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CENTER BARRIER DELINEATOR SPACING STUDY

FINAL REPORT

BY

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16. Abstract

This study reviews delineator spacing intervals of 40, 80 and 160 feet placed along median barrier divided roadways. Optimum spacing of the delineators was determined by having observers view film of several installations. Spacings of delineation were considered undesirable when, in the raters opinions, the delineators provided an inadequate amount of information to be considered an effective aid for nighttime driving. Primary considerations for driver information were the ability to detect the path of the road ahead and the lateral location of the barrier. Reduced spacing distances were identified for specific geometric situations.

The following conclusions have been made:

1. Desirable levels of delineation can be provided as long as the spacing between delineators does not exceed 160 feet where roadway geometry is straight and level;
2. The spacing of delineators should be no more than 80 feet where roadway geometry contains crest vertical curves whose ratio of percent change in grade to hundreds of feet of run is .4 or more;
3. The spacing of delineators should be 40 feet where horizontal curves are 2 degrees (3000 foot radius) or more.

Based on the costs of installation, the impacts on maintenance and the desirable spacing, delineators should be spaced at 80 feet in general and 40 feet whenever engineering judgement indicates an additional need for delineation.

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SUMMARY AND CONCLUSIONS

The visibility of center barrier delineators is primarily affected by roadway design, delineator spacing, and reflectivity.

Effects of Horizontal and Vertical Geometry

Both horizontal and vertical geometry were found to affect the raters' opinion of each spacing scheme. The greatest effects were noted at horizontal curves of 6 degrees and on crest vertical curves when the ratio of slope change, referred to as either the R or K value, approached .5. Horizontal curves of as little as 2 degrees (3000 foot radius) negatively affected opinions about spacing. Vertical crest curves were found to negatively affect opinions about spacing when the R value approached .4.

Horizontal curves of 6 degrees (1000 foot radius) significantly inhibit center barrier delineators from providing information on the longitudinal path of the center barrier.

MUTCD Spacing Schemes

MUTCD recommendations for the spacing of right shoulder delineation do not appear to have value when delineating median barriers. Even though the barrier itself can be considered to provide a substantial amount of delineation, it appears to deserve greater amounts of reflectorized marking than the MUTCD recommends for the right shoulder area. A study, similar to this one, of MUTCD right side spacing recommendations may be useful.

Loss of Reflectivity

Review of film taken in 1983 of a test installation for a 1979 study on Route 80 indicates that reflectors retain enough reflectivity to clearly delineate the barrier despite substantial loss of reflectiveness overtime. Based on this observation, reflectivity should not be a concern. Reflectivity of several delineator types was studied in previous work.

RECOMMENDATIONS

Spacing Schemes

Maintaining more than two spacings in combination presents unnecessary maintenance complications. Maintaining the skip line module as the basic increment is appropriate since it provides consistency with Raised Pavement Marker (RPM) guidelines. The skip line module as an increment provides an automatic spacing mechanism in the field simultaneously simplifying installation, inventorying and maintenance activities.

Eighty foot is the best choice for a general spacing interval since it was desirable in most conditions. Forty foot spacing should be used where horizontal curves of 2 degrees or more exist and elsewhere when engineering judgement suggests. Data of this study supports providing at least 3 visible delineators whenever possible as a rule of thumb.

Observing the barrier during installation of delineators at 80 feet spacing would allow identification of locations where less than three are visible. Applying this rule of thumb would then identify most locations where 40 foot spacing is appropriate. Predetermining site characteristics or reviewing plans prior to installation could be avoided. Initial system wide installation is expected to involve 24,000 delineators at a cost of about $90,000.

TABLE 1 RECOMMENDED DELINEATOR SPACING

Interval	Roadway Curvature	
(Feet)	Vertical	Horizontal
80	None	>,= 3000 Foot Radius (<,= 2 Degrees)
40	None	< 3000 Foot Radius (> 2 Degrees)

Maintenance Impacts

Yearly loss rates (about 2.5 to 10 %) suggest that a system life expectancy of ten years may be possible. However, partial replacement on a more frequent basis will be necessary since delineator losses tend to occur in groups. Areas with a demanding environment, such as exists in highly industrialized and urbanized areas, may experience even higher loss rates than noted to date.

Maintaining the full system of delineators spaced as recommended, (40 and 80 foot) will involve about 50 crew-hours per year including the time to travel to and from sites. Planning maintenance at sites where groups of two or more delineators are missing translates to about 30 crew-hours per year. A criteria of maintenance at only sites where three or more are missing would cut this commitment down to about 20 crew-hours.

Yearly maintenance of the system involves the cost for crew time at about $100 an hour and about $2.50 each for materials to replace the delineators. Full maintenance would run about $8400 while plans of reduced maintenance for groups of two or more would be $5000 while three or more would be $3400.

<u>Minimum Section Lengths</u>

Minimum section lengths, or minimum distances of constant spacing, should be 240 feet. Such unit distances are also recommended by NJDOT's RPM replacement guidelines. The value of this distance is substantiated by this research effort since seeing 3 delineators at 80 feet spacing was clearly desirable in the opinion of most observers. While the best maintenance schedule would be to replace all the delineators that are missing on a regular basis, providing replacements where groups are missing should do a reasonable job of maintaining the desirable 240 feet minimum on delineated roadways.

INTRODUCTION

Center barrier delineators have been the subject of several research efforts in N J in the recent past. The first study (Reference 1) identified top mounting as desirable and led to a second (Reference 2) which tested mountings and basic installation techniques. The results were encouraging when a four mile installation demonstrated that top mounting double faced reflectors was felt to effectively delineate the location and path of the concrete median barrier.

The primary question not addressed in these studies was what impact the spacing, that is the distance between delineators, had on the effectiveness of the installation as a whole. Secondary to this question was whether the substantial loss of delineator reflectiveness (up to 70 % in two years) will affect the ability of a spacing scheme to provide appropriate levels of delineation as time passes.

BACKGROUND

The MUTCD has recognized delineators as "effective aids for night driving" (Reference 3) and determined visibility standards for them. (Reference 4) The MUTCD also suggests adjusting spacing between delineators to offset the effects of horizontal curvature. Spacing right side post mounted reflectors as close as 90 feet is recommended for 6 degree (1000 foot radius) curves. Such curves are of importance because they are commonly the minimum radius for roads whose design speed is 60 MPH. No adjustment for vertical curvature (crests or sags) is discussed, however.

Also presented by the MUTCD is a scheme for varying spacing for adjacent sections of straight and curved roadway. The MUTCD scheme first doubles, then triples the spacing (based on the spacing within the curve which is in turn a function of the degree of curvature). In this way, the spacing becomes greater and greater as the section progresses from curved to tangent. The final spacing is then reached, a factor of 6 times the minimum. This system or scheme is intended to provide a transition from spacings which need to be quite short, due to the limited viewing distance which exists on curves, to spacings which are quite distant, though acceptable, when alignment allows longer viewing distances. These longer recommendations range from 200 feet up to 1/10th of a mile in the MUTCD. However, there is no guidance on choosing basic straight section spacings in terms of roadway alignment. Instead decisions are left to some other policy or a general system wide policy.

Few studies have addressed the relative merits of spacing schemes. NCHRP Report 130, entitled "Roadway Delineation Systems," does discuss how many delineators were visible when spacing seemed desirable. Desirability in this case is in the opinion of several contributors. NCHRP 130 recommends that at "tangent and general situations...three delineators should be visible at all times." (Reference 5). In comparing center versus right side delineation, the report suggests that the most effective roadside delineation occurs when delineators are used on the outside of curves for horizontal curves of 5 or more degrees and have a 20 degree central angle (page 42). However, NCHRP 130 also reports studies of rural horizontal curves that indicate strengthening centerline delineation was related to "major improvements" in lateral placements while right side (post mounted or edgeline) improvements were minimal (page 14). This last comes from a study which compared the two techniques in combination.

