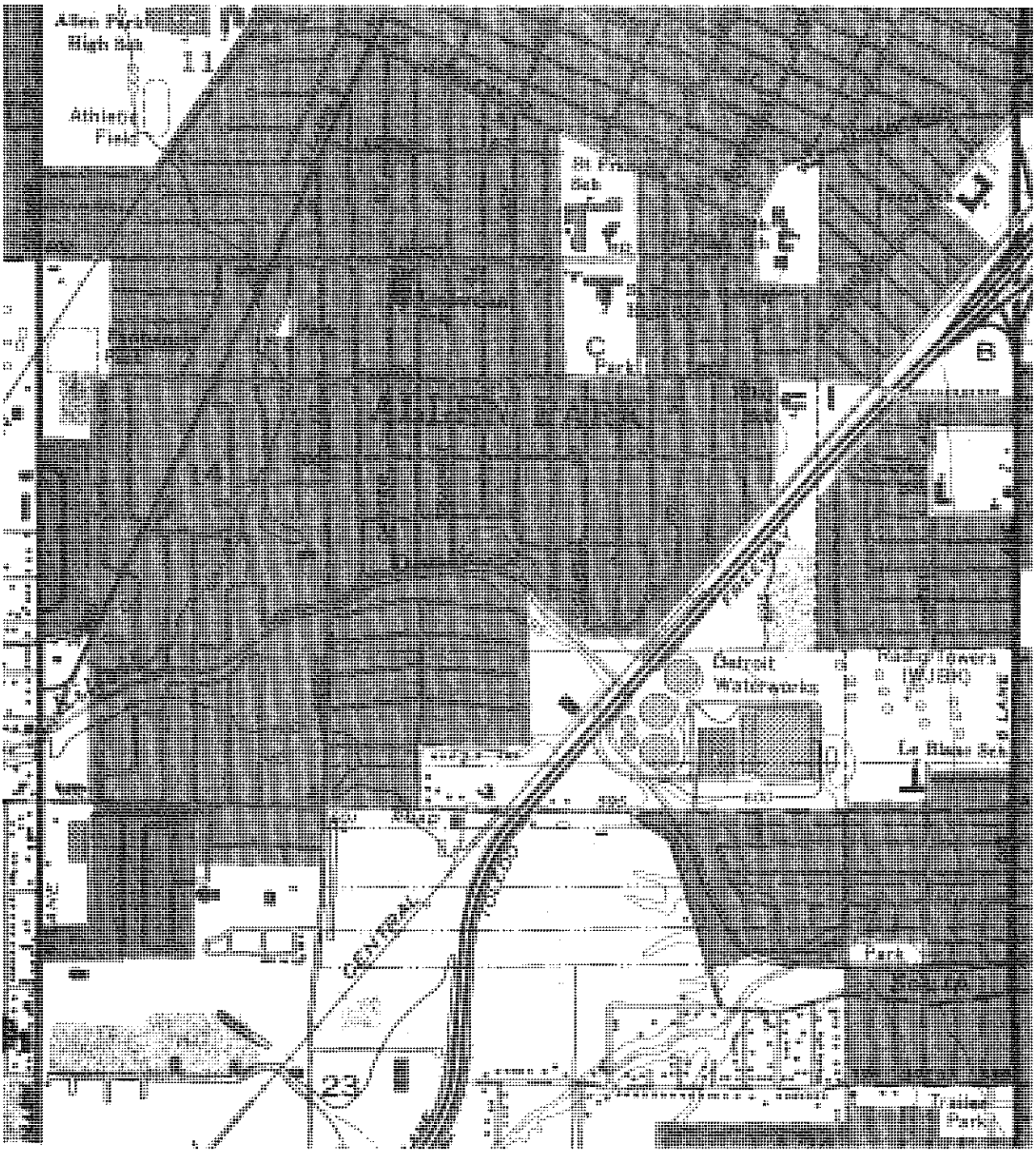
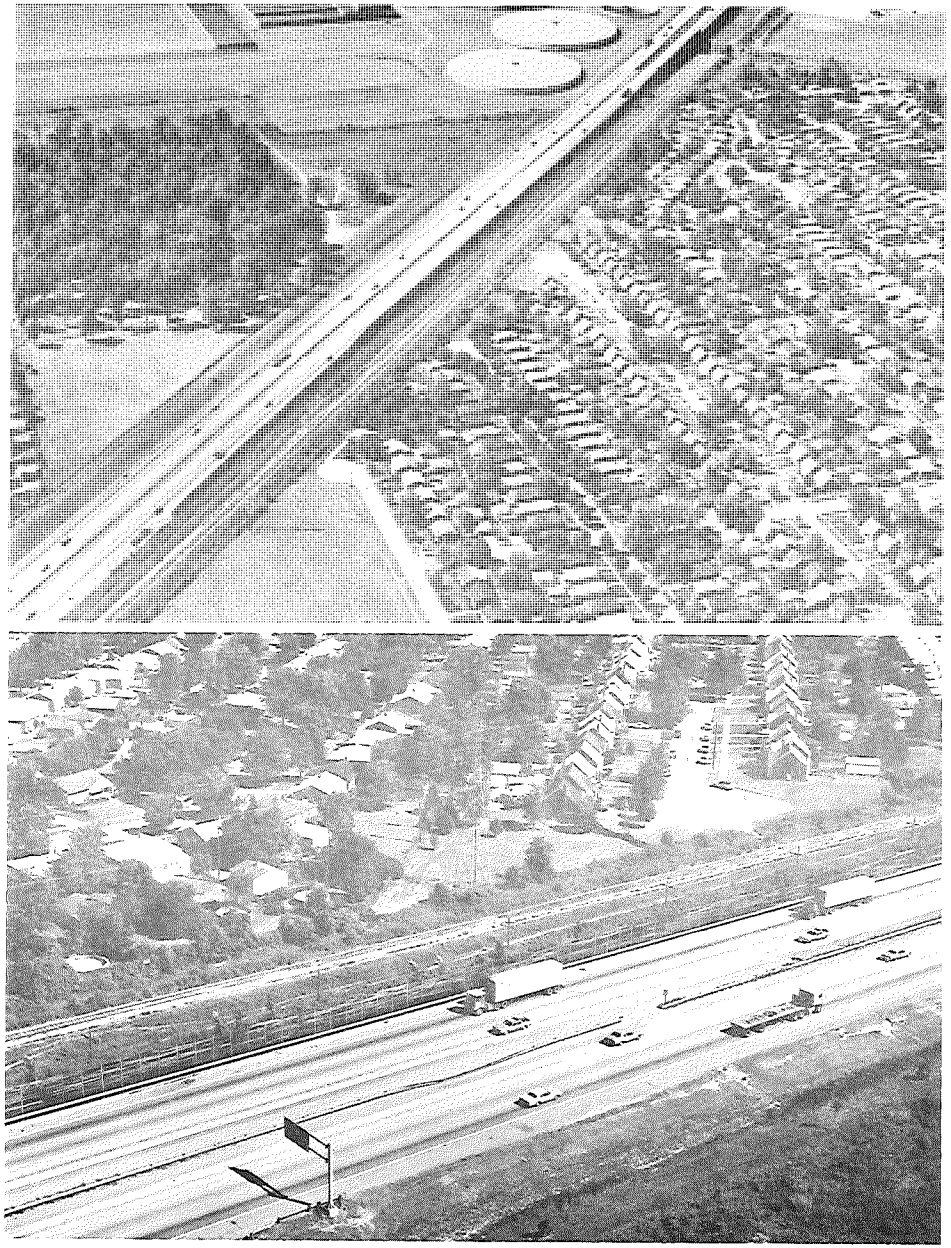


