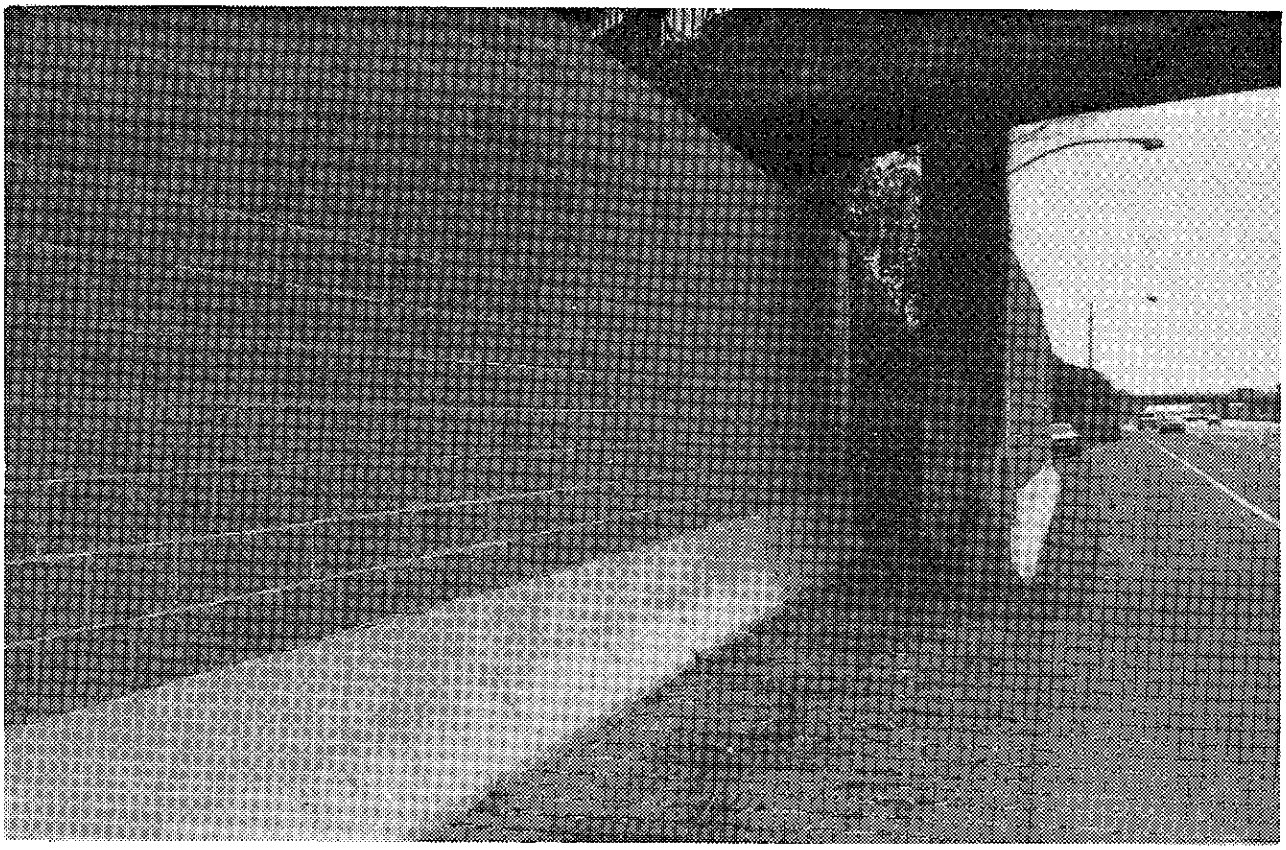
REPORT NO. CA/TL-80/19

MAINTENANCE ACCESS FOR NOISE BARRIERS



FINAL REPORT

JUNE, 1980

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16. ABSTRACT

This study evaluates the acoustical properties of two unrestricted openings with overlapped walls which provided maintenance access through sound barriers. One opening was treated with sound absorptive cladding and a second with a redwood baffle system to minimize reflected noise that passed through the opening.

The test data indicated the openings were properly designed and the noise levels at the closest residences did not increase as a result of the opening. As expected, the noise levels near the openings were high but rapidly decreased as distances from the openings were increased.

Sound absorptive cladding placed at one opening appeared to reduce noise levels by about 3 dBA. The redwood baffle placed at a second location did not appear to help.

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

June 1980

TL No. 604190

MAINTENANCE ACCESS FOR NOISE BARRIERS

Study Made by ..... Enviro-Chemical Branch
Noise, Vibration and
Energy Research and
Development Section

Under the Supervision of ..... Earl C. Shirley, P.E.

Principal Investigator ..... Mas M. Hatano, P.E.

Report Prepared by ..... Mas M. Hatano, P.E.

Field Work Supervised by ..... Rudy Hendriks

APPROVED BY

NEAL ANDERSEN
Chief, Office of Transportation Laboratory

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Virginia Dong (TransLab)
Hossein Mojtahedi (TransLab)
Roger Smith (TransLab)

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CONVERSION FACTORS

English to Metric System (SI) of Measurement

Quanity	English unit	Multiply by	To get metric equivalent
Length	inches (in)or(")	25.40 .02540	millimetres (mm) metres (m)
	feet (ft)or(')	.3048	metres (m)
	miles (mi)	1.609	kilometres (km)
Area	square inches (in^2) square feet (ft^2) acres	6.432×10^{-4} .09290 .4047	square metres (m^2) square metres (m^2) hectares (ha)
Volume	gallons (gal) cubic feet (ft^3) cubic yards (yd^3)	3.785 .02832 .7646	litres (l) cubic metres (m^3) cubic metres (m^3)
Volume/Time			
(Flow)	cubic feet per second (ft^3/s)	28.317	litres per second (l/s)
	gallons per minute (gal/min)	.06309	litres per second (l/s)
Mass	pounds (lb)	.4536	kilograms (kg)
Velocity	miles per hour(mph) feet per second(fps)	.4470 .3048	metres per second (m/s) metres per second (m/s)
Acceleration	feet per second squared (ft/s^2)	.3048	metres per second squared (m/s^2)
	acceleration due to force of gravity(G)	9.807	metres per second squared (m/s^2)
Weight Density	pounds per cubic (lb/ft^3)	16.02	kilograms per cubic metre (kg/m^2)
Force	pounds (lbs) kips (1000 lbs)	4.448 4448	newtons(N) newtons (N)
Thermal Energy	British thermal unit (BTU)	1055	joules (J)
Mechanical Energy	foot-pounds(ft-lb) foot-kips (ft-k)	1.356 1356	joules (J) joules (J)
Bending Moment or Torque	inch-pounds(ft-lbs) foot-pounds(ft-lbs)	.1130 1.356	newton-metres (Nm) newton-metres (Nm)
Pressure	pounds per square inch (psi) pounds per square foot (psf)	6895 47.88	pascals (Pa) pascals (Pa)
Stress Intensity	kips per square inch square root inch (ksi $\sqrt{in}$)	1.0988	mega pascals $\sqrt{metre}$ (MPa $\sqrt{m}$)
	pounds per square inch square root inch (psi $\sqrt{in}$)	1.0988	kilo pascals $\sqrt{metre}$ (KPa $\sqrt{m}$)
Plane Angle	degrees (°)	0.0175	radians (rad)
Temperature	degrees fahrenheit (F)	$\frac{tF - 32}{1.8} = tC$	degrees celsius (°C)

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INTRODUCTION

The California Department of Transportation (Caltrans) initiated the Community Noise Program in 1974 to reduce traffic noise impacts on communities by retrofitting noise barriers to existing highways. This program was formalized by California State law on September 18, 1978 (Section 215.5 of the Streets and Highways Code). It is not a federally mandated program but matching funds are provided where projects qualify. Barriers are also included with construction of new highways where they meet state or federal requirements.

Caltrans has constructed about 50 miles of noise barriers to date. It appears that this program will continue because it is mandated by law and most people desire to have a reasonably quiet environment.

One problem which has developed in a number of cases is the need to provide maintenance access through noise barriers. Unless properly designed, openings in the barrier could affect acoustical performance. Solid wood gates have been used to close openings to insure continuity of the noise barrier but are not aesthetically pleasing and are expensive.

Other barriers have been constructed with overlapped walls and unrestricted openings. The designers of the overlapped walls have often asked how much of an overlap is required for a given opening so acoustical properties are not affected.

District 03 designed a wall on Road 03-Sac-99-21.9/22.5 in Sacramento (Figure 1). The purpose of this noise barrier project was to reduce noise levels for the residents next

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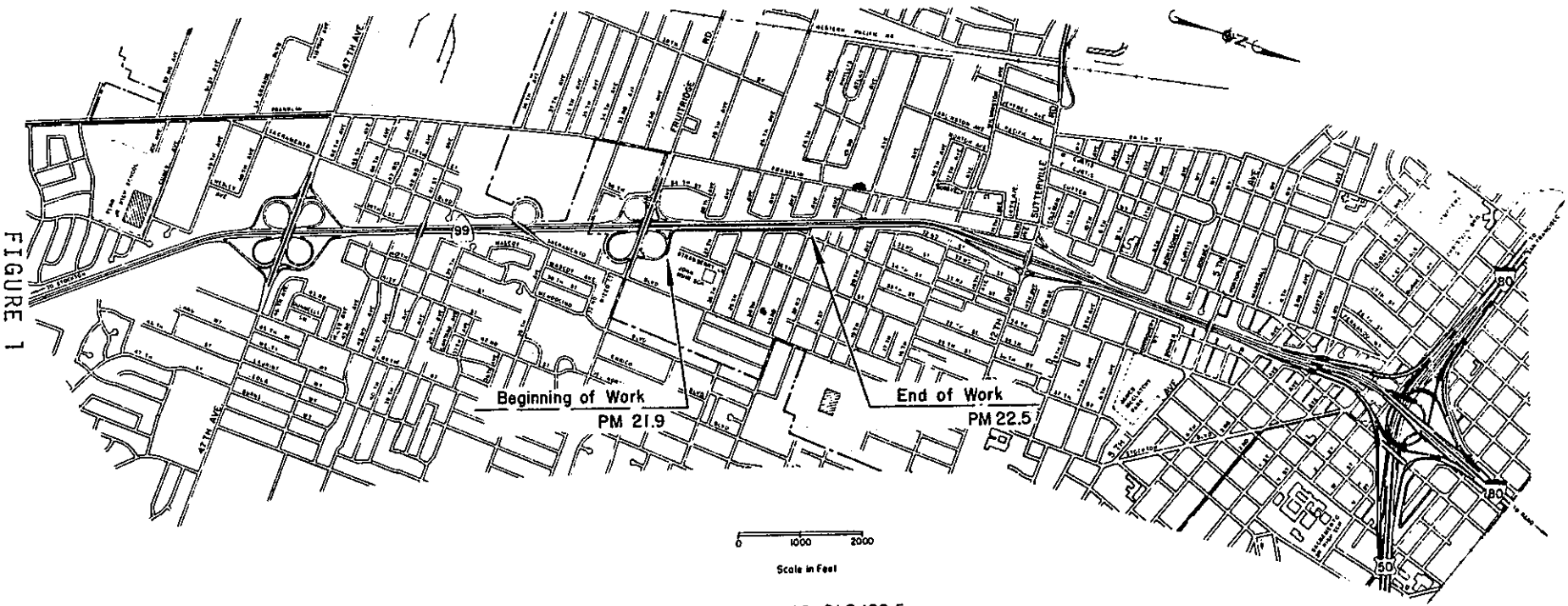
IN SACRAMENTO COUNTY IN SACRAMENTO
FROM FRUITRIDGE ROAD OVERCROSSING TO 23RD AVENUE



03-Sac-99-21.9/22.5

Length of Work = 0.6 mile

FIGURE 1

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to the freeway and at the nearby John Muir Elementary School. Two maintenance access openings were designed into the wall. These were overlapped openings (Figures 2 and 3). One access opening was treated with sound absorbent cladding and the second with a wood baffle system. These were experimental in nature and their purpose was to reduce reflected noise through the openings.

This report presents the study which evaluated the constructed wall openings and their acoustical performance. The study also evaluated the effectiveness of treating the openings to minimize reflected noise.

OBJECTIVES

1) Determine noise levels before construction of noise barriers near the overlapped openings.

2) Determine noise levels after construction of noise barriers at the same locations as Item 1.

3) Determine noise levels after one opening is treated with acoustically absorbent cladding.

4) Determine noise levels after the second opening is treated with a redwood baffle system.

5) Develop criteria for designing maintenance access opening in barriers by overlapping.

6) Estimate additional costs of barrier construction due to overlapping.