The studies which provided these seemingly conflicting results were aimed at rather specific but unrelated questions. As such, the above reported results have been taken somewhat out of context. The point is, however, there is no concurrence as to location guidelines. Even less is reported on spacing.

OBJECTIVES

Estimating the impacts of spacing and loss of reflectivity during hours of darkness were the objectives of this study. The spacing schemes which form the primary focus of this research were chosen with the dual purpose of rating desirability when the delineators are new as well as after age has reduced reflectivity.

The prime functions of delineation are the ability to provide information about the lateral proximity of the barrier and about downstream changes in roadway alignment. Within this context, a spacing scheme coordinates reflectors with other delineation and with the geometric character of the road. Coordinating spacing with roadway geometry can also act to reduce system costs. By comparison, a "conservative" alternative would be to assure that some minimum number of delineators is always visible by basing the spacing on the viewable number observed at the most restrictive curves known to exist. The potential savings of variable spacing occurs because the conservative approach would also maximize the delineators needed while variable spacing works to minimize the delineator quantities.

STUDY DESIGN

Evaluation Technique

Observation of delineator installations during hours of darkness was the basic technique applied. The primary evaluation measure is "undesirability". Undesirability is defined herein as the relative inability of a specific delineator spacing to provide enough information about the longitudinal path of the road ahead and the lateral location of the barrier for observers to consider the delineators an effective aid to nightime driving. Observers were instructed to rate an area as inadequately delineated whenever they felt that the barrier delineation did not provide enough information to satisfy their individual desire for longitudinal and lateral barrier location information. All raters were given a written description of the intended functions of delineation (as outlined above) to consider.

Using such a system, knowledge about the level of delineation that would impress each rater is available. The aggregation of rater opinions describes the relative merits of individual spacings in each given situation. Further, so that the responses weren't biased toward a predetermined notion or existing guideline, a variety of subjects were selected. Both trained and untrained observers were included in rating sessions. Table G of the appendix describes the rater cross section in detail.

Each delineator spacing was observed under comparable nighttime conditions using the same section of roadway for all spacing installations. To accomplish this, each of the spacings to be evaluated was filmed. Each film was verified to insure that it closely represented field conditions by comparing counts of visible delineators on film to a record made of the specific numbers of delineators visible with low beams in the field. Such comparison is important since high beams were needed while filming to adjust for the limitations of even the fastest available film.

A test group was formed to compare "lab" or film viewing rating results to actual nighttime drive through results to further confirm the lab method. The resulting confirmation of the lab method made possible simultaneous viewing by a number of raters during normal working hours. Table F of the appendix presents the details of the comparison.

Test Site Selection

Figure 1 describes a 2.5 mile freeway segment of US Route 1. The test site was extracted from this section since it was observed to contain horizontal and vertical curves which represent the limits for 60 mph design speed, based on the NJDOT design Manual (Reference 3). The section has a posted speed limit of 50 MPH. Eight basic alignment combinations were identified which, in addition to a straight and level situation, form a matrix of nine test situations. Table Two identifies the numbers of combinations that were studied.

Spacing Scheme Selection

A range of candidate schemes was developed for initial screening prior to selection of a relative few for installation and rating. All schemes proposed were multiples of forty feet to ensure coordination with the painted skip line, the primary roadway delineation system. Based on previous work (Reference 2), forty feet was also expected to be the closest spacing which would be needed on divided roadways. Based on a preliminary screening, it was decided to test schemes of delineators placed at intervals of 40 to 160 feet.

FIGURE 1

RT. 1 TEST SECTION

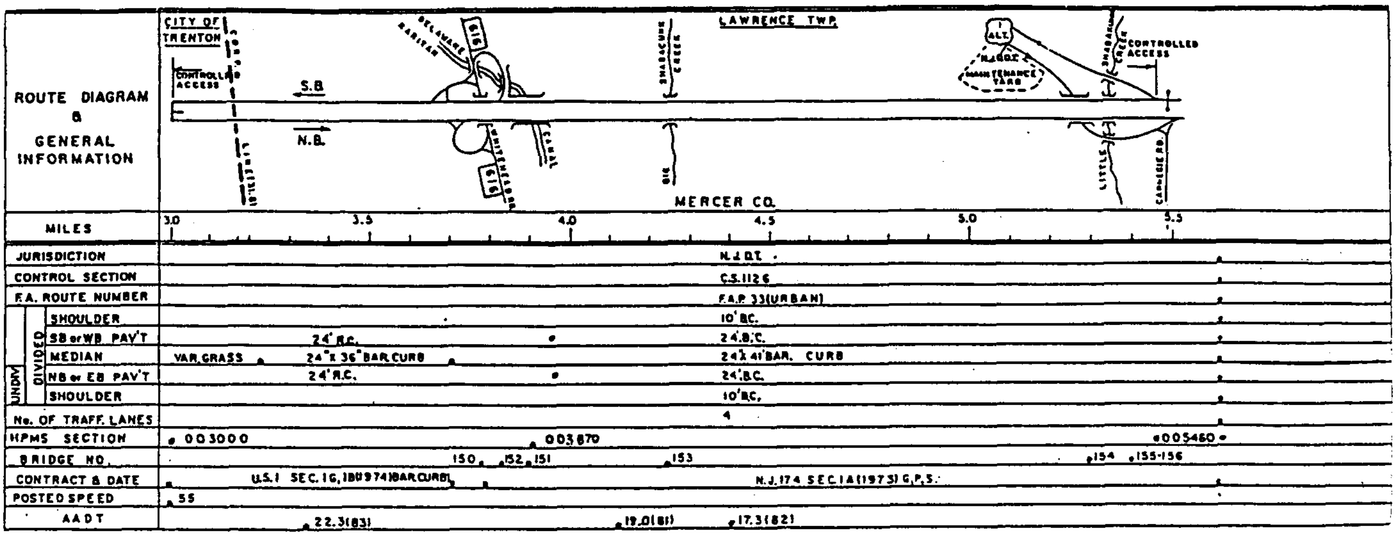


TABLE 2

BASIC ALIGNMENT VARIATIONS

Sites Studied

GEOMETRY		HORIZONTAL		
		LEFT	RIGHT	STRAIGHT
V				
E	CREST	3	3	3
R				
T	LEVEL	1	1	2
I				
C	SAG	2	2	2
A				
L				

Rating Process

Beginning with the longest spacing, filming and rating was done with progressively closer spacings because opinions of desirability are relative. By reducing the spacing in successive viewings, viewers asked to rate a second scheme can do so without having been biased by having already observed a spacing expected to be "more desirable."

In each viewing session a single spacing was observed throughout the test site. Differences in opinion of desirability for any observer during any viewing session are then a function of differences in roadway alignment. At least several weeks were allowed to pass between consecutive viewings so that repeat viewers to reduce the tendency use mental images formed in previous viewing sessions. As a further control, viewing sessions always contained new viewers. Copies of the instruction and answer forms given to the raters are included in Appendix A along with a description of the raters involved.

RESULTS

Survey Data

Combinations of horizontal and vertical roadway geometric were grouped into nine basic categories. Presented in Table 3 are the results of the questionnaire survey. The Table 2 matrix of basic site characteristics is used as a base to organize the results.