Figure 1. Noise analysis study area, Allen Park.



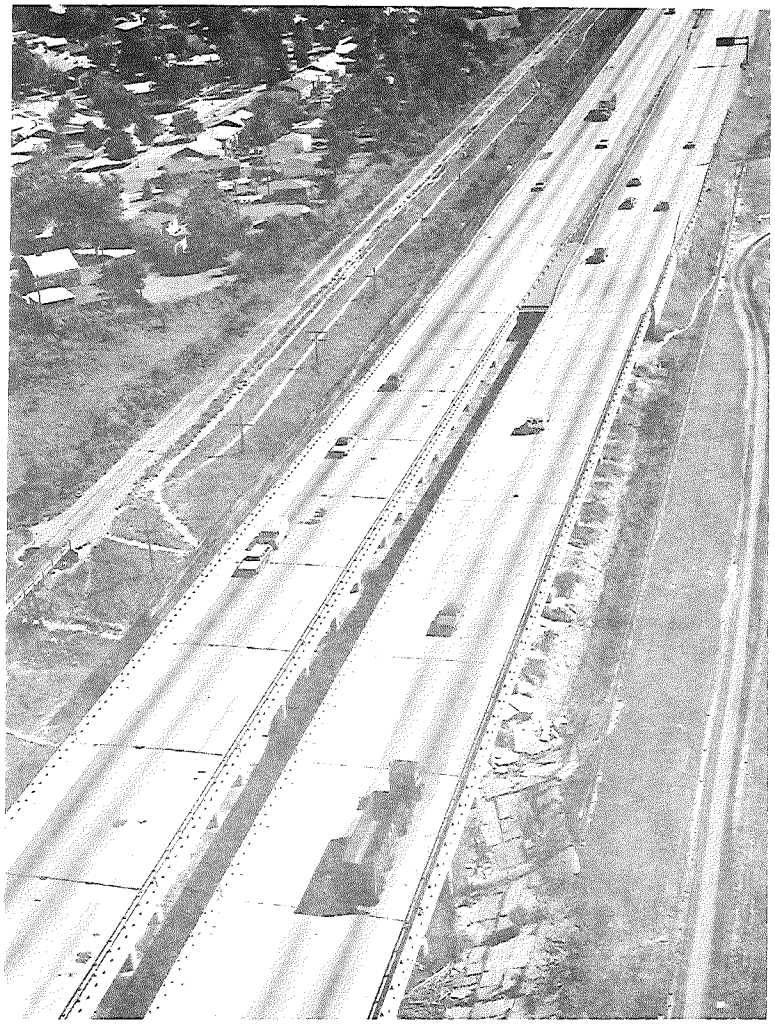


Figure 2. Aerial views of the barrier area. View at upper left looks southeast toward the barrier; view at lower left looks northwest; view above shows southern end of the barrier on the overpass structure.