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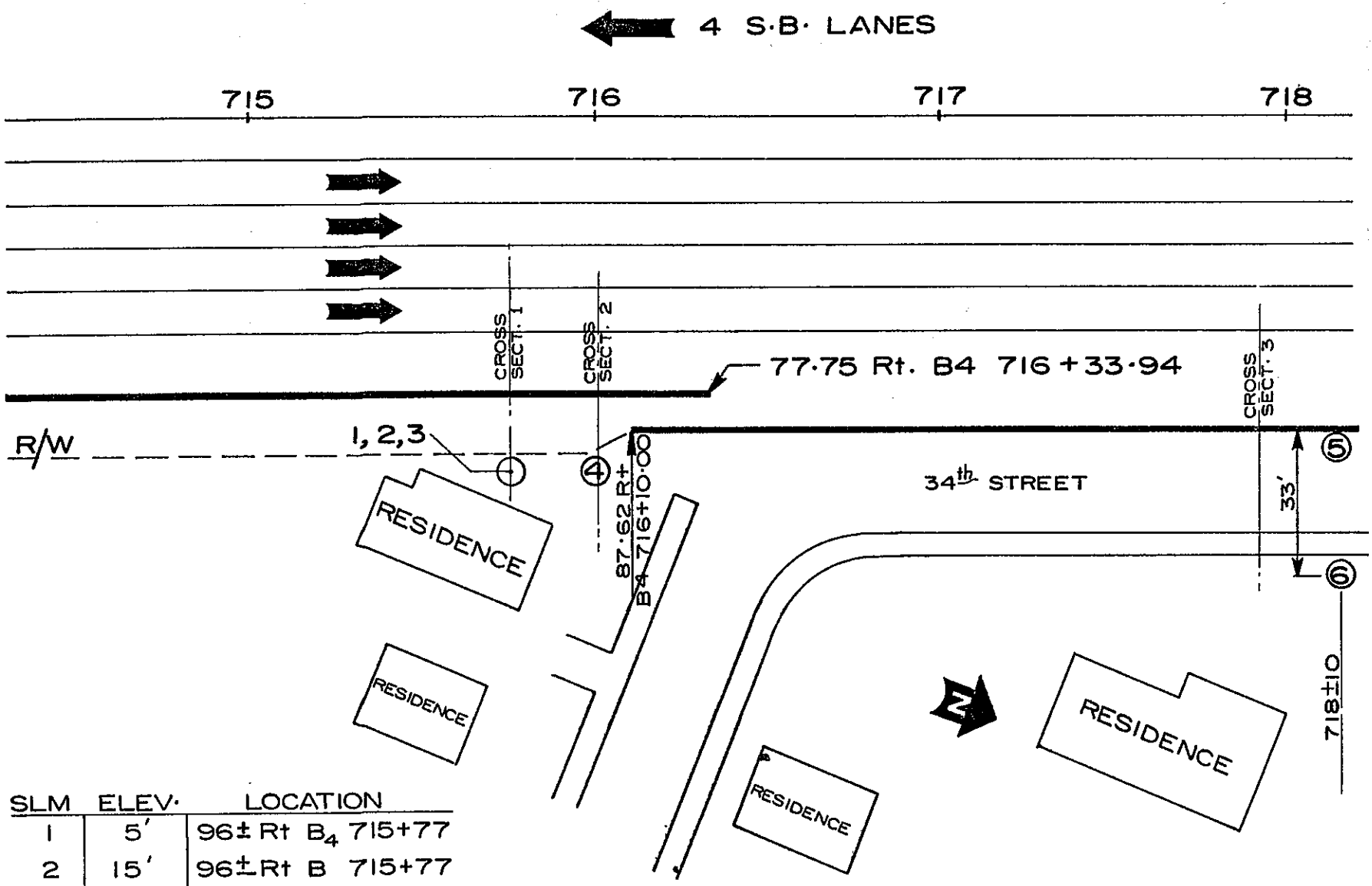

SLM	ELEV·	LOCATION
1	5'	96± Rt B_4 715+77
2	15'	96± Rt B 715+77
3	23·5'	96± Rt B 715+77
4	5'	96± Rt B 716+02
5	23'	89± Rt B 718+10
6	5'	121± Rt B 718+10

SITE 1

BARRIER OPENING

NO SCALE

Figure 2

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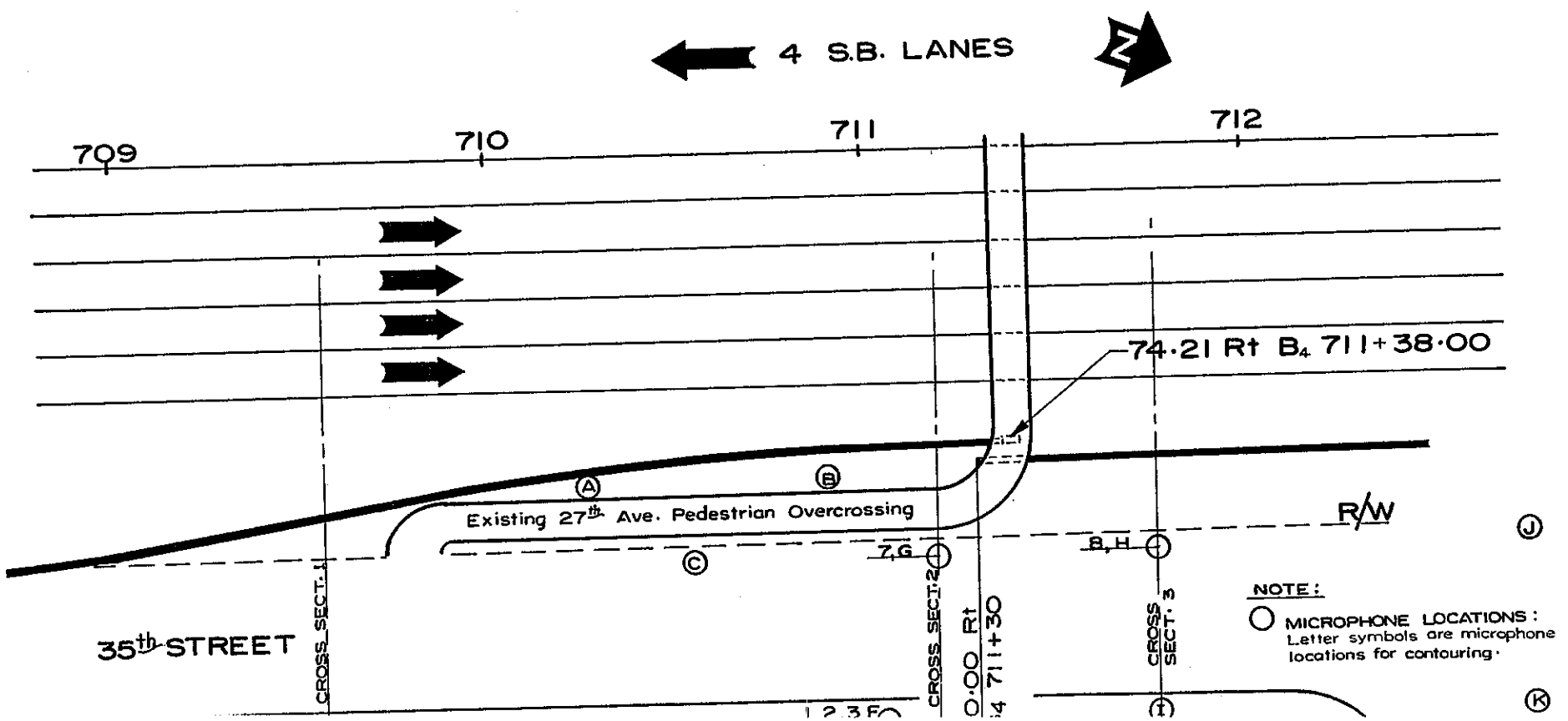

Figure 3

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CONCLUSIONS

1) There is a degradation in acoustical properties of noise barriers when maintenance access openings are constructed. However, the high noise levels are concentrated near the opening and diminish rapidly as distance from the opening increases. Therefore, the locations of the receiver, the noise source, and the barrier opening position are determining factors in designing barrier openings and assessing impact.

2) The design of the barrier and opening for one site on this project, using an opening-overlap ratio of 2.4 and sound absorbing cladding, was successful. The after-construction noise level at the nearest residence, about 45 feet from the opening, was about the same as it would have been if there were no opening.

The noise level before barrier construction at this site was about 77 dBA, Leq, and after construction it was about 63.

3) The design of the maintenance access for a second site on this project using an opening-overlap ratio of 2.0 and redwood baffles also appeared to be adequate, but could not be fully evaluated because of noise reflections from a pedestrian overcrossing directly over the opening.

4) The use of sound absorptive cladding at one maintenance access indicated noise reductions of about 3 dBA, Leq, were achieved. The use of a redwood baffle at the second opening did not appear to minimize noise passing through the opening.

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5) The cost of the maintenance access at one site was $4,632.00 for the overlapped opening plus $5,603.29 for the cladding for a total of $10,235.29. The cost at a second site was $1,731.00 for the opening plus $1,367.41 for the redwood baffle for a total of $3,098.41.

IMPLEMENTATION

Copies of this report will be given widespread distribution to all Districts, the Federal Highway Administration (FHWA) and local agencies to provide guidance in designing barriers with a maintenance access opening using the overlap method.

BENEFITS

The results of this study will provide information for effectively designing maintenance access openings from a cost and acoustical effectiveness standpoint.

PROJECT DESCRIPTION

Highway 99 is an eight-lane freeway at the study location. It is one of two major north-south highways in California which connect the southern and northern parts of the state. The terrain is level through this area and the highway cuts through a residential area in the south part of Sacramento.

The barrier constructed adjacent to Highway 99 is about 2,650 feet long and is 10.8 to 16.7 feet high. Masonry blocks were

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used for the wall and it was placed on concrete piles and Type 27 concrete crash barrier (Figure 4) through most of the project.

MAINTENANCE OPENINGS

The maintenance openings which were previously mentioned are shown in Figures 2 and 3. They are identified as Site 1 near Station 716±20 and Site 2 near Station 711±38 (pedestrian overcrossing). Site 1 has an opening about 10 feet wide and the wall overlapped about 24 feet. Site 2 has an opening about 5 feet wide and the wall is overlapped about 10 feet.

Both openings were treated to minimize reflected noise passing through the openings. The opening at Site 1 was treated with a sound absorptive cladding on both faces. Basically, the cladding is a 4 inch x 2 foot x 12 foot panel constructed with perforated sheet metal over fiberglass. The details of the cladding are shown in Figures 5 and 6. Site 2 was treated with a redwood baffle on one face of the opening. The details of this treatment are shown on Figures 7 and 8.

The contract costs for the treatment are shown in Table I.

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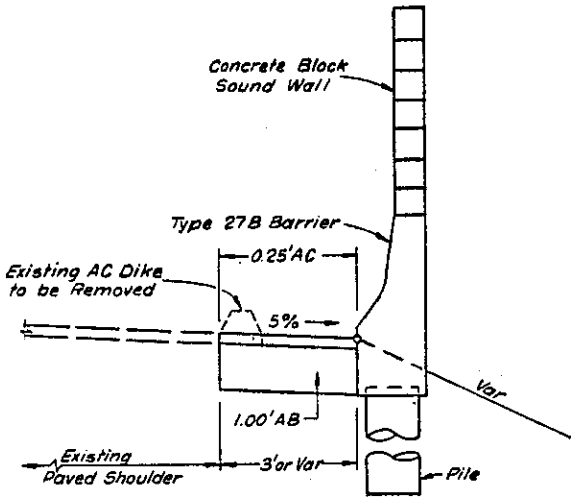
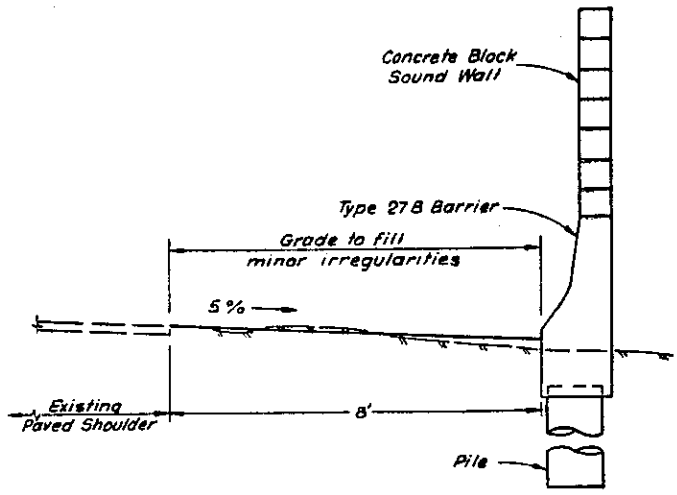