In Table 3, vertical alignment variations are listed vertically at the left and identify rows of common vertical

TABLE 3

QUESTIONNAIRE RESULTS

Percent Undesirable By Site

HORIZONTAL GEOMETRY

VERTICAL GEOMETRY	Spacing	LEFT			RIGHT			STRAIGHT		
		Sites			Sites			Sites		
CREST		1*	3	7A	8*	6	2C	2	7	7B
CREST	160 ft	70	70	43	48	25	3	5	3	20
CREST	80 ft	45	52	14	24	0	0	0	0	0
CREST	40 ft	43	25	11	14	-	0	-	-	-
		Sites			Sites			Sites		
LEVEL		4			5 **			4A	5A	
LEVEL	160 ft	23			28			0	3	
LEVEL	80 ft	21			0			0	0	
LEVEL	40 ft	11			-			-	-	
		Sites			Sites			Sites		
SAG		6A	8A*		3A	1B*		2A	7C	
SAG	160 ft	48	33		3	13		5	3	
SAG	80 ft	14	3		3	3		0	0	
SAG	40 ft	21	-		-	-		-	-	

Notes: * - 6 Degree Curve, All Other Curves 2 Degrees
** - Barrier Diverges From Left Edge Line

conditions within the table. Horizontal alignment variations are listed horizontally and describe columns of common horizontal conditions. Three of the initial spacing schemes (40, 80, and 160 feet) are identified along the left margin of Table 3 within each vertical alignment type. Dashes placed where test results would be indicate that this spacing was not tested.

The nine total sites with crest curves present reflects anticipation that crests curves would present difficult viewing situations. Vertical curve "sag" combinations were also observed as well as vertically flat or "level" combinations. Results of Table 3 are reported in terms of the percent of raters who felt the spacing undesirable. Table A of Appendix A contains more specific site location information.

General Observations

From Table 3, it can be clearly seen that the 160 foot was well received in straight and level conditions. The percents are all very low in the column of straight locations indicating that changes in vertical curvature were relatively unimportant in the eyes of the raters when the roadway is straight. In each case the 160 foot spacing performed well.

From further comparisons of the Table 3 columns, left curvature results in more demanding conditions than right curvature. The effect can be seen at each spacing variation. Also, the sites with greater degrees of curvature (smaller radii) tend to provoke a greater percent undesirable. Comparing rows, spacings perform less well on crest curves when right or left hand horizontal curves were present and sags are demanding in combination with left curves. While there are exceptions to these observations, they confirm that the testing mechanism provided consistent and logical data. When compared to the literature review expressed in the background section of this paper, the results reflect observations made by others.

Aggregated Data

To better describe the impacts of the actual site geometric a single descriptive measure was developed to integrate the results as in Figure 2. The "viewable" distance of the x-axis of Figure 2 is the distance in feet that a delineator will be from the viewer if it is at the furthest visible location. This measure was chosen because it combines the independent tendencies of both horizontal and vertical curvature to limit viewing distance.

Regression equations of the desirability data have been presented. Table 4A presents the viewable distance data by site and the reader can compare specific site characteristics for the resultant viewable distances. The viewable distance for each site was determined by reviewing film of the installed delineators for the furthest distance a delineator was viewable. For example, a site where a minimum of three delineators were visible when the spacing was 160 feet, the viewable distance is estimated to be 3 x 160 or 480 feet.

FIGURE 2

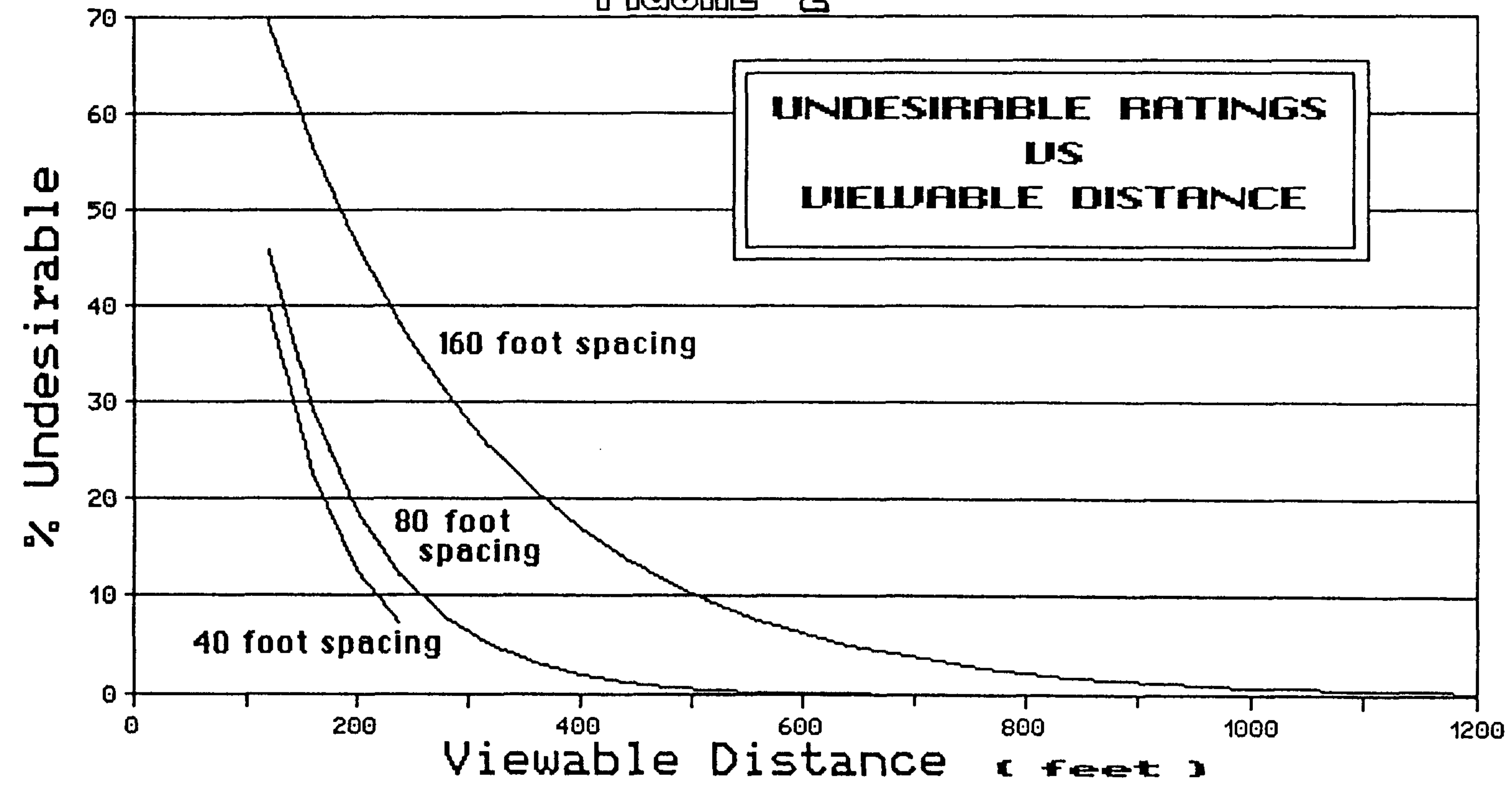

UNDESIRABLE RATINGS
VS
VIEWABLE DISTANCE
% Undesirable
Viewable Distance (feet)
160 foot spacing
80 foot
spacing
40 foot spacing
70
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200

TABLE 4A SITE CHARACTERTICS

Site Number	Viewable Distance Feet	Vertical Curves Type	Vertical Curves R Value	Horizontal Curves Type	Horizontal Curves Radius Ft	Degrees	Site Number
1	120	Crest	0.56	Left	1000	5.7	1
1B	320	Sag	0.90	Right	1000	5.7	1B
2A	560	Sag	0.49	Straight			2A
2	560	Crest	0.51	Straight			2
2C	560	Crest	0.50	Right	3000	1.9	2C
3A	560	Sag	0.73	Right	3000	1.9	3A
3	160	Crest	0.61	Left	3000	1.9	3
4A	720	Level		Straight			4A
4	200	Level		Left	3000	1.9	4
5	640	Level		Right	3000	1.9	5
5A	1200	Level		Straight			5A
6A	200	Sag	0.80	Left	3000	1.9	6A
6	320	Crest	0.61	Right	3000	1.9	6
7A	160	Crest	0.50	Left	3000	1.9	7A
7	560	Crest	0.51	Straight			7
7C	560	Sag	0.49	Straight			7C
7B	400	Crest	0.45	Straight			7B
8A	240	Sag	0.90	Left	1000	5.7	8A
8	240	Crest	0.56	Right	1000	5.7	8