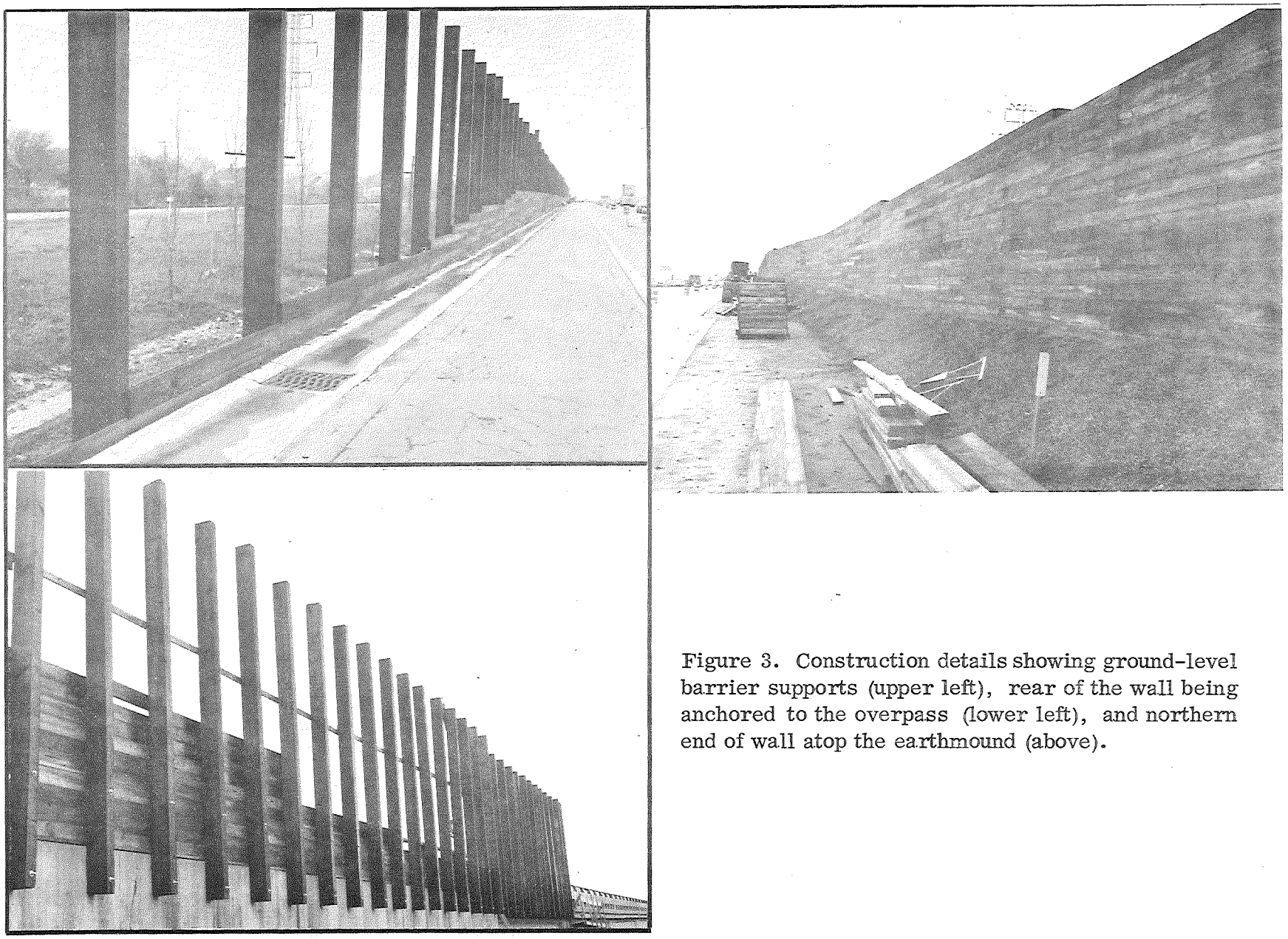


Figure 3. Construction details showing ground-level barrier supports (upper left), rear of the wall being anchored to the overpass (lower left), and northern end of wall atop the earthmound (above).

OBJECTIVE (MEASURED AND PREDICTED) NOISE LEVELS

Field noise measurements at the nearest residential property lines indicated existing (1973) L_{10} dbA noise levels of mid to high 70's. Since the Federal standard specifies a maximum of L_{10} = 70 dbA for these residential areas, it was decided that the barrier should provide at least a 10 dbA reduction at the property line equidistant from either end of the barrier. The FHWA barrier nomograph (Form 1443) was used to design the height and length of the noise wall. Calculations were made at location Sites 2 through 6, and 10 and 11 as indicated in the aerial mosaic (Fig. 4). Allowing for prediction tolerances, a height of 13-1/2 ft relative to the pavement was selected.

After construction, L_{10} noise levels were obtained by the sampling technique outlined in AASHTO's "Guide on Evaluation and Attenuation of Traffic Noise." From Site pairs 5 - 6 and 7 - 8, measurements indicated a noise fall-off rate of 4.5 dbA per distance doubling[1] for distances over 50 ft and 6 dbA per distance doubling for distances less than 50 ft. The measured barrier attenuation values were determined, relative to control Sites 1, 7, and 9, by application of these distance adjustments and a shielding adjustment (4.5 dbA per row of homes at Site 3 only). The nomograph-predicted barrier attenuation values compared reasonably well with the measured values (Table 1).

TABLE 1
PREDICTED AND MEASURED
BARRIER ATTENUATION

Site No.	Barrier Attenuation, L_{10} (dbA)	
	Predicted	Measured
2	11.0	9.5
3	6.0	9.0
4	11.5	11.5
5	11.5	9.5
10	6.0	7.5
11	3.0	0.5

[1] For example, if the noise level at 100 ft from the center of the near lane was determined to be 74.5 dbA, then at the doubled distance of 200 ft, with a fall-off rate of 4.5 dbA per distance doubling, the level would drop to 70 dbA.