Rt. 709 + 50 to Rt. 711 + 36
Rt. 720 + 00 to Rt. 724+50



SBW No 2 Rt. 711 + 30 to Rt. 716 + 35

TYPICAL SECTIONS

No Scale

FIGURE 4

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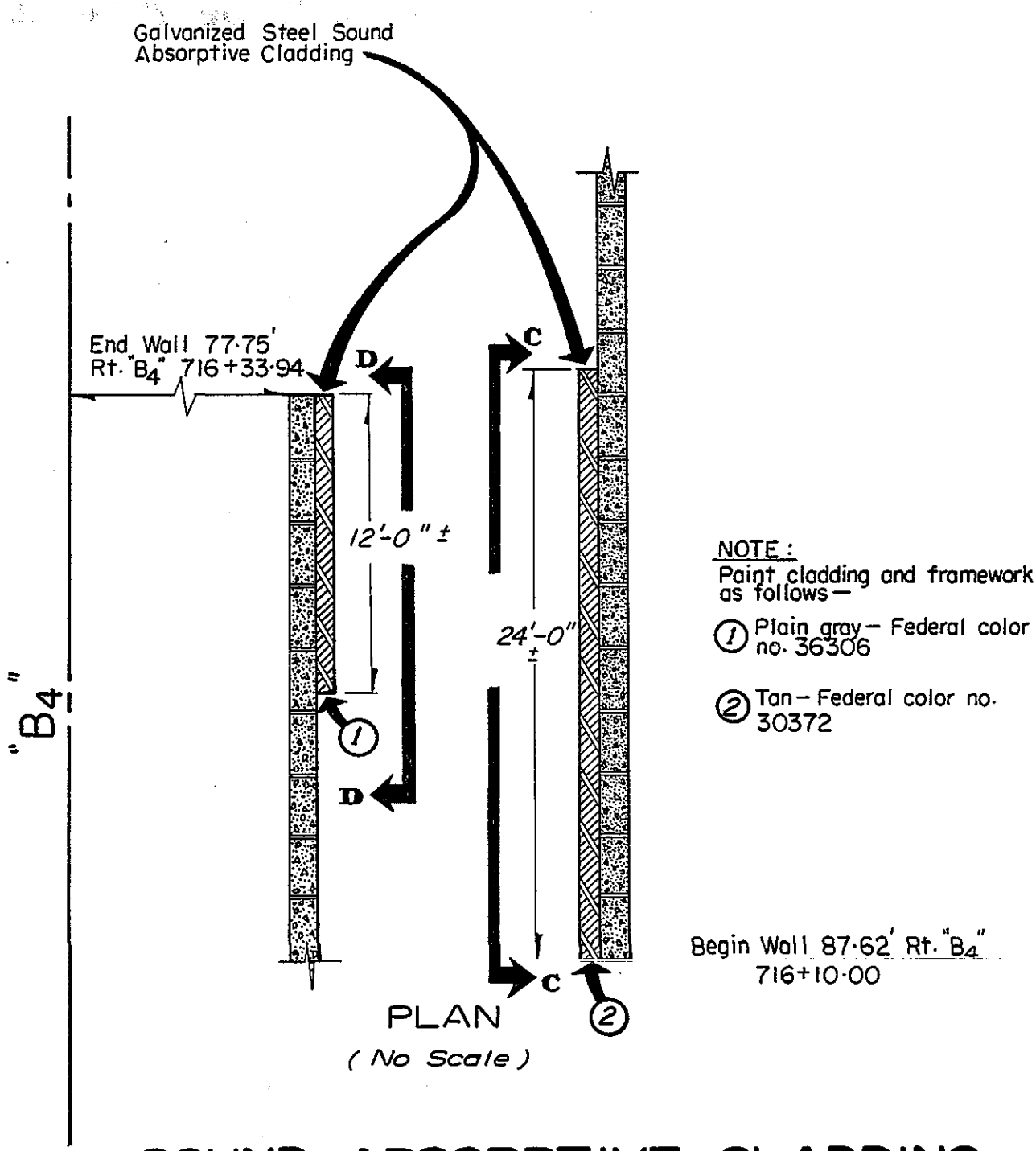

SOUND ABSORPTIVE CLADDING

FIGURE 5

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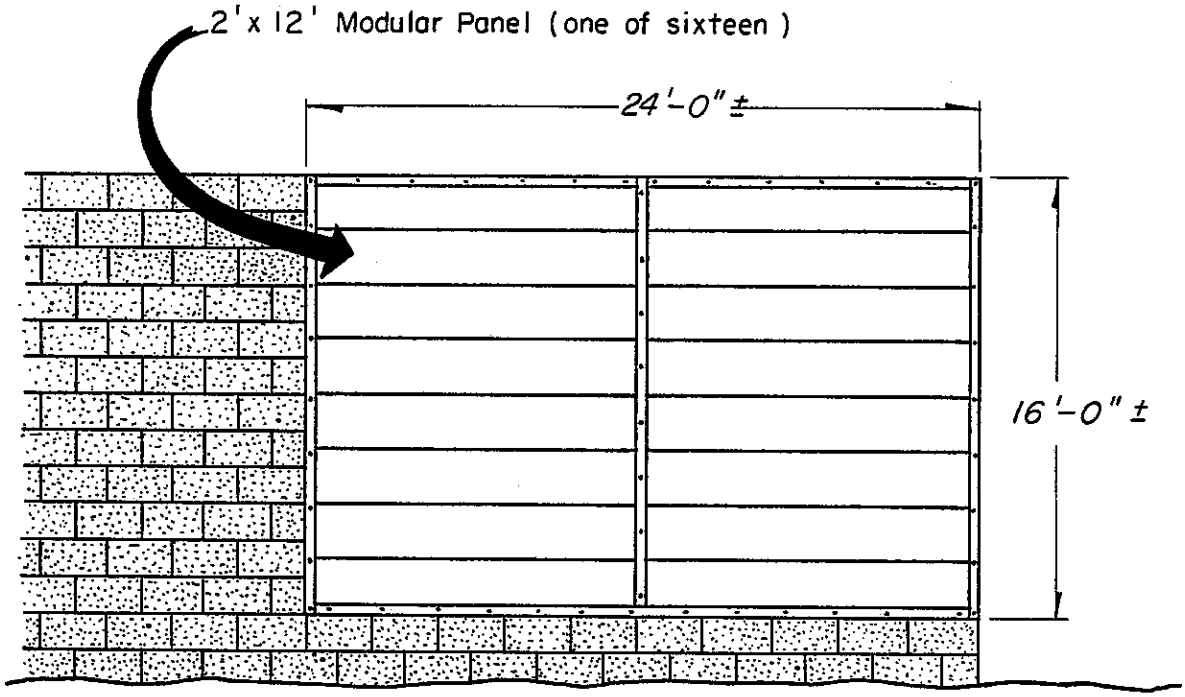
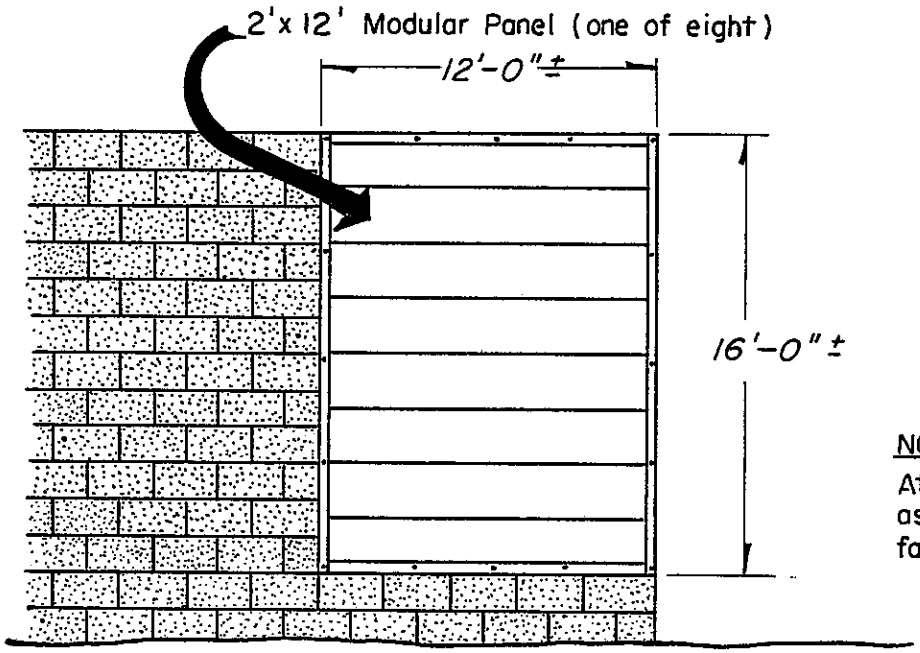


ELEVATION: SECTION C—C
(no scale)



NOTE:
Attach cladding to wall as specified by manufacturer.

ELEVATION: SECTION D—D
(no scale)

SOUND ABSORPTIVE CLADDING

FIGURE 6

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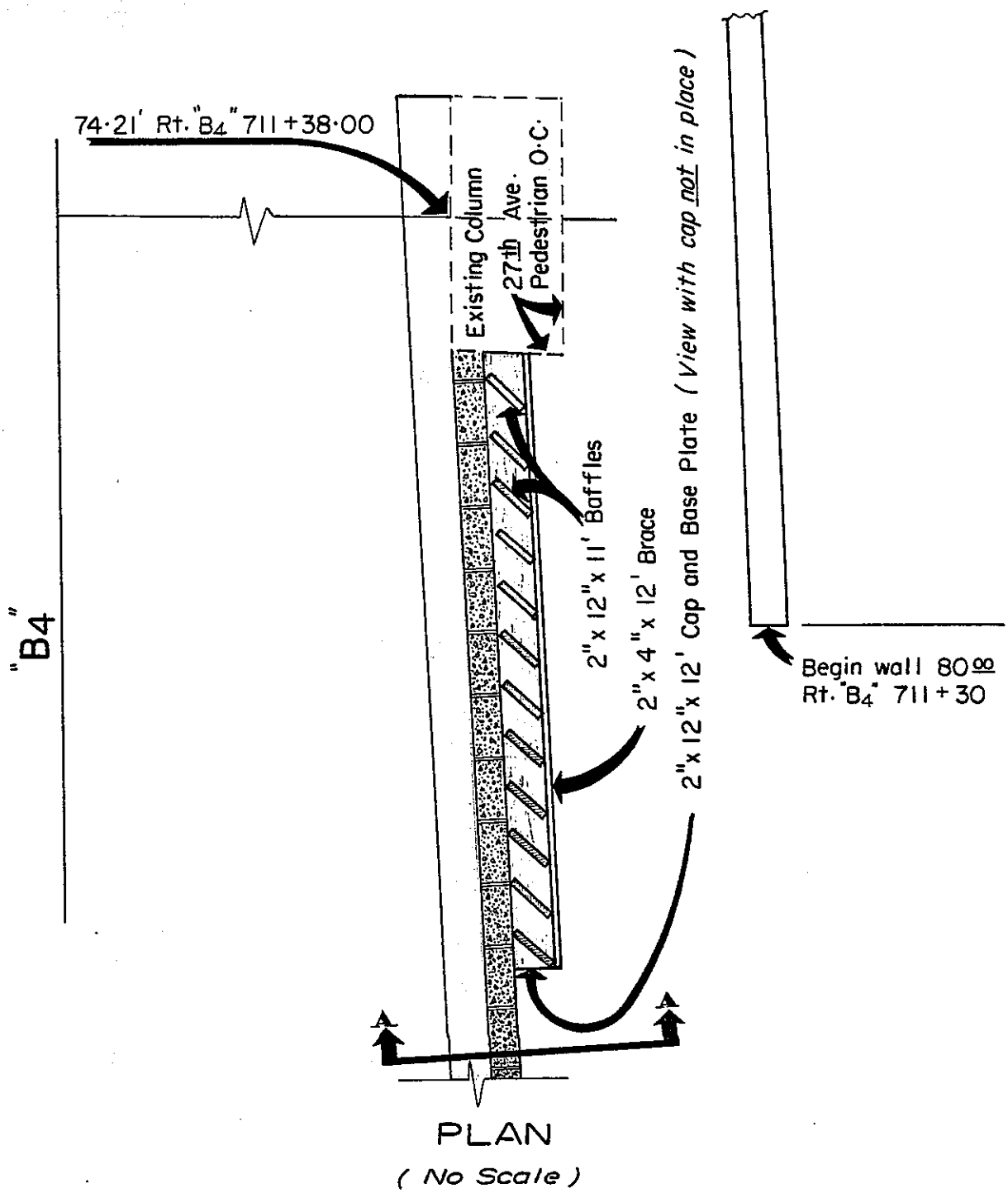