TABLE 4B GEOMETRICS AND VIEWABLE DISTANCE

Viewable Distance (Feet)	Sites	Principal Horizontal Geometrics: Curve Left (Degrees) 6	Curve Left (Degrees) 2	Curve Right (Degrees) 6	Curve Right (Degrees) 2	Straight	
120	1	Crest					
160	3, 7A		Crest				
200	4		Level				
	6A		Sag				
240	8			Crest			
	8A	Sag					
320	6, 1B			Crest	Sag		
400	7B					Crest	
560	2C, 3A			Crest	Sag		
	2, 2A,					Crest	Sag
	7, 7C					Crest	Sag
640	5				Level		
720	4A					Level	
1200	5A					Level	

The regression curves of Figure 2 clarify the relationship of site characteristics and the spacing between delineators. It can be seen that the raters were quite impressed with delineators spaced at 160 feet when the viewable distance reached 700 feet as evidenced by the low % undesirability (5% or less). Similarly, 80 foot spacing performed well where the viewable distance was at least 350 feet. The 40 foot spacing was not impressive enough to achieve 5% or less undesirable. The viewable distance was 240 feet or less in each site tested at 40 feet, however, and the curve of Figure 2 suggests that sites of more than 240 feet viewable will achieve such a rating.

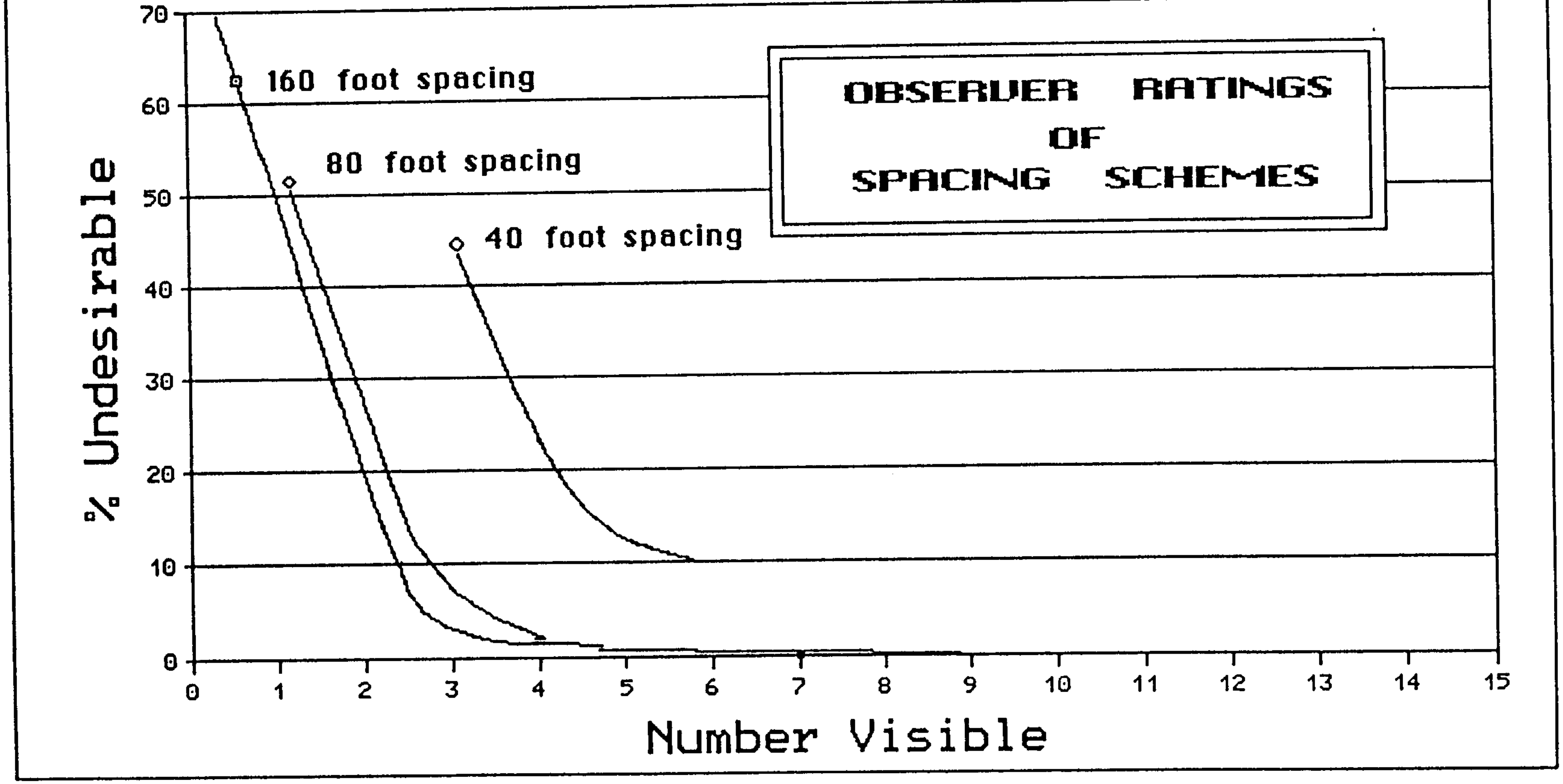
The vertically asymptotic nature of each of the curves of Figure 2 suggest the limits of their perceived value. The positive value of delineators disappears when the viewable distance approaches 100 feet, regardless of spacing.

Number of Visible Delineators

Figure 3 describes the relationship between rater opinions and the number of delineators visible. In Figure 3 the effect of the number of delineators in view can be seen. The sharp change in the slope in the 80 and 160 foot spacing curves is clear evidence of the raters reaction to and desire to see at least three delineators.

Based on the 40 foot spacing curve, which does not achieve the slope change noted for the 80 and 160 foot curves, it is clear that merely setting 3 as a minimum visible requirement will not automatically provide a desirable degree of delineation. This is apparently a reaction to the very short viewable sections of barrier (120 to 160 feet). It also is clear that providing information as to

FIGURE 3



OBSERVER RATINGS
OF
SPACING SCHEMES
160 foot spacing
80 foot spacing
40 foot spacing
% Undesirable
Number Visible
0
10
20
30
40
50
60
70
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

the path of the road ahead will not be possible at such sites, at least not with center barrier mounted delineators alone.

In summary, then, seeing at least three delineators was considered increasingly important as the viewable distance increased. However, even when three delineators are visible, some sites will be less well delineated than others.

Geometric and Viewable Distance

Table 4B sorts the sites of Table 4A for each viewable distance increment observed. Specific sites and the geometry at each are identified. Compared to sag or level conditions, crest curves result in a shorter viewable distance, regardless of horizontal geometrics. Vertical geometry alone produces sites with as little as 400 feet of viewable distance, less than the distance needed to install 3 delineators at 160 feet.

Curves of only 2 degrees when viewed to the left will cause the viewable distance to fall below 240 feet, the distance needed for 3 delineators to be seen when spaced at 80 feet. The same curves when seen to the right (as when travelling in the opposite direction on the same road) are not a concern since they provide at least 240 feet of viewable distance, even at 6 degree curvature.

The curves of figures 2 and 3 indicate a narrow band of conditions at which 120 foot spacing would be "best." Since this band was so limited, 120 foot was not investigated further.

To summarize, Figure 2 shows that the desire for reduced delineation spacing becomes pronounced when viewable distances drop to about 400 feet. Thus having "reduced" spacing choices available would aid in delineating specific sites, in particular from 80 to 40 feet when 2 or more degrees of horizontal curvature exists. Curves of 2 degrees were chosen since at least 320 feet of viewable distance will be needed to provide room for 4 delineators at 80 feet and 2 degree curves limit the distance to 240 feet in left curves.