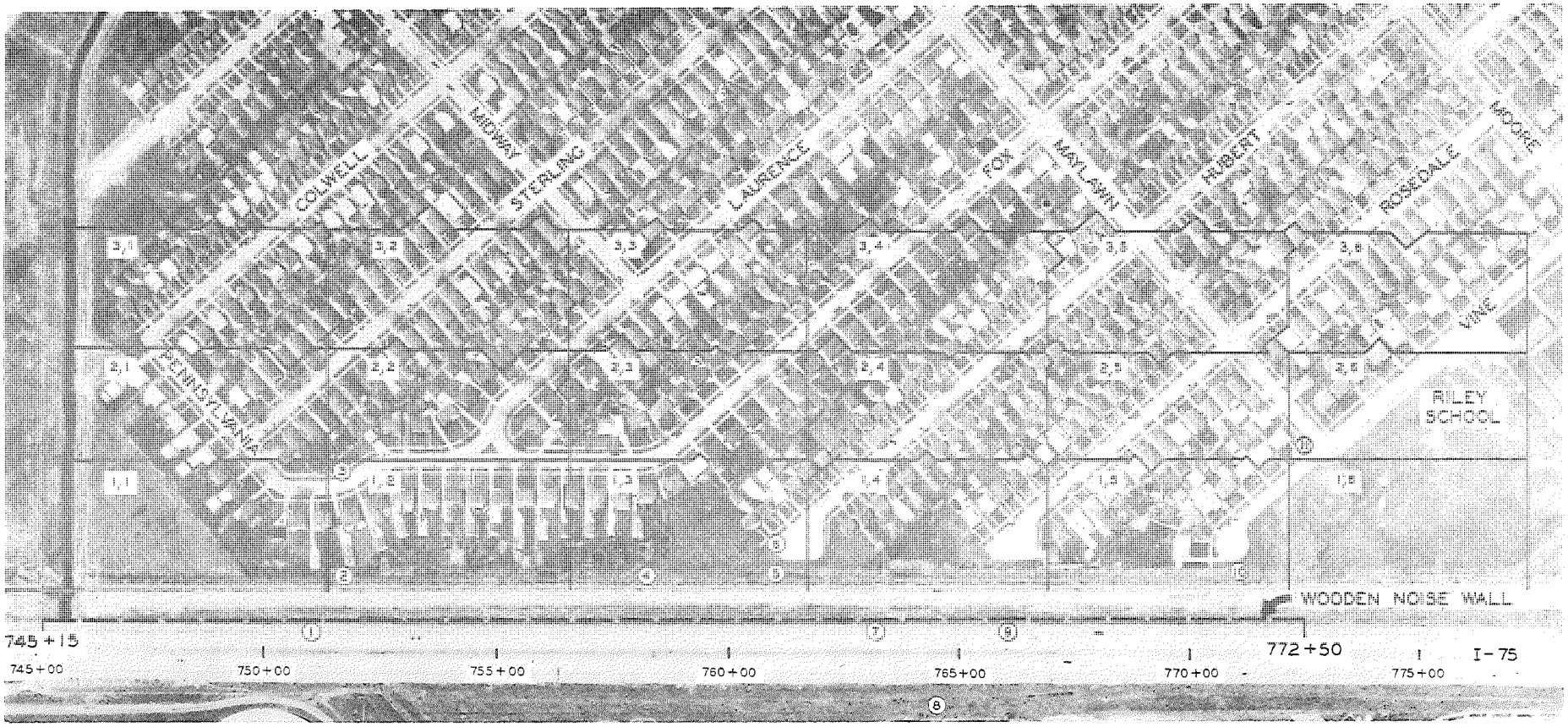


Figure 4. Barrier wall area divided into 18 cells.

RESIDENT RESPONSE TO BARRIER

After completion of the noise wall, the Department decided to determine the general response of the residents in the neighborhood behind the wall. For this purpose, a questionnaire was designed and hand delivered to each of 240 homes directly behind the barrier (Fig. 5).

Description of the Questionnaire

The first five questions pertained to personal information about each family; the length of time at the residence, the number of times per week each family utilized the freeway, and whether or not each residence had an air-conditioner. The degree of subjective effectiveness of the noise barrier was investigated relative to the above personal information.

Question six asked the resident if the I 75 traffic noise disturbed his family. If yes, the resident was asked to identify the nature of the disturbances and the time of day and week that they occurred most often. The results of this question are explained later in this report. It should be pointed out that by requiring respondents to identify the disturbance sources, one would be biasing the response to a lesser degree than with a check off list.

The purpose of question seven, was to measure the general attitude toward the barrier in terms of 11 items and activities. The respondent was asked to give a favorable, unfavorable, or no change opinion regarding each item or activity and how each has affected his family since the construction of the barrier. If the respondent had no opinion he was asked to leave that item or activity blank. The responses of those residents who moved into the neighborhood after the wall was installed were omitted from the analysis.

Questions eight and nine were designed to determine if the preceding questions were answered consistently; if so, did the answers agree with the overall opinion regarding the noise barrier. Similarly, question ten was designed to identify flaws in the barrier design concept. The last question, number eleven, was designed to allow the resident to express in his own words general attitudes toward the noise barrier and freeway annoyances.

Description of the Neighborhood

Prior to the distribution of the questionnaires, the appropriate portion of the Allen Park neighborhood was divided into 18 cells (three rows of six cells each). As illustrated in Figure 4, only 17 of the cells were populated.