REDWOOD BAFFLE

FIGURE 7

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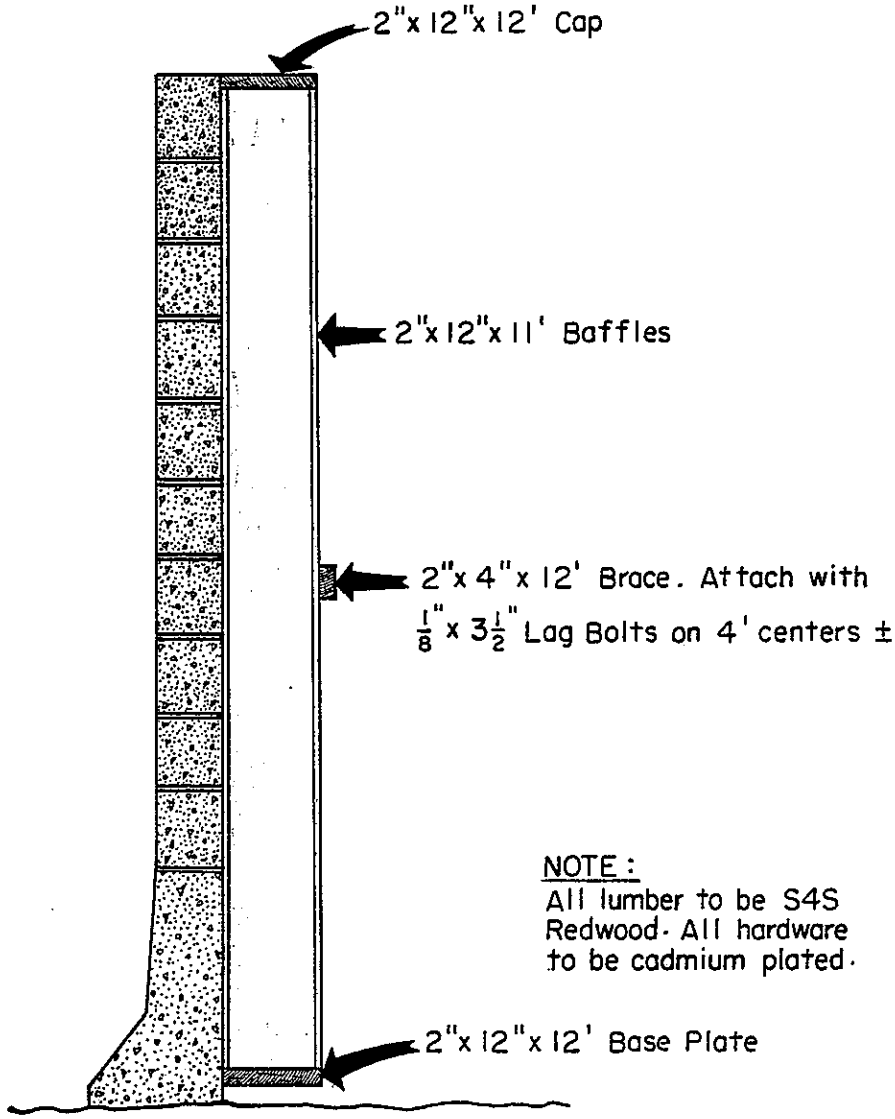

SECTION A–A
(no scale)

REDWOOD BAFFLE

FIGURE 8

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TABLE I

Barrier Opening Treatment Costs

	Absorptive Cladding (Site 1)	Redwood Baffle (Site 2)
Materials	$ 4,450.40	$ 467.18
Labor	1,152.89	900.23
Total	$ 5,603.29	$ 1,367.41

TRAFFIC DATA

A summary of the traffic counts made during the study period are shown in Appendix A. Most of the counts coincided with the time that the noise measurements were performed. However, some additional traffic counts performed for other studies are included as additional information because they were taken during the same time period as this study.

Figure 9 shows a plot of the traffic data. The trend appears to indicate a slight drop in traffic from June 20, 1979 to May 6, 1980. This may be due to more traffic using the parallel freeway, I-5, which was opened in October, 1979. I-5 also passes through Sacramento about three miles to the west. Other reasons for the decrease may be increasing fuel costs or seasonal effects.

Traffic speeds normally ranged between 55 and 60 miles per hour. An average speed of 57 miles per hour was used for calculation purposes. A radar unit was used to obtain vehicle speed.

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TRAFFIC COUNTS

Highway 99 Near Fruitridge Road

03-Sac-99

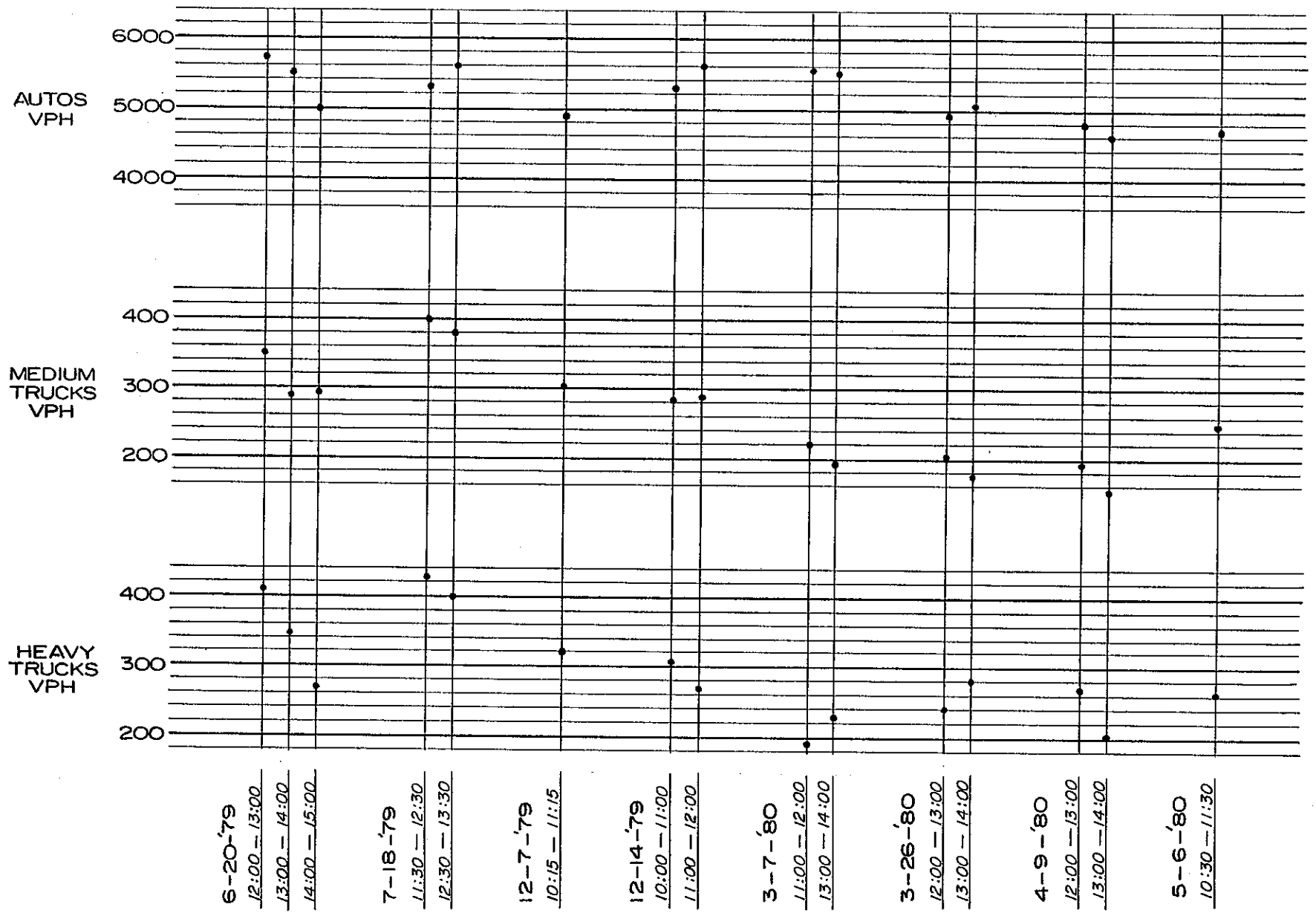

Figure 9

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INSTRUMENTATION

Figures 2 and 3 show placement of the microphones to measure the sound levels. Various microphone positions and heights (Figures 10 and 11) were used to evaluate the opening and one microphone was placed above the top of wall to serve as a control.

Instruments used were:

1) Nagra S.J. Tape Recorder
2) B&K Type I, Model 2218 Sound Level Meter
3) B&K Type I, Model 2206 Sound Level Meter
4) B&K Type I, Model 4426 Noise Level Analyzer
5) B&K Type I, Model 2306 Level Recorder
6) B&K Type I, Model 4230 Sound Level Calibrator
7) 16 Channel Data Logger (specially built to TransLab specifications)
8) Decater Range Master 715 Speed Radar
9) Wind Measuring Set (Belfort Instrument Co.)

The data logger is an instrument which receives signals from the sound level meters and automatically gives a printout of the Leq, dBA at preset intervals. This function is performed after receiving data simultaneously from one to 16 sound level meters.

All noise measurement equipment was calibrated periodically at the Transportation Laboratory which has the facilities and instruments for performing this work. The sound level meter calibrations are traceable to the National Bureau of Standards via two B&K 4160, one-inch laboratory standard microphones.

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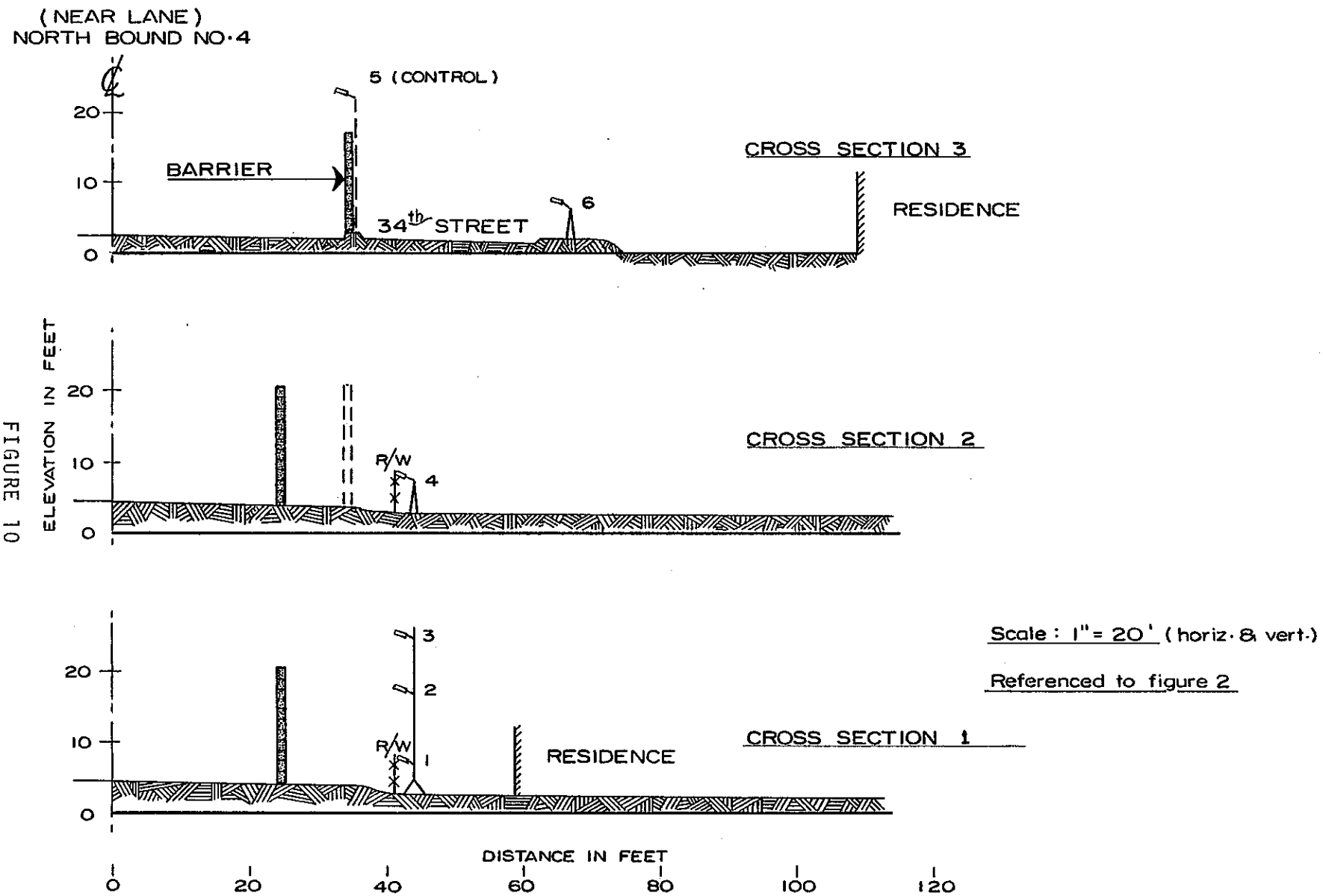

SITE 1
BARRIER OPENING
STATION 216±20

FIGURE 10

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Sound levels are reported in 0.1 dBA as displayed on the data logger rather than rounding to the whole decibel as is commonly done.

A wind measuring instrument was used whenever it was suspected the wind was blowing over 10 miles per hour. No sound level measurements were taken when the wind exceeded 12 miles per hour.

PREDICTION ANALYSIS

It was not an objective of this study to investigate the prediction model (FHWA-RD-77-108, 12-78) currently being used by Caltrans. However, traffic data were obtained during the study as background information and to check changes in noise levels. Therefore, because of the available data, a limited analysis of traffic versus noise levels was made.

Two sets of traffic data which represented wide ranges in number of vehicles are copied from Appendix A and shown on Table II. Medium and heavy truck traffic was about 50% and autos about 20% less on 4-9-80 as compared to 6-20-79. These data were used to calculate noise levels for various conditions and are shown on Table III.

The data on Table III indicate no change in level from using equivalent lanes for each direction, various microphone heights and calculations with and without the median barrier. However, there was a three dBA drop from 6-20-79 to 4-9-80, which was attributed to the decrease in auto and truck traffic. There was also a 2 dBA difference when the ground was considered a hard or soft site. This appeared to be a hard site based on the author's judgement.