Curves of greater curvature than 6 degrees merely produce shorter viewable distances than observed at the test section. Based on poor results at 6 degree curves, there is no reason to determine performance on tighter curves. In any event such curves are beyond the recommended standards for roads with median barriers. Curves of lesser curvature than 2 degrees will cause viewable distances which fall within the range of the curves of Figures 2 and 3. As a result, these curves should be adequate for estimating virtually all center barrier delineation needs.

Maintenance Inventories

Review of three installations of Center Barrier Delineators in New Jersey suggests that maintenance will be needed on 2.5 to 10 % of delineators yearly. While the data is limited since only three installations have been made, flexible mounts appear desirable by comparison. Details of this review can be found in the appendix.

While loss of delineators over an extended period does not appear to be a problem, a strong tendency for delineators to be missing in groups was noted at each of three existing installations.

Even though the loss of a single delineator at any point will not destroy the value of the delineation system, consecutive missing delineators should be avoided. It stands to reason that maintenance preference should be directed to those locations where consecutive delineators require maintenance. If missing delineators are limited to a single location in any sequence, reasonable conformance with the 240 preference (as voiced in RPM Guidelines) should be maintained.

DISCUSSION

Installation Costs

Estimates of costs for various spacing schemes have been prepared. As this report is written, data on horizontal and vertical curvature for the State system is not readily available. The cost estimates are based on the gross assumption that horizontal and vertical geometry exists on the system which could make delineators spaced at 40 feet desirable on some 40 % of the system while delineators at 80 feet could be desirable on 50 % of the system. On the remaining 10 %, delineators spaced at 160 feet could be desirable. This assumption is made in lieu of data. Discussions with various department personnel indicates that these estimates appear reasonable and conservative and that actual costs could be somewhat lower.

Data available from NJDOT'S Bureau of Data Resources indicates that some 260 of the 2200 mile State highway system has concrete median barrier installed. While there is no reason for guardrail median barriers to be excluded from delineation plans, data is not available to use for cost estimating purposes.

Table 5 identifies the costs associated with placing typical double sided amber delineators on a median barrier. Cost estimates are for preassembled double faced delineators meeting MUTCD standards. Adhesive costs will vary since the adhesive will be applied in both cold and hot weather. Thick layers occur in colder weather averaging about 10 delineators per tube, as opposed to 15 or more mounts per tube in the summer application. The estimates are intentionally conservative in that the estimated amount would allow all installations to be made in cold weather. The time to install markers is dependent on the speed a crew will walk between proposed installation points as well as the time spent installing each delineator. A speed of 4 miles per hour has been assumed based on observations of crews performing test site installations for this study. The installation time per delineator is also based on these crews.

Table B of the appendix presents details of the effect of crew size on installation time. In brief, crew size and experience can substantially reduce the installation time. No more than a minute per delineator should be needed, on average, for an experienced crew. This is dependent on doing certain parts of the preparation while walking as well as having installers do nothing but walk and install. The speed of installation varies directly with delineator spacing, the time for any given number of mounts decreasing as the distance from mount to mount decreases. Time per mount will also decrease as the crew develops a routine. Crew costs reported by the Bureau of Maintenance were used for typically salaried work crews. Costs are detailed in Appendix Table C and average up to $144 per hour as adjusted for overhead and including vehicle costs.

Table 5 SUMMARY OF SYSTEM INSTALLATION COSTS

Spacing Scheme	Constant "80"	Constant "40"	Dual "40/80"
Feet/Delineator	80	40	* 57
Delineators	17,160	34,320	24,024
Hours per Mile	0.80	1.34	1.05
Crew Hours	209	349	273
Costs :	$$	$$	$$
Materials	42,042	84,048	58,858
Labor	26,599	44,452	33,565
TOTAL COSTS $	68,641	128,536	92,424
PER DELINEATOR	4.00	3.75	3.85

* - Average

System Size: 260 Miles;
Fixed costs: $2.25 per del. + $0.20 for adhesive;
$98/hr when installing;
Factor cost of time by 1.3 to include Travel;

A complete breakdown of cost data is contained in appendix tables B, C, & D.

<u>Summary</u>

Candidate schemes for delineating the portions of the state highway system containing concrete median barrier is estimated to range from 68 to 128 thousand dollars with the average installed cost per delineator averaging just under $4. Competitive bid pricing and competition of alternative devices could result in even lower costs.

Table 6 expands the loss per site data of existing installations to the statewide system. From Table 5, spacing delineators generally at 80 feet, with exceptions at 40 feet where needed, the entire system can be expected to average about 57 feet between delineators. At this rate, the system would be comprised of some 24,000 double faced delineators.

If maintenance is scheduled yearly at all multiple loss sites, the total cost would be some $5000 yearly and some 3.5 % of the system would be replaced yearly. Projecting maintenance similarly but for only sites where three or more delineators are missing, about 130 sites would be involved yearly. Some 2.5% of the system would be involved on a yearly basis. Including material costs, this total would come to about $3400 annually.

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APPENDIX CONTENTS Page

Appendix A

Questionnaire, Site & Cost Details

The Division of Research and Demonstration is evaluating spacing systems for median barrier delineators. Your assistance in this effort by participating in the following opinion survey is appreciated.

You will be observing (a film of) delineators placed on the median barrier on a section of freeway. The stretch of road to be observed will be several miles long. The purpose of the survey will be to identify any places within this stretch where the delineators seem inadequate. To assist you in referencing locations, numbers will be heard from one to forty as you view the section.

As you view the delineators, each of the locations you felt the delineators inadequate are to be identified by circling the number(s) which you feel describe the section best. If only one or two numbers best describe the location, circle only that (those) numbers. If the section you feel is inadequate extends for more than two numbers circle the first and last and line out all the numbers between them.

The following example is illustrative of the situation where locations 3 through 8, 21, 22 and 36 were felt inadequate:

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40

In forming your opinion of the delineation, consider the following several factors:

- Currently there is no standard for delineator spacing on the median barrier.
- Guidelines for right shoulder delineators are not nesessarily appropriate for median barriers.

- Delineators are usually thought to be useful when they provide information about the path of the road ahead and/or information about how far the barrier is from the observer vehicle.

Before starting (the film), please fill in your name, title, work phone and the date on the attached answer form.

Questionnaire Survey Form

Project 7714509 – Center Barrier Delineation Spacing Study

NAME ______________________ TELEPHONE NUMBER __________

TITLE ______________________ DATE ________________

CIRCLE REFERENCE NUMBERS BELOW WHICH RELATE TO AREAS OF INADEQUATE DELINEATION:

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80

USE THE SPACE BELOW FOR ANY COMMENTS YOU MAY HAVE:

TABLE A

RT 1 FREEWAY TEST SITE

HORIZONTAL AND VERTICAL CHARACTERISTICS

Limits Station Numbers	Milepost	Length 100's of Feet	Principal Geometry (North)		Questionnaire Test Site Nbd	Sbd
158.00	3.14	Start				
163.25	3.24	525	.7% D	Straight		
167.00	3.31	375	Sag + 3K	Right	4	5
170.50	3.38	350	.5% U	Straight		
175.50	3.47	500	.5% D + 3K	Right		
178.50	3.53	300	.5% U	Straight	4A	5A
183.00	3.61	450	.5% U	Straight		
185.00	3.65	200	1.4% U	Straight		
188.50	3.72	350	1.4% U	Straight		
191.25	3.77	275	Sag + 3K	Left		6A
194.00	3.82	275	3.6%U + 3K	Left		
195.00	3.84	100	Crest + 3K	Left		
198.25	3.90	325	Crest + >3K	Right		
200.00	3.94	175	PVI + 3K	Right	3	6
204.25	4.02	425	Crest + 3K	Right		
206.00	4.05	175	Crest + >3K	Right		
208.25	4.09	225	3.3%D + >3K	Left		
210.50	4.13	225	3.3%D + 3K	Left		
218.50	4.29	800	Sag + 3K	Left	3A	7A
220.50	4.32	200	C-PVI + 3K	Left		
222.00	4.35	150	Crest + 3K	Left	2C	
225.75	4.42	375	1% U + 3K	Left		
227.75	4.46	200	1% U + >3K	Left		
232.00	4.54	425	Crest PVI	Straight	2	7
235.50	4.61	350	Crest	Straight		
238.00	4.66	250	Sag	Straight		
242.50	4.74	450	Sag	Straight	2A	7C
244.00	4.77	150	1.3%U + >3K	Right		
247.50	4.84	350	1.3%U	Straight		
250.50	4.89	300	C-PVI + >3k	Left		7B
253.50	4.95	300	Crest + >3k	Left		
256.00	5.00	250	1.4%D + >3K	Left		
257.00	5.01	100	Sag + >3K	Left		
258.50	5.04	150	Sag + >3K	Left		
260.25	5.08	175	Sag + <3K	Left		8A
261.00	5.09	75	Sag + <3K	Left	1B	
262.50	5.12	150	3.1%U + <3K	Left		
263.00	5.13	50	3.1%U + >3K	Left		
264.50	5.16	150	Crest + >3K	Left		
266.50	5.19	200	Crest + >3K	Right		
267.25	5.21	75	Crest + >3K	Right		
269.00	5.24	175	PVI + <3K	Right	1	8
274.50	5.35	550	Crest + <3K	Right		
276.50	5.38	200	3.6%D + >3K	Right		
281.50	5.48	500	Sag + >3K	Right		
282.75	5.50	125	0.4%U + >3K	Right		
Total =		12475 Feet				

TABLE B

INSTALLATION TIME ESTIMATES

Installation System	Field Measured Spacing				Pre-Determined Spacing (Constant or Pre-measured)		
Crew Size	2 Person	8 Person	8 Person	8 Person	5 Person	5 Person	5 Person
///////////	////////	////////	////////	////////	////////	////////	////////
Spacing Ft	160	160	80	40	160	80	40
Miles	2.39	1	1	1	1	1	1
Delineators	80	33	66	132	33	66	132
Observed Hr	4						
Walking							
Mi per Hr	4	4	4	4	4	4	4
Total Hrs	0.60	0.25	0.25	0.25	0.25	0.25	0.25
Installing	*	**	**	**			
Rate per Hr	23.47	60	60	60	120	120	120
Del per Min	0.39	1	1	1	2	2	2
Min per Del	2.56	1	1	1	.5	.5	.5
Hours	3.40	0.55	1.10	2.20	0.28	0.55	1.10
///////////	////////	////////	////////	////////	////////	////////	////////
SUMMARY							
Hours/Mile							
Walking:	.25	.25	.25	.25	.25	.25	.25
Installing:	1.42	0.55	1.10	2.20	0.28	0.55	1.10
Total	1.67	0.80	1.35	2.45	0.53	0.80	1.35
Min/Del:	3.04	1.45	1.23	1.11	0.95	0.73	0.61
///////////	//				//////////////////////////////////		

NOTE - * Observed at Pilot Test Site
** Based on Comparison To Raised Pavement Marker Replacement Times

TABLE C HOURLY CREW AND VEHICLE COSTS

	RATES		FIELD MEASURING		PRE-DETERMINED	
	$$ Base	$$ Adj	Crew	Cost	Crew	Cost
/////////	///////	///////	///////	///////	///////	///////
PERSONNEL		* Factor 1.86				
Assistant Foreman	12.25	22.79	1	22.79	1	22.79
Truck Driver	8.69	16.17	2	32.34	2	32.34
Maintenance Man	8.27	15.39	5	76.95	2	30.78
-------			-------	-------	-------	-------
Total			8	132.08	5	85.91
VEHICLES						
Five Man Cab	9.29	9.2925	1	9.29	1	9.29
2.5 Ton + Imp. Att.	2.42	2.42	1	2.42	1	2.42
-------			-------	-------	-------	-------
Totals			2	11.7075	2	11.7075
=======	=======	=======	=======	=======	=======	=======
CREW TOTALS				143.79		97.62
/////////////////////////////			/////////////////		/////////////////	

Note: * - Factor Includes Fringe, Overhead, Etc.

TABLE D

SYSTEM INSTALLATION COST ESTIMATES

TOTAL MILES = 260

ALTERNATIVE: "40/80/160"

Basis:	Field	Measured	Geometrics	TOTALS	
Ft/Delineator	40	80	160	59	(Average)
/////////////	//////////	//////////	//////////	////////	////////////
System Length					
Percent:	40	50	10	100	%
Miles:	104	130	26	260	Miles
MATERIALS					
Delineators:	13728	8580	858	23166	Delineators
Unit Cost: $	2.25	2.25	2.25	2.25	Dollars
Sub-Total: $	30888.00	19305.00	1930.50	52123.50	Dollars
Adhesive:	1372.8	858	85.8	2316.6	Tubes
Unit Cost: $	2.00	2.00	2.00	2.00	Dollars
Sub-Total: $	2745.60	1716.00	171.60	4633.20	Dollars
-------------	--------	--------	--------	--------	------------
Cost $	33633.60	21021.00	2102.10	56756.70	Dollars
INSTALLATION					
(Min/Del):	1.11	1.23	1.47	1.21	Minutes
Hours/Mile:	2.44	1.35	0.81	1.79	(Average)
Hours:	254	176	21	451	Hours
Crew Rate: $	144 per hour,	Field Measure and Install			
-------------	--------	--------	--------	--------	------------
On Site: $	36571	25328	3027	64927	Dollars
Travel Factor	1.3	1.3	1.3		
Cost $	47543	32927	3935	84405	Dollars
/////////////	//////////	//////////	//////////	////////	////////////
TOTAL COSTS $	81176	53948	6037	141161	Dollars
AVERAGE $/Del	5.91	6.29	7.04	6.09	Dollars

TABLE E

SYSTEM INSTALLATION COST ESTIMATES

TOTAL MILES = 260

ALTERNATIVE:	"40"	"80"	"40/80/160"	"40/80"	
Ft/Delineator	40	80	59	57	(Average)
//////////////	////////	////////	////////	////////	////////
System Length					
Percent:	100	100	100	100	%
Miles:	260	260	260	260	Miles
MATERIALS					
Delineators:	34320	17160	23166	24024	Delineators
Unit Cost: $	2.25	2.25	2.25	2.25	Dollars
Sub-Total: $	77220.00	38610.00	52123.50	54054.00	Dollars
Adhesive:	3432	1716	2316.6	2402.4	Tubes
Unit Cost: $	2.00	2.00	2.00	2.00	Dollars
Sub-Total: $	6864.00	3432.00	4633.20	4804.80	Dollars
-------------	--------	--------	--------	--------	--------
Cost $	84084.00	42042.00	56756.70	58858.80	Dollars
INSTALLATION					
(Min/Del):	0.61	0.73	0.71	0.66	Minutes
Hours/Mile:	1.34	0.80	1.05	1.01	
Hours:	349	209	272	263	Hours
Crew Rate: $	98 per hour, Install Only				
-------------	--------	--------	--------	--------	--------
On Site: $	34194	20460	26676	25819	Dollars
Travel Factor	1.3	1.3	1.3	1.3	
Cost $	44452	26599	34678	33565	Dollars
//////////////	////////	////////	////////	////////	////////
TOTAL COSTS $	128536	68641	91435	92424	Dollars
AVERAGE $/Del	3.75	4.00	3.95	3.85	Dollars