STATE OF MICHIGAN

WILLIAM G. MILLIKEN, GOVERNOR

DEPARTMENT OF STATE HIGHWAYS AND TRANSPORTATION

STATE HIGHWAYS BUILDING, 425 WEST OTTAWA PHONE 517-373-2090
POST OFFICE DRAWER K, LANSING, MICHIGAN 48904

JOHN P. WOODFORD, DIRECTOR

Dear Citizen:

This letter is to request your assistance in a research investigation that we are conducting on highway vehicle noise. Last year the Department installed an experimental wooden noise barrier between your neighborhood and the I 75 expressway. Now, we would like your opinion as to the effectiveness of this noise barrier.

If you would take a few minutes to fill out the attached questionnaire and then return it to us in the enclosed envelope we would be very appreciative. Neither your name nor your property will be identified in our report but your answers to the questions could be very helpful in aiding us to develop new and effective highway noise reduction policies and procedures.

We thank you in advance for your cooperation.

Sincerely,

/s/ Gerald J. McCarthy - Deputy Director
Bureau of Highways

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

MICHIGAN The Great Lake State

Figure 5. Cover letter and noise barrier questionnaire.

Questionnaire No. _____

Date _____

1. Persons Living in Home

	Number	Ages
Male Adults	_____	_____
Female Adults	_____	_____
Children	_____	_____

2. Circle the entry above which represents the person filling out the questionnaire.

3. Length of time at this address, _____ years?

4. How many times a week do you use the nearby I 75 Expressway? _____ and for what reason(s)? _____

5. Do you have an air-conditioner in your home? Yes _____ No _____ If yes, what hours of the day is it in use? _____

6. Does the nearby I 75 Expressway disturb you in any way? Yes ___ No ___ If so, please identify the nature of the disturbance(s), the time of day, and day(s) of the week. _____

7. Since the construction of the wooden noise barrier how have the following items and activities been effected for you and your family. If you have no opinion please leave blank.

	Decreased	No Change	Increased
Salt spray	_____	_____	_____
Trash	_____	_____	_____
Headlight annoyance	_____	_____	_____
Expressway vehicle noise	_____	_____	_____
Other	_____	_____	_____

	Better	No Change	Worse
Sleep	_____	_____	_____
View	_____	_____	_____
Use of yard	_____	_____	_____
Use of TV, radio and/or stereo	_____	_____	_____
Use of porch/patio	_____	_____	_____
Relaxation	_____	_____	_____
Conversation	_____	_____	_____
Other _____	_____	_____	_____

8. Would you recommend using such a wooden noise barrier in other neighborhoods? Yes _____ No _____

9. Would you like the wooden noise barrier removed? Yes _____ No _____

10. If you could change the present wooden noise barrier, what changes would you suggest? _____

11. Make any additional remarks or comments you have in regard to the wooden noise barrier and expressway vehicle noise. _____

Figure 5 (Cont.). Noise barrier questionnaire.

The cell numbers provided a means by which to code the questionnaire before they were hand carried to each of the 240 households comprising the neighborhood. Thus, the actual location of each household within its cell was left unknown in order to preserve anonymity. The residents were asked to fill out the questionnaire at their convenience and mail it back to the Bureau of Highways Research Laboratory in the pre-addressed, stamped envelope.

Before beginning the analysis of results, cells with similarities in regard to engineering opinion and geography were grouped together to form three regions as illustrated in Figure 6.

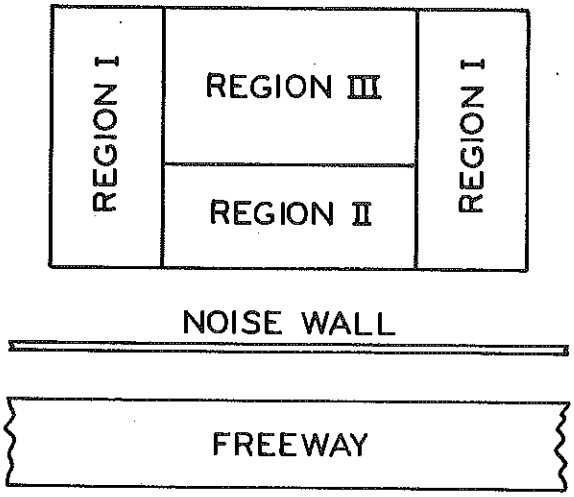


Figure 6. Sample area classification (three regions).

The grouping of the 18 cells into the three groups was based upon the author's knowledge of traffic acoustics in general. Although the northern and southern sides of the neighborhood differ in geography, they both lie at an end of the barrier and are subjected to noise barrier end-flanking to some extent. This group of cells was selected as Region I. Next, the group of cells directly behind the barrier exclusive of the end cells was anticipated to receive the most noise benefit and thus were grouped into Region II. The remaining cells comprise Region III. These three regions provided the basis of the analysis.

Of the 240 questionnaires delivered to the respondents, 130 were returned yielding a 54.2 percent response. Individual cell and row responses are tabulated in Figure 7. As expected, the residents living in the first row of cells directly behind the freeway had a higher response rate (72.3 percent) than those residents living in the back row (46.9 percent).

						TOTALS
3,1 21/12 57.1%	3,2 22/13 59.1%	3,3 16/7 43.8%	3,4 19/7 36.8%	3,5 19/5 26.3%	3,6 16/9 56.2%	113/53 46.9%
2,1 11/9 81.8%	2,2 12/8 66.7%	2,3 15/8 53.3%	2,4 20/6 30.0%	2,5 18/10 55.6%	2,6 4/2 50.0%	80/43 53.8%
1,1 5/4 80.0%	1,2 9/7 77.8%	1,3 11/8 72.7%	1,4 11/7 63.6%	1,5 11/8 72.7%	1,6 0/0	47/34 72.3%
WOODEN NOISE WALL						240/130 54.2%

a/b = NUMBER OF QUESTIONNAIRES SENT OUT/ NUMBER RETURNED

Figure 7. Questionnaire response per cell.