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Table II

Summary of Field Counted

Traffic Data

6-20-79 12:00 to 13:00 (Average of 2-18 minute counts extrapolated to 1 hour)

	NBL					SBL					
	1	2	3	4	Total	1	2	3	4	Total	Total 1 hour
Auto	172	816	1017	810	2815	453	892	779	824	2948	5763
MT	5	40	37	58	140	13	55	77	67	212	352
HT	0	8	100	112	220	2	38	100	53	193	413

4-9-80 13:00 to 14:00 (1-20 minute count extrapolated to 1 hour)

	NBL					SBL					
	1	2	3	4	Total	1	2	3	4	Total	Total 1 hour
Auto	105	555	921	783	2364	261	621	624	792	2238	4602
MT	3	18	39	21	81	3	18	33	21	75	156
HT	0	6	48	27	81	0	6	93	27	126	207

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Table III

Calculated Noise Levels (dBA, Leq)

Calculations By Computer Program SNAP1, Based on FHWA RD-77-108)

Horizontal Distance of 50 Ft. From Microphone to ℄ of Near Lane

Site 1

	Calculations Performed Using 8 Individual Lanes				Calculations Performed Using 2 Equivalent Lanes			
	No Median Barrier	With Median Barrier			No Median Barrier	With Median Barrier		
Microphone Height	5'	5'	20'	30'	5'	5'	20'	30'
6-20-79 12:00-13:00	80/78	80	80	80	80/78	79	80	80
4-9-80 12:00-13:00	77/75	77	77	77	77/75	77	77	77

80/ Calculations for a hard site (3dBA dropoff with distance)
/78 Calculations for a soft site (4.5dBA dropoff with distance)

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The field measured sound levels from Site 1 before barrier construction using microphone heights of 5, 20 and 23 feet, are shown on Table IV. Calculated sound levels based on the prediction model (FHWA-RD-77-108, 12-78) are also shown on Table IV for the same traffic data obtained during the field measurements.

It appears that the predicted (calculated sound levels are slightly higher than the measured levels.

The ground was judged to be hard but the soft site calculated values (5' height) resulted in levels which were more closely comparable to the measured values (Table IV). However, it was felt that the measured levels were more reliable for evaluating the openings. Subsequent analyses are all based on measured levels.

SITE 1 DATA AND ANALYSIS

The barrier opening identified as Site 1 and the microphone measurement locations were previously discussed and are referenced to Figure 2. This is the opening treated with sound absorption material. The cross sections at three positions near the opening are shown in Figure 10. Figures 11 through 15 show photographs of the site. Appendix B shows the field measured sound level data and a summary is on Table V.

A reduction in noise of 8.9 to 10.9 dBA Leq was achieved at the 5-foot microphone heights at locations 1, 4 and 6 before treatment of the barrier. The reduction was 10.7 and 5.8 dBA, Leq, at the 15 and 23 foot microphone heights at location 2 and 3.

Treatment of the opening showed a reduction of 3.2 to 3.9 dBA Leq (locations 1, 2, 3 and 4). It does appear that the sound absorption cladding provided some attenuation from noise that is reflected off the walls through the opening.

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Table IV

Sound Levels Before Barrier Construction

Site 1

	Field Measured Levels (7-18-79)				Calculated Levels			
Microphone Location	1	3	4	5	1	3	4	5
Hor. Dist. to ℄ Near Lane	42'	42'	42'	35'	50'	50'	50'	50'
Microphone Height	5'	23'	5'	20'	5'	23'	5'	20'
Sound Level dBA, Leq Adjusted to 50'	76.3	78.3	75.3	78.4	80.3 78.1	80.1	80.3 78.1	80.1

Note: 80.3 calculations for a hard site (3dBA dropoff with distance)
78.1 calculations for a soft site (4.5dBA dropoff with distance)

Soft site only applies to the 5' height

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TABLE V

Site 1 Barrier Opening

Noise Level Data Station 716 ± 20
(Leq,dBA)

A	B	C	D	E	F	D1	E1	F1	G	H
			Barrier Construction Measured $\bar{x}$ dBA			Adjusted for Changes in Traffic $\bar{x}$ dBA				
Micro-phone Location	Distance (ft)	Micro-phone Height	Before	After No Treat	After With Treat	Before	After No Treat	After With Treat	Before & After Barrier (D1-E1)	Effect of Treat (E1-F1)
1	42	5	77.1	67.4	63.0	77.1	66.2	63.0	-10.9	-3.2
2	42	15	79.0	69.5	64.4	79.0	68.3	64.4	-10.7	-3.9
3	42	23	79.1	74.7	70.1	79.1	73.3	70.1	- 5.8	-3.2
4	42	5	76.1	66.4	61.9	76.1	65.2	61.9	-10.9	-3.3
5	35	20	80.0	81.2	80.0	80.0	80.0	80.0	--	--
6	67	5	74.0	66.3	64.3	74.0	65.1	64.3	- 8.9	-0.8

A See Figure 2 for locations relative to roadway and barrier

B Distance from microphone to ℄ of near lane

C Microphone height is above ground (Figure 10)

D,E,F See raw data in Appendix B

E1 These data were adjusted for difference in traffic as determined by control microphone 5, column D

F1 Treatment at this site was a sound absorbent cladding (Figures 5 & 6)

G $\Delta L = (L_m - L_c)_{Bef.} - (L_m - L_c)_{Aft.}$ [dBA] or (D1-E1)

L_m = Level measured at various locations

L_c = Level at control location

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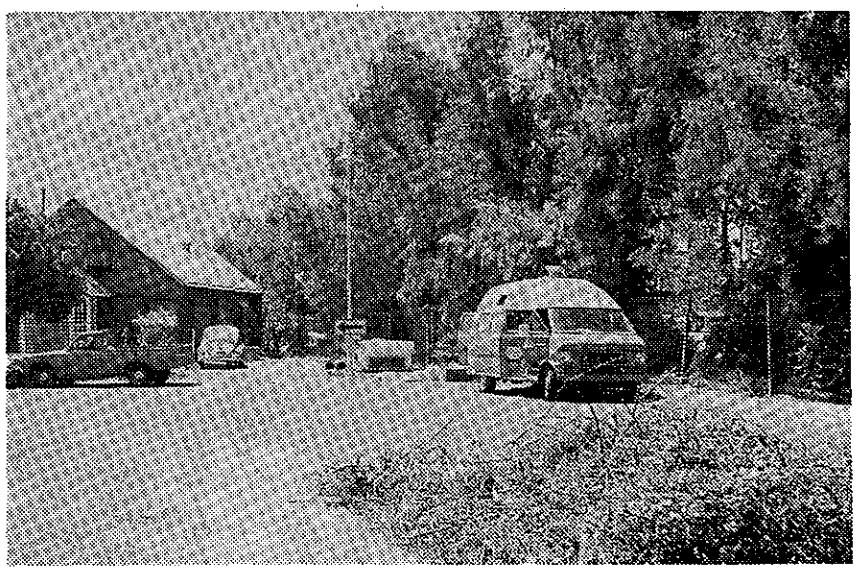
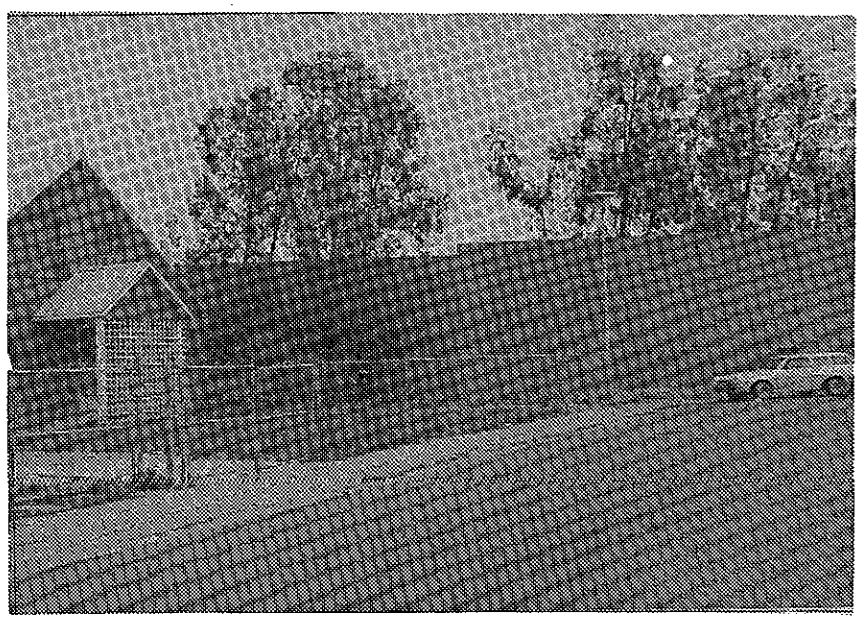


Site 1 Looking south before construction of wall. Opening will be located directly opposite the street light.

Figure 11



Site 1 Looking west towards opening and nearby residence. Completed wall.

Figure 12

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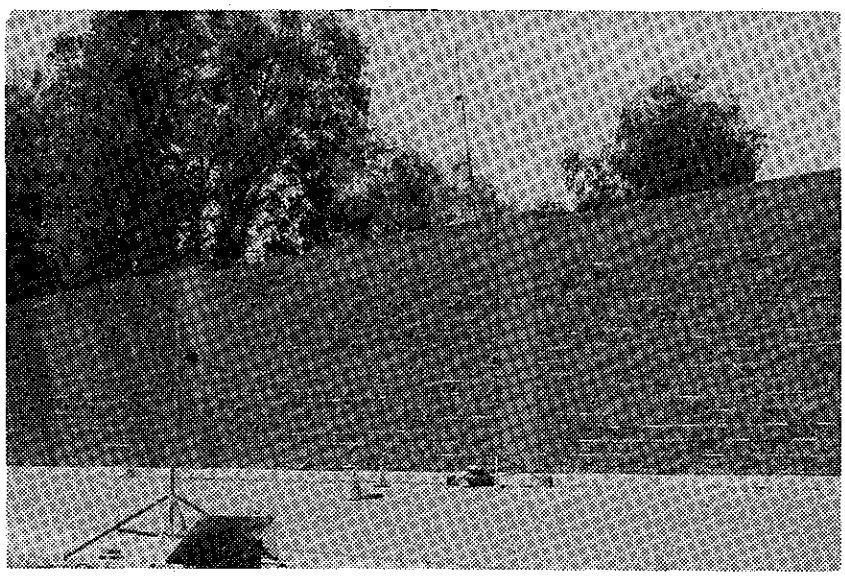
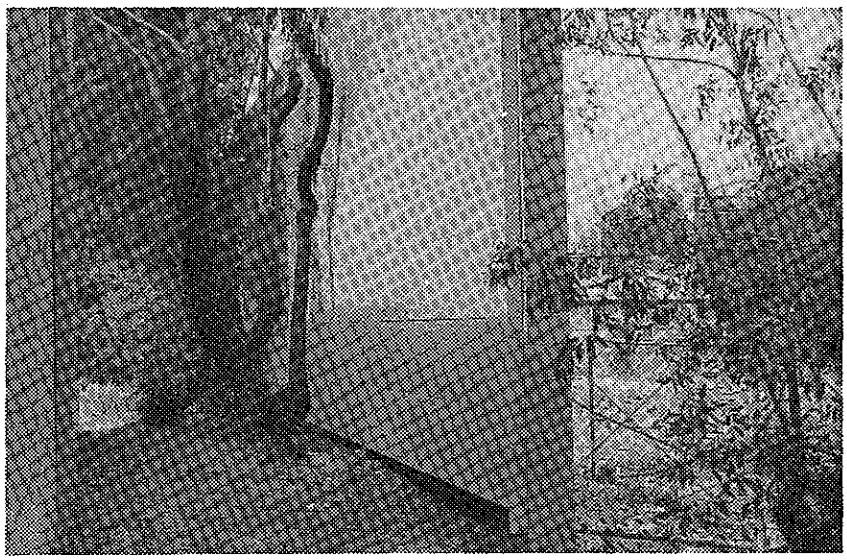


Site 1 Looking west toward completed wall at microphone locations 5 and 6.

Figure 13



Site 1 Looking north towards opening and freeway from the residence side. Sound absorptive cladding in place.

Figure 14

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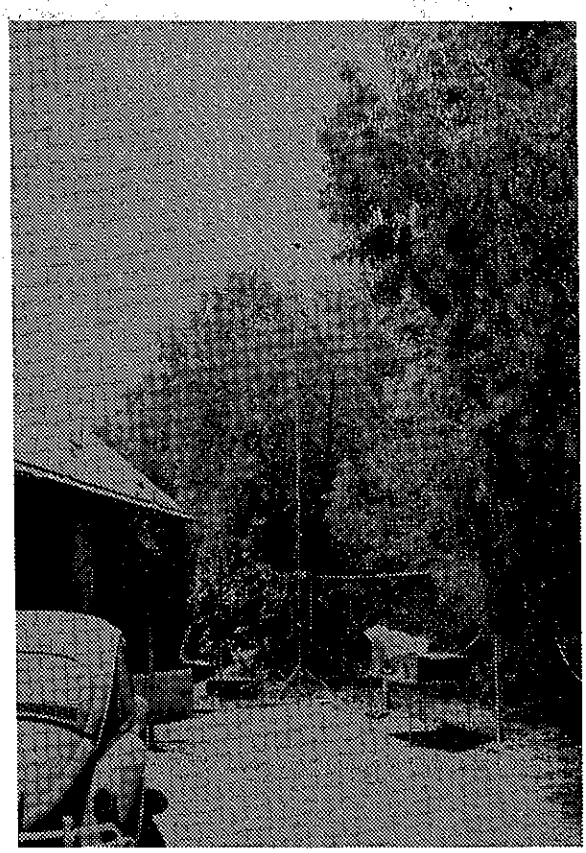

Site 1 Looking south towards nearby residence and microphone locations 1, 2 & 3.