TABLE F COMPARISON OF "LAB" AND FIELD RATINGS

Sites Rated Inadequate

Observer	"lab"	Field
" E "	1,3	1,3
" J "	None	None
" L "	1,4,6A,7A	1,3,4,6A,7A

TABLE G

RATER CROSS SECTION

	Professional	Technical & Clerical	Total
Male	42	9	51
Female	3	4	7
TOTAL	45	13	58

TABLE H 10 REPEAT OBSERVERS VS ALL OBSERVERS

Percent Undesirable By Observer Group

HORIZONTAL GEOMETRY

			LEFT		RIGHT		STRAIGHT	
			Observers		Observers		Observers	
		Spacing	All	"10"	All	"10"	All	"10"
VERTICAL GEOMETRY	CREST	160 ft	61	73	25	15	9	0
		80 ft	37	37	8	0	0	0
		40 ft	26	27	7*	0*	-	-
			Observers		Observers		Observers	
			All	"10"	All	"10"	All	"10"
	LEVEL	160 ft	23	20	28	30	1	0
		80 ft	21	10	0	0	0	0
		40 ft	11	0	-	-	-	-
			Observers		Observers		Observers	
			All	"10"	All	"10"	All	"10"
	SAG	160 ft	40	55	8	10	29	0
		80 ft	9	10	3	0	0	0
		40 ft	21*	20*	-	-	-	-

Notes: * - Not All Sites Tested At40 Foot

TABLE I

EXPERT OBSERVERS VS ALL OBSERVERS

Percent Undesirable By Observer Group

HORIZONTAL GEOMETRY

Vertical Geometry	Spacing	LEFT Observers All	LEFT Observers Expert	RIGHT Observers All	RIGHT Observers Expert	STRAIGHT Observers All	STRAIGHT Observers Expert
CREST	160 ft	61	93	25	50	9	13
CREST	80 ft	37	50	8	0	0	0
CREST	40 ft	26	25	7*	0*	-	-
LEVEL	160 ft	23	80	28	20	1	0
LEVEL	80 ft	21	0	0	0	0	0
LEVEL	40 ft	11	0	-	-	-	-
SAG	160 ft	40	70	8	30	29	0
SAG	80 ft	9	0	3	0	0	0
SAG	40 ft	21*	25*	-	-	-	-

Notes: * - Not All Sites Tested At 40 Foot

Appendix B

Observed Ratings

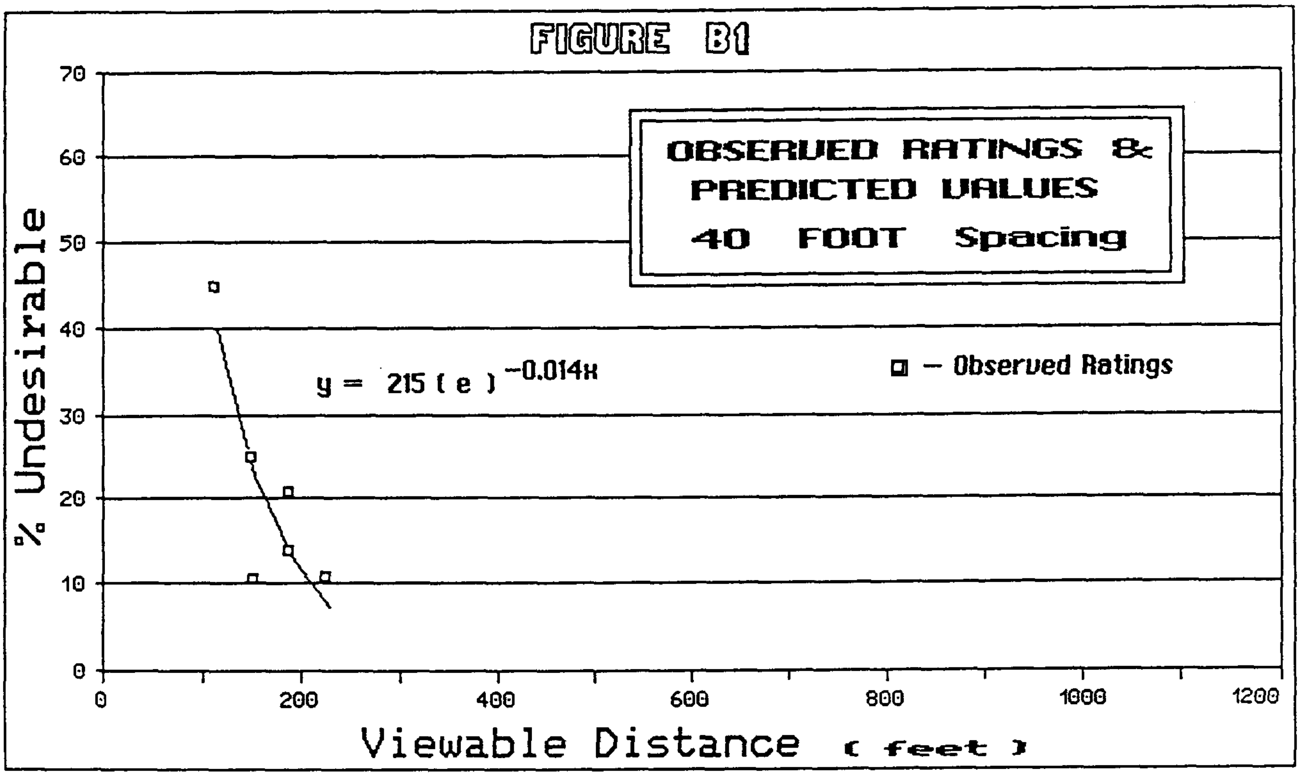
FIGURE B1
OBSERVED RATINGS &
PREDICTED VALUES
40 FOOT Spacing
y = 215 (e) −0.014x
□ – Observed Ratings
% Undesirable
Viewable Distance (feet)
0
10
20
30
40
50
60
70
0
200
400
600
800
1000
1200

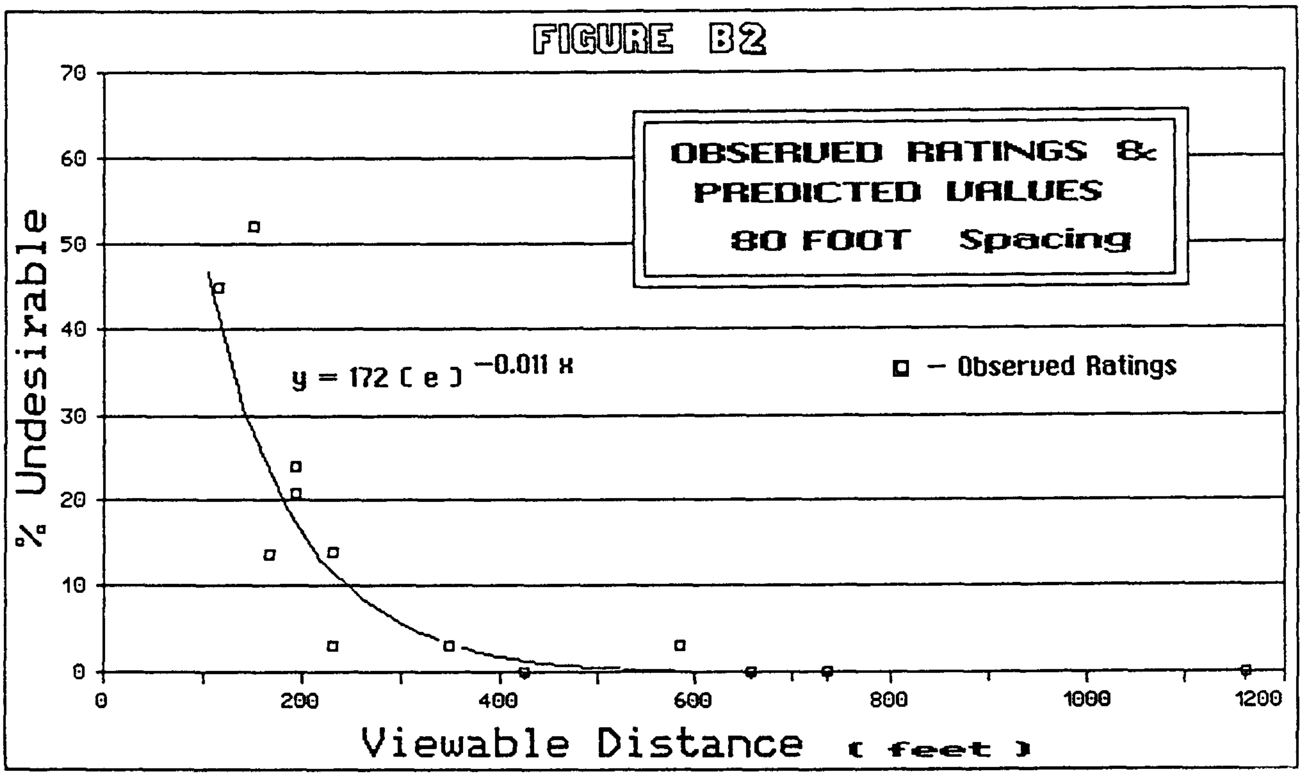
FIGURE B2
OBSERVED RATINGS &
PREDICTED VALUES
80 FOOT Spacing
y = 172 (e) −0.011 x
□ – Observed Ratings
% Undesirable
Viewable Distance (feet)
0
10
20
30
40
50
60
70
0
200
400
600
800
1000
1200