General Attitudes of Respondents

Before getting to the specifics, a general summary of the 130 responses to questions 3 through 6, and 8 and 9 are presented in Table 2.

TABLE 2
GENERAL QUESTIONNAIRE RESPONSE

Question No.	Event (Xi) Affecting Respondent	Responses	Conditioned Responses		
		Percent Xi of Total	Percent Disturbed Given Xi	Percent Not Disturbed Given Xi	Percent Missing Data Given Xi
3	Lived there prior to I 75	69.2	71.1	24.4	4.5
	Moved in after I 75	30.8	57.5	42.5	0.0
4	Use I 75 < 5 times/wk	48.5	69.8	27.0	3.2
	Use I 75 ⩾ 5 times/wk	51.5	64.2	32.8	3.0
5	Home air-conditioner	63.8	63.9	32.5	3.6
	No air-conditioner	35.4	71.7	26.1	2.2
	Missing data	0.8	100.0	0.0	---
8	Recommend barrier	57.7	68.0	26.7	5.3
	Don't recommend	33.1	74.4	25.6	0.0
	Missing data	9.2	33.4	66.6	---
9	Want barrier removed	13.8	61.1	38.9	0.0
	Leave barrier	73.9	70.8	25.0	4.2
	Missing data	12.3	50.0	50.0	---

Where, according to question 6, percent disturbed = 66.9
percent not disturbed = 30.0
percent missing data = 3.1

for sample size = 130

As mentioned before, question seven was designed to indicate the general opinion of all residents toward the noise barrier. The simplest statistic to measure the general attitude toward the barrier is the proportion of residents who are favorable to the noise barrier. The question is how to classify each resident as a favorable or nonfavorable person toward the noise barrier based on his response to the 11 items in question seven. It is apparent that there are many ways to do so, e.g., classify each resident as a favorable person if he has given at least six favorable responses among the 11 items. The defects of the above classification are that the number '6,' is not chosen objectively and each item in question seven is equally weighted which might not be proper since some questions may be better

measures of attitude than others. To objectively classify each resident as a favorable or nonfavorable person toward the noise barrier, the method of factor analysis was selected. This technique is generally used to reduce large sets of intercorrelated variables to a few independent factors or groups. The factor analysis also computes the correlation coefficient of each variable with each determined factor or group. This in turn indicates the strongest factor influencing each variable.

In our case, each resident is considered a variable and each group is composed of residents who have similar opinions toward the noise barrier based on the 11 items of question seven. The factor analysis indicated that there were only two distinct groups among the residents, designated as Groups 1 and 2. In examining the responses of each individual in each group, we defined strong members in Group 1 as those giving no unfavorable and at least one favorable response among the 11 items, while strong members of Group 2 gave either no opinion or at least one unfavorable response among the 11 items. Therefore, each member in Group 1 can be considered as a favorable resident toward the noise barrier, while each member in Group 2 was considered to be a nonfavorable resident. Based on this classification scheme, the proportion of residents in each region who are favorable to the noise barrier are presented in Table 3. It should be noted that only 112 of the 130 returned questionnaires were used in the factor analysis since the method requires a complete set of answers to the 11 parts of question number seven.

TABLE 3
FAVORABLE VERSUS TOTAL RESPONDENTS
(Three Regions)

Region	Total Respondents	Favorable Respondents	Percent Favorable
I	31	11	35.4
II	25	19	76.0
III	56	26	46.4
Total	112	56	50.0

Table 3 shows that when all regions are combined, 50 percent of the residents are favorable to the noise barrier. As expected, the residents directly behind the barrier (Region II) who objectively benefited most from its construction, delivered a higher percentage of favorable responses. At this point it was desirable to know whether the differences in favorable per-

centages among the three regions could be considered statistically significant. The typical Chi-square test was used for this purpose. At the 0.05 significance level, the three region samples could not be considered as belonging to the same population. In other words, the observed differences were significantly different. Our interpretation was that the high sample percentage of favorable responses in Region II suggests that this region is characterized by a more positive attitude toward the barrier even though not all households returned a questionnaire. While the residents in Regions I and III had about the same general attitude toward the noise barrier, the residents in Region II were distinctly more favorable. Because the difference is statistically significant, we expect that similar results would be obtained with other sample surveys.

Since Region I comprises the cells along the sides of the neighborhood it was felt that another approach would be to look at each side of the neighborhood separately. The barrier extends southerly along the northwest side of I 75 and continues up onto six spans of the Goddard Rd bridge as shown on the map in Figure 4. Thus, the barrier stops on the incline of the hill which incidently is where the neighborhood ends. The residents in the homes near this end of the barrier are subjected to more truck noise, because of end-flanking, than those residents in the rear of Region III. We designated this as Region IB. On the northern end of Region I there is a school with a large play area and the freeway on this end is depressed, and is designated IS. An illustration of the four region approach is given in Figure 8.

This splitting of Region I into IB and IS resulted in the values shown in Table 4.