Figure 15

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Figure 16 shows the noise contours around the opening after treatment. Table VI shows the field measured levels for drawing the contours. As expected, the noise levels are somewhat higher at the opening as compared to a location without the opening, but diminish rather rapidly as the distance from the opening increases. The noise levels about 45 feet from the opening are about 62 dBA Leq which is the level estimated if there were no opening.

SITE 2 DATA AND ANALYSIS

The barrier opening identified as Site 2 and the microphone measurement locations were previously discussed and are referenced to Figure 3. This was the opening treated with the redwood baffle. The cross sections at three positions near the opening are shown in Figure 17. Figures 18 through 22 show photographs of the site. Appendix B shows the field measured sound level data and a summary is shown in Table VII.

A reduction in noise of 8.4 to 9.0 dBA, Leq, was achieved at the 5 foot microphone heights at locations 1, 4 and 7 before treatment of the barrier. The reduction at locations 2 and 5 at a microphone height of 15 feet was 7.9 and 7.7 dBA, Leq. The reduction at locations 3 and 6 at a microphone height of 23 feet was 4.8 and 4.2 dBA Leq.

After the opening was treated by installing a redwood baffle on one side of the wall opening, the measured noise level reductions at locations 1 through 6 ranged from -0.4 to -2.5 dba, Leq. The level at microphone location 7 at a height

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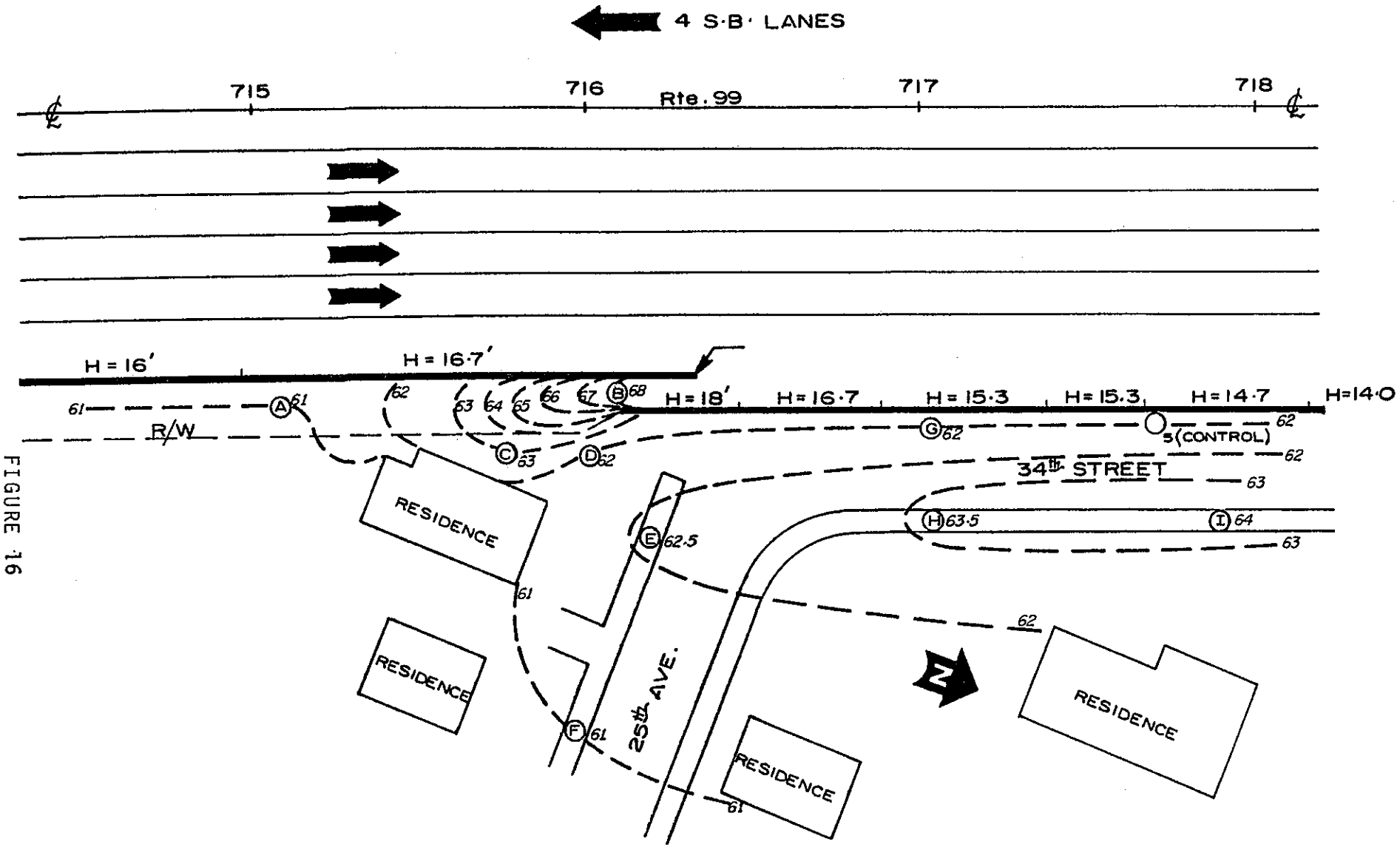

FIGURE 16

SITE 1

BARRIER OPENING

No Scale

NOTE:

○ MICROPHONE LOCATIONS: Letter symbols are microphone locations for contouring.

Sound Contours: — — — —

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Table VI

Sound Levels For Contouring

Microphone Locations (Figure 2 & 3)

All Measurements at microphone height of 5 feet

Site 1
Measured 4-10-80

Microphone Location	Leq dBA
A	61
B	68
C	63
D	62
E	62.5
F	61
G	62
H	63.5
I	64

Site 2
Measured 4-9-80

Microphone Location	Leq dBA
A	65.2
B	67.6
C	64.2
D	62.3
E	63.1
F	63.9
G	67.3
H	64.4
I	63.0
J	61.6
K	62.1

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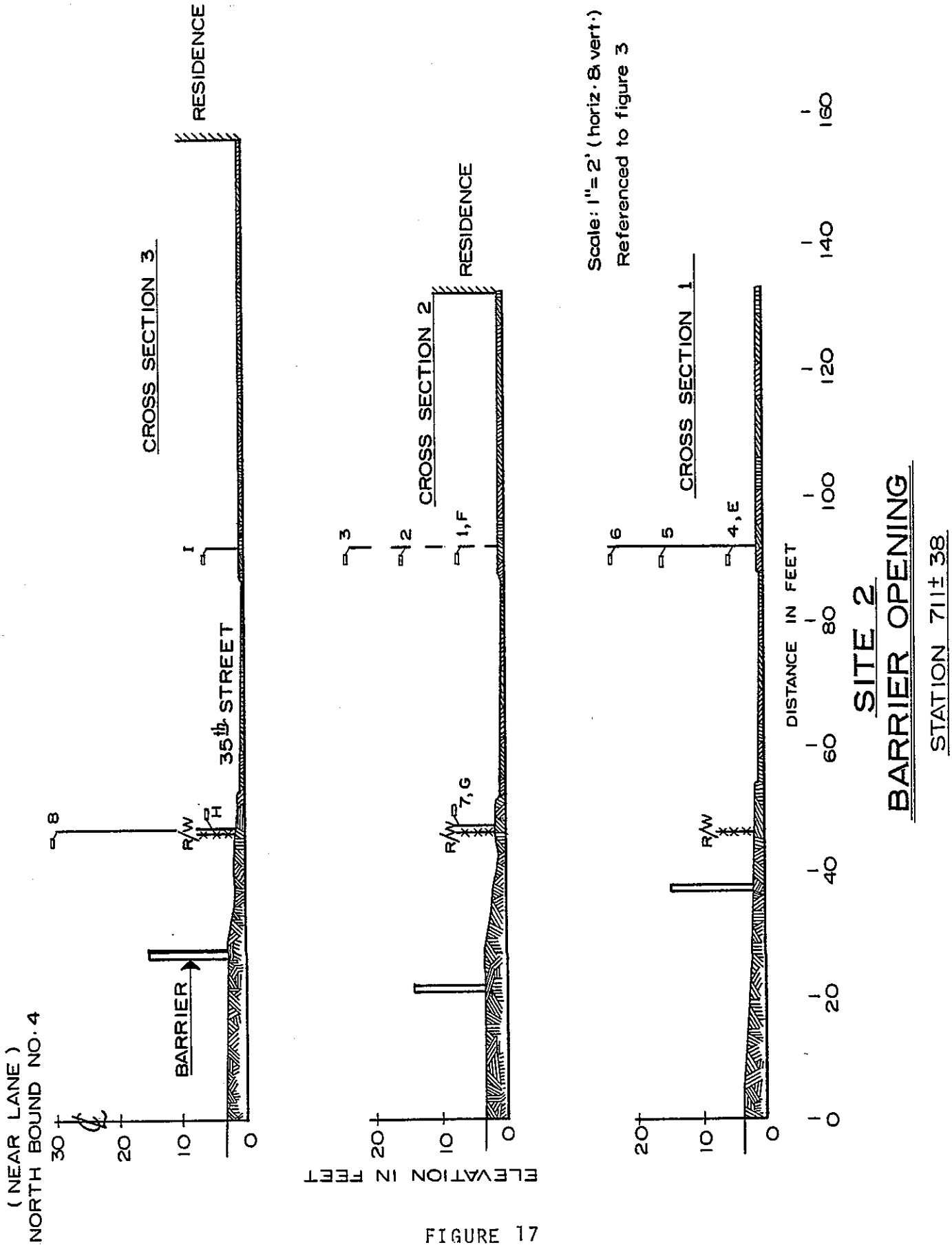

FIGURE 17

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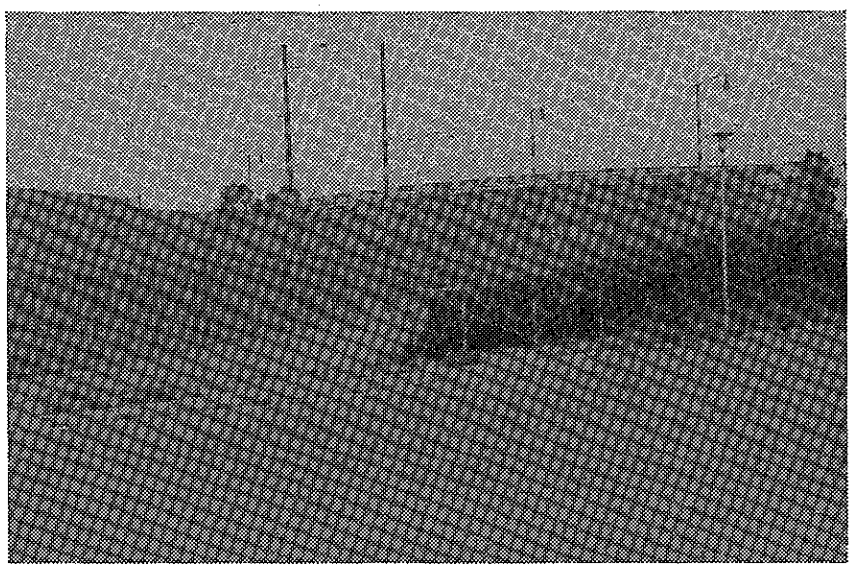

Site 2 Looking west. Overview of pedestrian overcrossing.

Figure 18

Site 2 Looking west at opening. Note the redwood baffle at the center of the photo.