TABLE 4
FAVORABLE VERSUS TOTAL RESPONDENTS
(Four Regions)

Region	Total Respondents	Favorable Respondents	Percent Favorable
IS	10	4	40.0
IB	21	7	33.3
II	25	19	76.0
III	56	26	46.4
Total	112	56	50.0

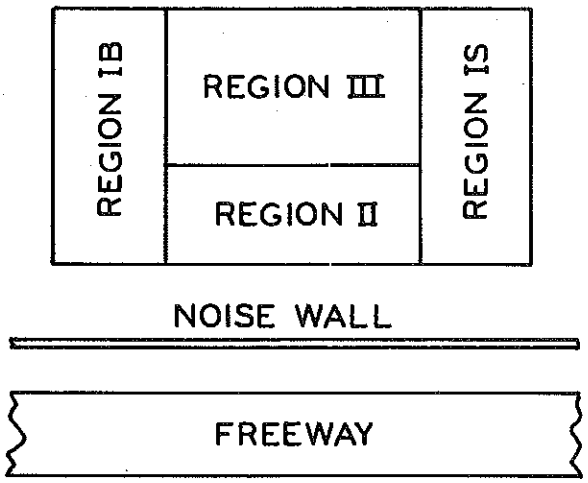


Figure 8. Sample area classification (four regions).

Based upon our definition of general attitude, there are only two attitude regions; namely, Region II and the remainder. However, since many of the residents did not completely answer question seven, a statistical determination of which of the 11 items and activities contributed to the difference between Region II, and Regions I and III, could not be made. Nevertheless, Table 5 does provide some indication of the general attitudes.

Each respondent was also asked to provide general background information about himself and his family. This information helped to confirm and understand the general attitudes mentioned previously in determining the effectiveness of the noise barrier in abating highway disturbances.

The average age of the respondent is 43 and he has lived in the neighborhood about 13-1/2 years. The average resident moved into the neighborhood a few years before the freeway was opened to traffic (1966). Thus, this fairly high degree of resident continuity established a basis for a 'before' and 'after' attitude comparison. The continuity breakdown by Regions is shown in Table 6.

The residents living on both ends (Region I) and directly behind the noise barrier (Region II) are slightly younger and more mobile than the residents living in the center of the neighborhood (Region III).

TABLE 5
RESULTS FOR QUESTIONNAIRES WITH COMPLETE QUESTION 7 BY REGION

Item or Activity	Region	Respondents With Positive Responses To All 11 Items Of Question 7		
		Total Respondents	Favorable Respondents	Percent Favorable Respondents
Salt Spray	II	4	4	100.0
Decreased	I, III	5	2	40.0
	Total	9	6	66.7
Trash	II	5	4	80.0
Decreased	I, III	6	4	66.7
	Total	11	8	72.7
Headlight	II	11	10	90.9
Annoyance	I, III	9	5	55.6
Decreased	Total	20	15	75.0
Freeway	II	21	19	90.5
Vehicle Noise	I, III	46	31	67.4
Decreased	Total	67	50	74.6
Sleep	II	16	16	100.0
Better	I, III	34	32	94.1
	Total	50	48	96.0
View	II	8	7	87.5
Better	I, III	21	11	52.4
	Total	29	18	62.1
Use of Yard	II	12	12	100.0
Better	I, III	20	18	90.0
	Total	32	30	93.8
Use of T.V.,	II	12	12	100.0
Radio and/or	I, III	16	14	87.5
Stereo	Total	28	26	92.9
Better				
Use of	II	11	11	100.0
porch/patio	I, III	21	17	81.0
Better	Total	32	28	87.5
Relaxation	II	13	13	100.0
Better	I, III	32	29	90.6
	Total	45	42	93.3
Conversation	II	17	17	100.0
Better	I, III	33	28	84.9
	Total	50	45	90.0

TABLE 6
AVERAGE AGE AND AVERAGE LENGTH OF TIME
AT THE ADDRESS FOR EACH REGION

Region	Average Respondent Age, years	Average Length of Time at Address, years
I	38.4	12.8
II	42.9	13.3
III	46.1	14.2
Total	43.3	13.6

Results for questions other than seven are given in Table 7 for each region.

Respondent Comments

Questions ten and eleven were provided to afford the respondents an opportunity to express their thoughts on the wooden noise wall and on freeway vehicle noise. It was thought that a sampling of their comments would be beneficial to the reader. As a result, the following quotes are listed:

"I would make it higher and longer so it would extend across the bridge. ...I must say the present barrier has cut the noise a great deal. It was well worth the experiment and we thank you." (Cell 2, 3)

"Such beautiful rustic beauty put in your backyard ... stop wasting the taxpayers money." (Cell 2, 3)

"The wall as we call it is ugly to look at but it has helped keep down the noise of trucks to some extent. ...We are bothered much more with the train sounds now than the trucks or traffic from I 75." (Cell 1, 3)

"Plant a row of trees or shrubbery. Possibly enforce speed limit and check vehicles for excessive noise." (Cell 1, 4)

"Until something is done about open mufflers on the x-way, I don't think anything will do much good to abate the noise..." (Cell 1, 5)