Figure 19

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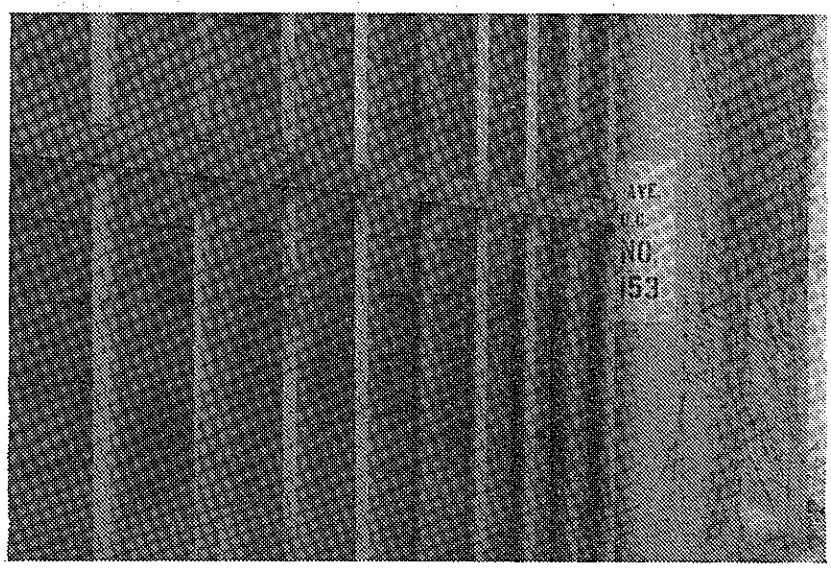
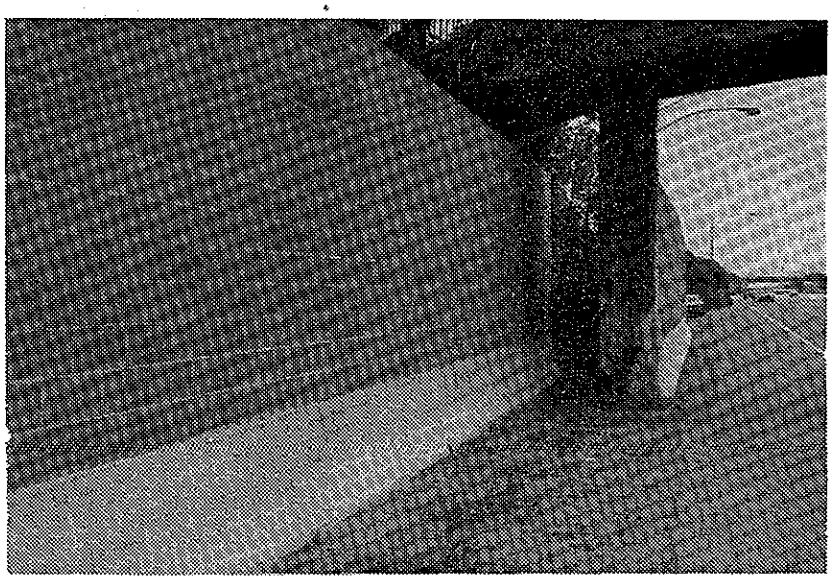


Site 2 Closeup of the redwood baffle.

Figure 20



Site 2 Looking south. Barrier opening from the freeway.

Figure 21

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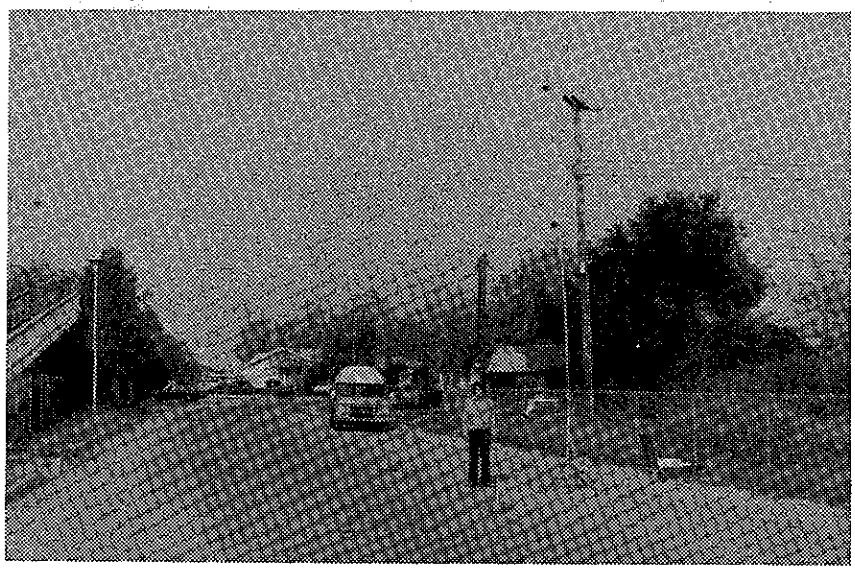

Site 2 Looking north toward microphone locations 4, 5 & 6.

Figure 22

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Table VII

Site 2 Barrier Opening

Noise Level Data Station 711±38
(Leq,dBA)

A	B	C	D	E	F	D1	E1	F1	G	H
			Barrier Construction Measured $\bar{x}$ dBA			Adjusted for Changes in Traffic $\bar{x}$ dBA				
Micro-phone Location	Distance (ft)	Micro-phone Height Ft.	Before	After No Treat	After With Treat	Before	After No Treat	After With Treat	Before & After Barrier (D1-E1)	Effect of Treat (E1-F1)
1	93	5	74.0	65.9	64.4	74.3	65.9	65.5	-8.4	-0.4
2	93	15	75.4	67.8	66.0	75.7	67.8	67.1	-7.9	-0.7
3	93	23	75.9	71.4	69.2	76.2	71.4	70.3	-4.8	-1.1
4	87	5	73.3	64.6	62.9	73.6	64.6	64.0	-9.0	-0.6
5	87	15	77.1	69.7	66.1	77.4	69.7	67.2	-7.7	-2.5
6	87	23	77.6	73.7	71.2	77.9	73.7	72.3	-4.2	-1.4
7	47	5	76.4	67.8	69.3	76.7	67.8	70.4	-8.9	+2.6
8	47	30	79.7	80.0	78.9	80.0	80.0	80.0	--	--

A — See Figure 3 for locations relative to roadway and barrier

B — Distance from microphone to ℄ of near lane

C — Microphone height is above ground (Figure 17)

D,E,F — See raw data in Appendix B

E1 — These data were adjusted for differences in traffic as determined by control microphone 8, column E

F1 — Treatment at this site was a redwood baffle (Figure 7 & 8)

G — $\Delta L = (L_m - L_c)_{Bef.} - (L_m - L_c)_{Aft.}$ [dBA] or D1-E1

L_m = Level measured at various locations

= [illegible] at control location

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of 5 feet showed an increase of +2.6 dBA, Leq. The reason for this is not known. The overall data indicated that the baffle did not contribute significantly to minimizing the reflected noise.

Figure 23 shows noise contours around the opening after treatment. Table VI shows the field measured levels for drawing the contours. The noise levels about 100 feet from the opening are about 63 dBA, Leq, which is close to the level estimated if there were no opening.

It was very difficult to obtain a clearly defined effect of the opening and treatment at Site 2 because of the reflected noise from the pedestrian overcrossing. The author noted increased noise levels along a continuous noise wall, near another pedestrian overcrossing in Los Angeles, which were attributed to reflected noise. No measurements were made in Los Angeles to document this occurrence by obtaining actual noise levels. The noise contours for Site 2 are unlike those for Site 1. This suggests that noise is reflected from the overcrossing making evaluation of this opening and treatment difficult.

MAINTENANCE ACCESS DESIGN DISCUSSION

Design of the access at Site 1 provided for an opening of 10 feet and an overlap of 24 feet, for a ratio of 10/24=2.4. This may be considered adequate depending on the noise levels, proximity of the receiver, the activity involved, and the distance of the source, receiver, and barrier.

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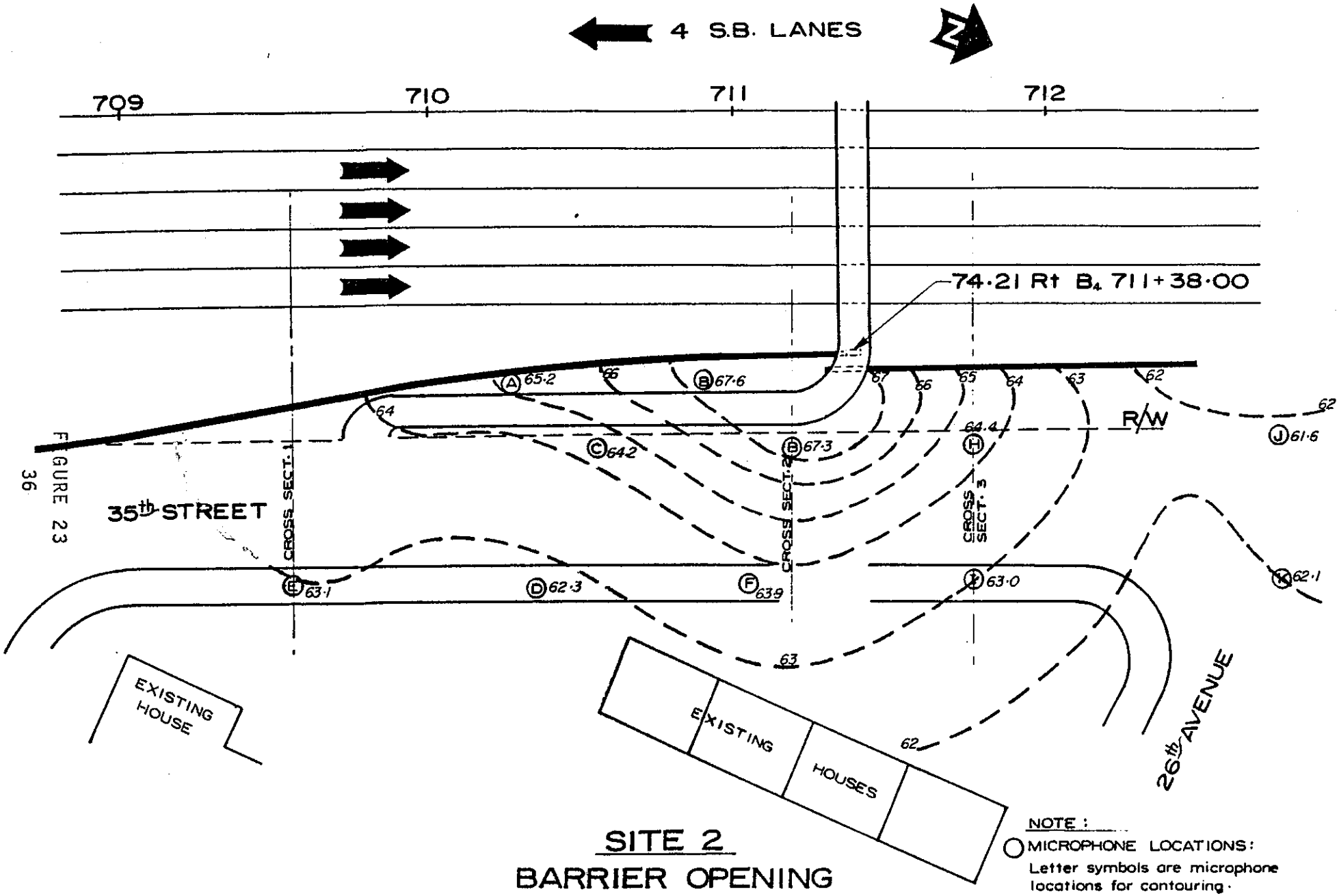

FIGURE 23

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SITE 2
BARRIER OPENING AT PEDESTRIAN OVERCROSSING

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Trees and shrubs around the opening probably provided a little attenuation (estimated 1dBA) and the cladding provided additional attenuation. Figure 24 shows other designs for minimizing noise passing through open maintenance access openings which may be less expensive.

Any opening in a barrier would degrade its acoustical properties but a properly designed opening would minimize this effect. The maintenance access openings of the types discussed might tend to collect trash, provide a reststop for motorists and permit people to come into direct view or contact with the residents which may be objectionable. The conclusion is that each maintenance access opening should be designed on a case by case basis.

Design of the access at Site 2 provided for an opening of 5 feet and an overlap of 10 feet for a ratio of 5/10=2.0. Evaluation of this barrier opening could not be clearly defined as previously discussed.

COST ANALYSIS

The bid prices for this project and for the various items are shown in Table VIII.

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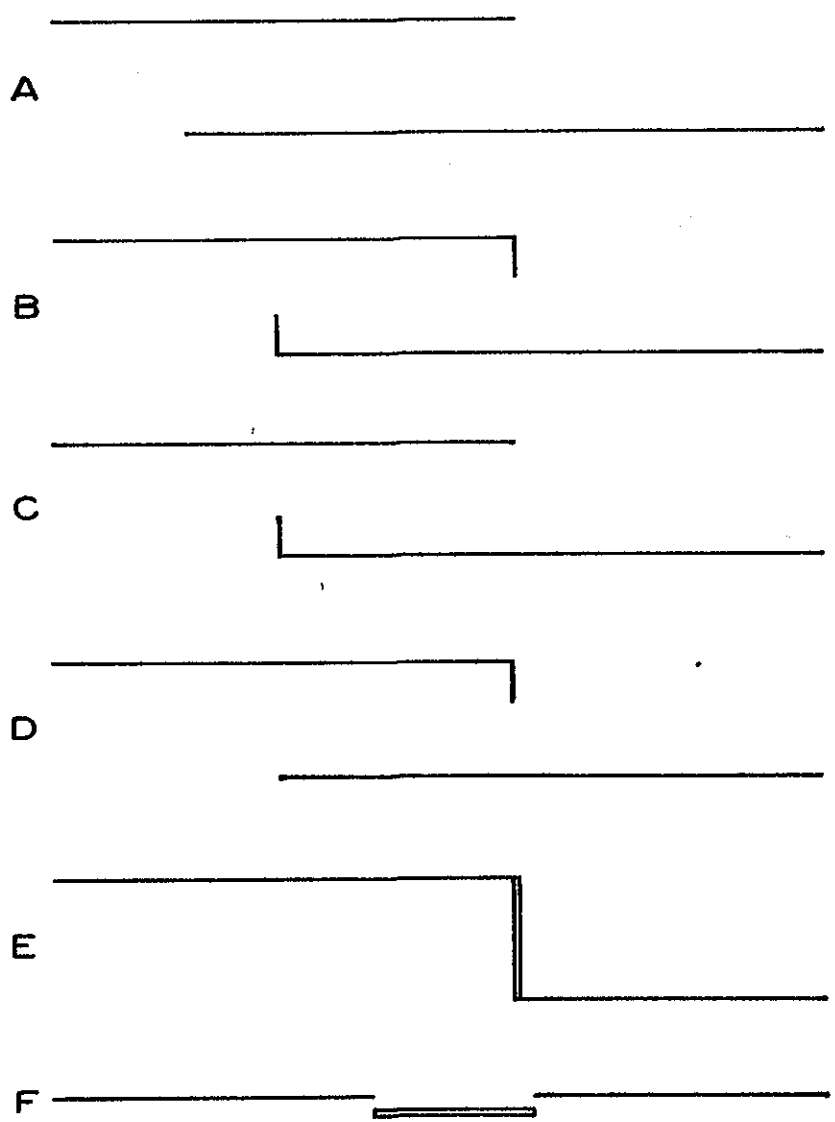
Barrier Opening Designs



	Comment
A	Increase opening to overlap ratio to 3.0 or more. An estimated cost of $150/lin.ft. for a 12-foot high wall might cost less than cladding. Adequate R/W must be available.
B	Use a baffle so noise would have to go around corners. An estimated cost of $200/lin.ft. might cost less than cladding.
C	Variation of B
D	Variation of B
E	Solid wood gate closing the opening. The gate should be relatively airtight.
F	Sliding wood or concrete gate closing the opening. The gate should be relatively airtight.

Figure 24

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TABLE VIII

Project Costs

Item	Quantity	Low Bid	Second Bid	Third Bid	Low Bid Total Cost
Masonry Block	31,034 SF	$ 6.50	$ 9.00	$ 7.00	$201,721
Concrete Barrier	1,354 LF	53.00	45.00	96.50	71,762
CIDH 15"	3,540 LF	31.00	25.00	30.00	109,740
CIDH 16"	81 LF	35.00	27.00	43.00	2,835

Total project costs for the three low bids were 1) $476,666.00, 2) $519,233.25 and 3) $564,000.00.

Barrier heights near the opening at Site 1 were 16.8 to 18 feet high. Calculations estimated the added cost of the barrier due to the opening at Site 1 at $4,632.00, using a barrier height of 17.5 feet, plus $5,603.29 for the cladding for a total of $10,235.29.

Barrier heights near the opening at Site 2 were 11.4 to 12.0 feet high. Calculations estimated the added cost of the opening at Site 2 at $1,731 plus $1,367.41 for the redwood baffle for a total of $3,098.41.

The variables of costs, noise levels, any sound absorptive treatment, location, receiver, and site conditions need to be evaluated and optimized before design of an opening is finalized.

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APPENDIX A

Summary of Traffic Counts

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APPENDIX A

SUMMARY OF
U.S. 99 & FRUITRIDGE
TRAFFIC COUNTS

Date: 6/20/79 (Before Barrier - Barrier Evaluation)

Time: 12:00-13:00 (Average of 2-18 min counts extrapolated to 1-HR)

Total	NB Lanes - VPH				Veh. Type	SB Lanes - VPH			
	Fast			Slow		Fast			Slow
NB+SB	#1	#2	#3	#4		#1	#2	#3	#4
5763	172	816	1017	810	Autos	453	892	779	824
352	5	40	37	58	Med. Tr.	13	55	77	67
413	0	8	100	112	H. Tr.	2	38	100	53

Time: 13:00-14:00 (Average of 2-18 min counts extrapolated to 1-HR)

Total	NB Lanes - VPH				Veh. Type	SB Lanes - VPH			
NB+SB	#1	#2	#3	#4		#1	#2	#3	#4
5487	168	831	1046	802	Autos	383	773	676	808
292	3	38	53	50	Med. Tr.	14	27	57	50
346	0	17	77	90	H. Tr.	2	27	103	30

Time: 14:00-15:00 (Average of 2-18 min counts extrapolated to 1-HR)

Total	NB Lanes - VPH				Veh. Type	SB Lanes - VPH			
NB+SB	#1	#2	#3	#4		#1	#2	#3	#4
5001	188	763	902	709	Autos	388	729	553	769
297	10	33	48	33	Med. Tr.	15	30	63	65
273	0	10	70	52	H. Tr.	0	23	100	18

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SUMMARY OF
U.S. 99 & FRUITRIDGE
TRAFFIC COUNTS

Date: 7/18/79 (Before Barrier - Barrier Opening #1)

Time: 11:30-12:30 (1 hour volume extrapolated from 1-50 min count)

Total	NB Lanes - VPH				Veh. Type	SB Lanes - VPH			
NB+SB	#1	#2	#3	#4		#1	#2	#3	#4
5375	170	776	978	775	Autos	433	839	582	822
400	2	18	67	67	Med. Tr.	20	49	83	94
429	0	10	95	86	H. Tr.	2	37	160	38

Time: 12:30-13:30 (1 hour volume extrapolated from 1-50 min count)

Total	NB Lanes - VPH				Veh. Type	SB Lanes - VPH			
NB+SB	#1	#2	#3	#4		#1	#2	#3	#4
5591	181	770	1018	818	Autos	450	850	665	839
386	2	16	54	70	Med. Tr.	18	46	110	70
403	0	7	101	88	H. Tr.	2	35	130	40

Date: 12/7/79 (After Barrier Opening 2@POC)
Before Acoustic Treatment

Time: 10:15-11:15 (Average of two 20 min counts extrapolated to 1-hr)

Total	NB Lanes - VPH				Veh. Type	SB Lanes - VPH			
NB+SB	#1	#2	#3	#4		#1	#2	#3	#4
4928	146	638	951	773	Autos	257	621	708	834
302	2	33	71	59	Med. Tr.	3	35	54	45
319	0	3	90	86	H. Tr.	0	17	84	39

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SUMMARY OF
U.S. 99 & FRUITRIDGE
TRAFFIC COUNTS

Date: 5/6/80

Time: 10:30-11:30 (Average of 2-20 min counts extrapolated to 1-hr)

Total	NB Lanes - VPH				Veh. Type	SB Lanes - VPH			
NB+SB	#1	#2	#3	#4		#1	#2	#3	#4
4657	135	688	945	645	Autos	236	633	655	720
253	2	17	72	50	Med. Tr.	2	24	39	47
262	0	2	65	51	H. Tr.	0	8	104	32

Date: 3/7/80 (After Barrier Opening 2-POC After Acoustical Treatment)

Time: 11:00-12:00 (Extrapolated from 1-20 min count)

Total	NB Lanes - VPH				Veh. Type	SB Lanes - VPH			
NB+SB	#1	#2	#3	#4		#1	#2	#3	#4
5565	168	807	981	840	Autos	366	765	729	909
219	0	12	54	45	Med. Tr.	6	24	42	36
195	3	24	39	33	H. Tr.	3	18	21	54

Time: 13:00-14:00 (Extrapolated from 1-20 min count)

Total	NB Lanes - VPH				Veh. Type	SB Lanes - VPH			
NB+SB	#1	#2	#3	#4		#1	#2	#3	#4
5508	132	741	999	786	Autos	354	882	738	876
195	3	24	39	33	Med. Tr.	3	18	21	54
231	0	3	33	54	H. Tr.	3	27	63	48

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SUMMARY OF
U.S. 99 & FRUITRIDGE
TRAFFIC COUNTS

Date: 3/26/80 (1st After Barrier Barrier Evaluation)

Time: 1200-1300 (Extrapolated from 1-20 min count)

Total	NB Lanes - VPH				Veh. Type	SB Lanes - VPH			
NB+SB	#1	#2	#3	#4		#1	#2	#3	#4
4980	129	597	876	765	Autos	324	696	708	885
210	3	30	48	42	Med. Tr.	6	27	30	24
240	0	6	72	42	H. Tr.	0	15	75	30

Time: 1300-1400 (Extrapolated from 1-20 min count)

Total	NB Lanes - VPH				Veh. Type	SB Lanes - VPH			
NB+SB	#1	#2	#3	#4		#1	#2	#3	#4
5103	135	699	930	832	Autos	303	645	729	810
177	0	6	36	51	Med. Tr.	6	21	39	18
282	0	3	96	48	H. Tr.	0	33	72	30

Date: 4/9/80 (2nd After Barrier Barrier Evaluation)

Time: 1200-1300 (Extrapolated from 1-20 min count)

Total	NB Lanes - VPH				Veh. Type	SB Lanes - VPH			
NB+SB	#1	#2	#3	#4		#1	#2	#3	#4
4842	126	555	828	714	Autos	273	696	738	912
198	0	12	45	33	Med. Tr.	9	27	36	36
271	0	9	93	36	H. Tr.	0	3	81	49

Time: 1300-1400 (Extrapolated from 1-20 min count)

Total	NB Lanes - VPH				Veh. Type	SB Lanes - VPH			
NB+SB	#1	#2	#3	#4		#1	#2	#3	#4
4602	105	555	921	783	Autos	201	621	624	792
156	3	18	39	21	Med. Tr.	3	18	33	21
207	0	6	48	27	H. Tr.	0	6	93	27

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SUMMARY OF
U.S. 99 & FRUITRIDGE
TRAFFIC COUNTS

Date: 12/14/79 (After Barrier Opening #1 Before Acoustic Treatment)

Time: 10-11 (Average of 2-20 min counts extrapolated to 1-hr)

Total	NB Lanes - VPH				Veh. Type	SB Lanes - VPH			
NB+SB	#1	#2	#3	#4		#1	#2	#3	#4
5322	149	705	957	965	Autos	294	701	708	843
285	2	12	57	81	Med. Tr.	3	17	51	62
313	2	2	90	78	H. Tr.	0	16	93	32

Time: 11-12 (Average of 2-20 min counts extrapolated to 1-hr)

Total	NB Lanes - VPH				Veh. Type	SB Lanes - VPH			
NB+SB	#1	#2	#3	#4		#1	#2	#3	#4
5613	150	699	972	780	Autos	330	831	822	1029
291	0	18	60	93	Med. Tr.	3	18	57	42
273	0	3	84	36	H. Tr.	0	12	123	15

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APPENDIX B

Site 1 and 2 Noise Measurement Data

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APPENDIX B

Site 2 Barrier Opening

Noise Level Data Station 711±38
(Leq,dBA)

Microphone Location	Distance (ft)	Microphone Height Ft	Barrier Construction: Before(8-16-79) 11:50 12:08	12:10 12:28	12:40 12:58	13:24 13:42	$\bar{X}$	After(12-7-79) No Treatment 10:20 10:40	10:50 11:10	$\bar{X}$	After(3-7-80) With Treatment 11:08 11:38	13:25 13:45	$\bar{X}$
1	93	5	73.7	74.4	73.9	73.9	74.0	65.5	66.3	65.9	64.8	64.0	64.4
2	93	15	75.2	75.7	75.0	75.5	75.4	67.3	68.2	67.8	66.4	65.6	66.0
3	93	23	75.8	76.3	75.5	76.0	75.9	70.8	72.0	71.4	69.5	68.8	69.2
4	87	5	73.2	73.6	73.0	73.4	73.3	63.9	65.0	64.6	63.3	62.5	62.9
5	87	15	77.0	77.3	76.7	77.2	77.1	69.1	70.3	69.7	66.5	65.6	66.1
6	87	23	77.5	77.8	77.2	77.7	77.6	73.2	74.1	73.7	71.5	70.8	71.2
7	47	5	76.4	76.7	76.0	76.5	76.4	67.5	68.1	67.8	68.8	69.8	69.3
8	47	30	79.5	80.1	79.3	79.8	79.7	79.8	80.2	80.0	78.9	78.8	78.9

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APPENDIX B

Site 1 Barrier Opening

Noise Level Data Station 716±20
(Leq ,dBA)

Microphone Location	Distance (ft)	Microphone Height Ft.	Barrier Construction: Before(7-18-79) 11:29 12:19	Before 12:29 13:19	Before $\bar{X}$	After(12-14-79) 10:15 10:35	After 10:50 11:10	After 11:20 11:40	After $\bar{X}$	After(5-6-80) With Treatment 10:30 10:50	With Treatment 10:55 11:15	With Treatment $\bar{X}$
1	42	5	77.0	77.2	77.1	67.7	67.4	67.2	67.4	63.2	62.8	63.0
2	42	15	78.8	79.1	79.0	69.8	69.5	69.2	69.5	64.5	64.3	64.4
3	42	23	79.0	79.1	79.1	74.8	74.7	74.7	74.7	70.2	69.9	70.1
4	42	5	75.9	76.2	76.1	66.8	66.3	66.1	66.4	62.1	61.6	61.9
5	37	23	79.9	80.0	80.0	81.3	81.3	81.1	81.2	80.0	80.0	80.0
6	67	5	74.0	73.9	74.0	66.1	65.6	67.2	66.3	64.4	64.1	64.3

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