TABLE 7

RESULTS OF QUESTIONS 3 THROUGH 6, 8 AND 9 BY REGION

Question	Region	Respondents With Positive Responses To Questions 3 Through 6, 8 And 9		
		Total Respondents	Favorable Respondents	Percent Favorable Respondents
Question 3:				
Moved into neighborhood before freeway was opened to traffic.	II	21	17	81.0
	I, III	61	27	44.3
	Total	82	44	53.8
Moved into neighborhood after freeway was opened to traffic.	II	4	2	50.0
	I, III	26	10	38.5
	Total	30	12	40.0
Question 4:				
Use freeway less than 5 times per week.	II	10	7	70.0
	I, III	43	20	46.5
	Total	53	27	50.9
Use freeway 5 or more times per week.	II	15	12	80.0
	I, III	44	18	40.9
	Total	59	30	50.8
Question 5:				
Have air-conditioner in home.	II	12	11	91.7
	I, III	59	26	44.1
	Total	71	37	52.1
Do not have air-conditioner in home.	II	13	8	61.5
	I, III	28	11	39.3
	Total	41	19	46.3
Question 6:				
I 75 expressway is disturbing.	II	22	16	72.7
	I, III	58	20	34.5
	Total	80	36	45.0
I 75 expressway is not disturbing.	II	3	3	100.0
	I, III	27	16	59.3
	Total	30	19	63.3
Question 8:				
Recommend barrier in other neighborhoods.	II	17	17	100.0
	I, III	50	29	58.0
	Total	67	46	68.7
Do not recommend barrier in other neighborhoods.	II	8	2	25.0
	I, III	27	3	11.1
	Total	35	5	14.3
Question 9:				
Remove present barrier.	II	3	1	33.3
	I, III	13	2	15.4
	Total	16	3	18.8
Do not remove present barrier.	II	20	18	90.0
	I, III	63	31	49.2
	Total	83	49	59.0

"...Trucks and cycles come out from behind the wall (bridge end) as if they were shot out of a cannon..." (Cell 2, 1)

"...However small a help, it is an attempt to satisfy our needs, and I personally do appreciate it. So often we little people are completely ignored." (Cell 1, 3)

These are just a few of the many diversified comments made by the respondents and they help to illustrate the difficulty in relating subjective attitudes to traffic noise.

Questionnaire Conclusions

As a result of testing at the 0.05 significance level, one major conclusion can be made:

By observation of the acoustically related items of Table 5, it can be inferred that the Region II respondents do indeed receive more noise abatement benefits from the noise barrier than do those from Regions I and III.

Several other conclusions result from Table 7:

Favorable attitudes toward the barrier wall do not depend upon:

1) length of occupancy,
2) the frequency with which the respondent uses the freeway,
3) whether the home is air-conditioned.

Favorable attitudes toward the barrier, however, do depend upon whether the respondent is in any way bothered by the freeway.

If a resident was not bothered by highway disturbances, he tended to have a favorable opinion toward the effectiveness of the noise barrier. All of the residents living directly behind the barrier (Region II) who indicated they were not bothered by the freeway had a favorable attitude toward the noise barrier. Conversely, if a Region I or III resident was bothered by highway disturbances, he tended to have an unfavorable opinion of the barrier, while a disturbed resident of Region II tended to have a favorable opinion of the effectiveness of the barrier. This suggests that the barrier did reduce noise impact enough to significantly change the attitude of the Region II residents towards highway vehicle noise but did not change the attitude of the Region I and III residents. Those residents who are disturbed by the highway indicated that faulty truck mufflers and tires are the prevalent source of annoyance, particularly during the evening hours and on weekends—times of family relaxation.

As mentioned in the discussion of question seven, 50 percent of all residents had a favorable opinion toward the effectiveness of the noise barrier in abating highway disturbances. In determining if the respondents answered all of the questions consistently, the results of questions 8 and 9 concerning the recommendation of noise barriers for other neighborhoods and the retention of the barrier itself were analyzed.

Clearly, there is a significant difference in attitude between those who recommend and those who do not recommend noise barriers in other neighborhoods.

For those residents who did not want the noise barrier removed, 59 percent had a favorable attitude toward its effectiveness in abating highway disturbances. However, only 19 percent of those residents who wanted the barrier removed had a favorable attitude toward the barrier. Again, this represents a significant difference between the favorable attitude proportions for the two groups. Thus, there appears to be moderate consistency in the manner in which people answered the questionnaire. Although not supported by the data of this survey, this author feels that it could be consistent for an individual to not want a barrier in his neighborhood yet recommend it for others.

We also found the residents to be consistent in regard to their location in the neighborhood. All of the residents in Region II who recommended the barrier in other neighborhoods had a favorable attitude toward the effectiveness of the noise barrier. However, 58 percent of the residents in the other Regions who recommended barriers had a favorable attitude. Ninety percent of the Region II residents who wanted the present barrier to remain had a favorable attitude toward the noise barrier. The consistency shown by Region II in questions eight and nine was also apparent in the other questions. Previously, we found the Region II residents to be more motivated toward returning the questionnaires and found 76 percent of these residents had a favorable attitude toward the barrier. Now, we find these residents to have strong feelings regarding the noise barrier and can conclude that Region II residents are highly consistent in their responses to the questionnaire.

The respondents were also asked to suggest what changes they would make with the present noise barrier if they could. Many residents from the bridge side of the neighborhood suggested that the barrier be extended farther south for the purpose of blocking out truck disturbances. When asked to make additional remarks regarding the barrier and freeway noise, the general comments indicated the noise barrier has been of help in decreasing highway disturbances. However, the neighborhood's situation is far from ideal.

CONCLUSIONS AND RECOMMENDATIONS

From Table 1 we conclude that the wooden noise barrier did reduce the L_{10} dbA noise levels at the nearest residential property lines to less than the $L_{10} = 70$ dbA Federal Noise Standard (FHPM 7-7-3) as planned.

Also, the design methods of determining barrier height and length for a given attenuation level appear satisfactory on a purely objective noise level basis.

The results of the questionnaire, however, indicate a need for improved esthetic design and landscaping of noise walls, vehicle noise control laws, and enforcement.

It is recommended that similar evaluations be performed on other types of noise barriers, i.e., concrete walls, steel panel walls, and earth mounds to determine the most esthetically pleasing noise barrier that is effective and economical for our use.

This research is not meant to imply that barriers are a superior solution to the vehicle noise problem; however, noise barriers must serve this purpose until effective and enforced vehicle noise control legislation can be implemented.