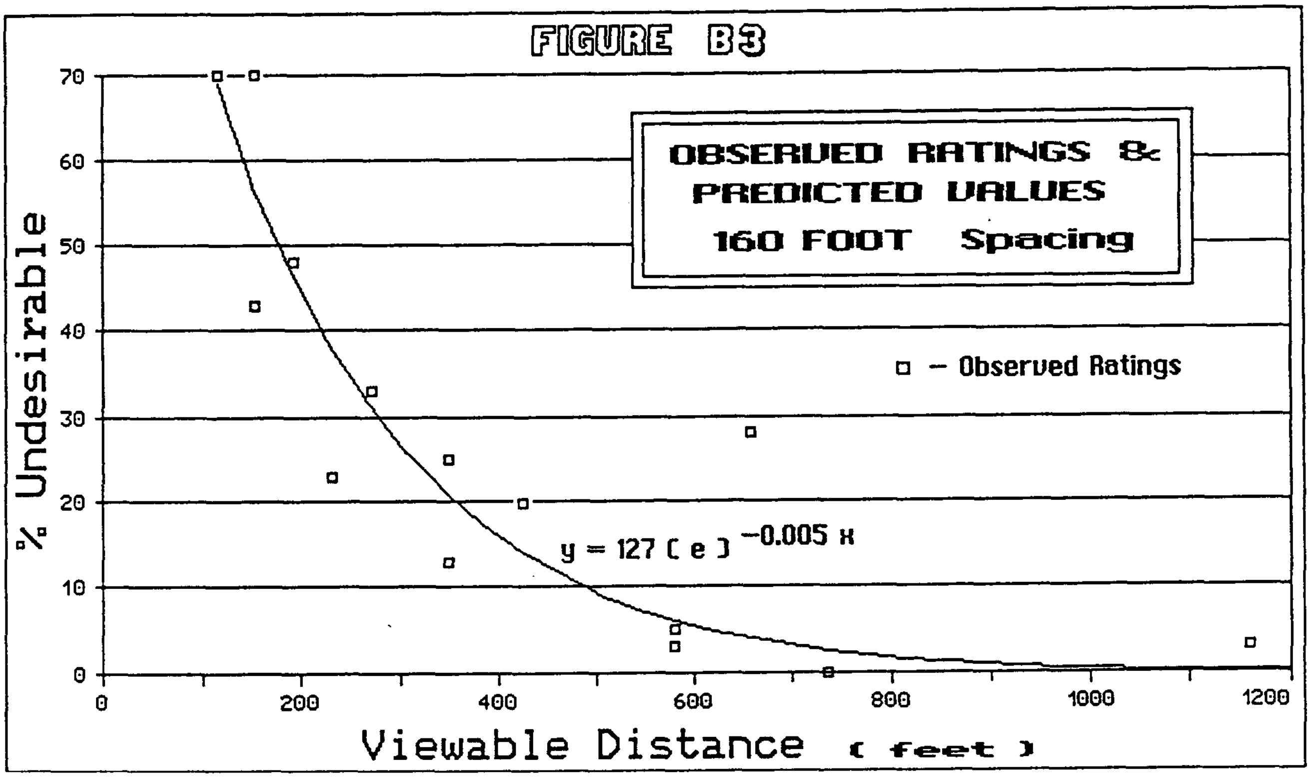
FIGURE B3
OBSERVED RATINGS &
PREDICTED VALUES
160 FOOT Spacing
□ – Observed Ratings
y = 127 (e) −0.005 x
% Undesirable
Viewable Distance (feet)
70
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200

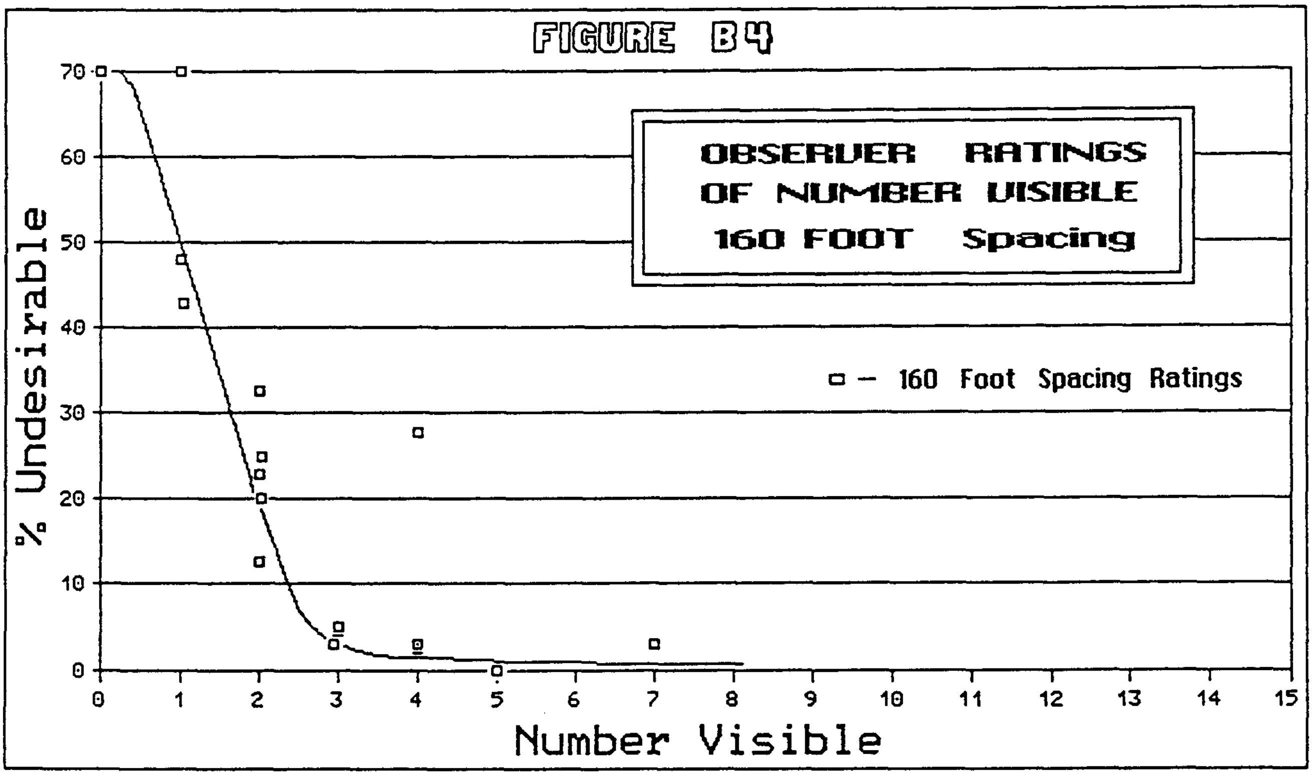
FIGURE B4
OBSERVER RATINGS
OF NUMBER VISIBLE
160 FOOT Spacing
□ – 160 Foot Spacing Ratings
% Undesirable
Number Visible
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

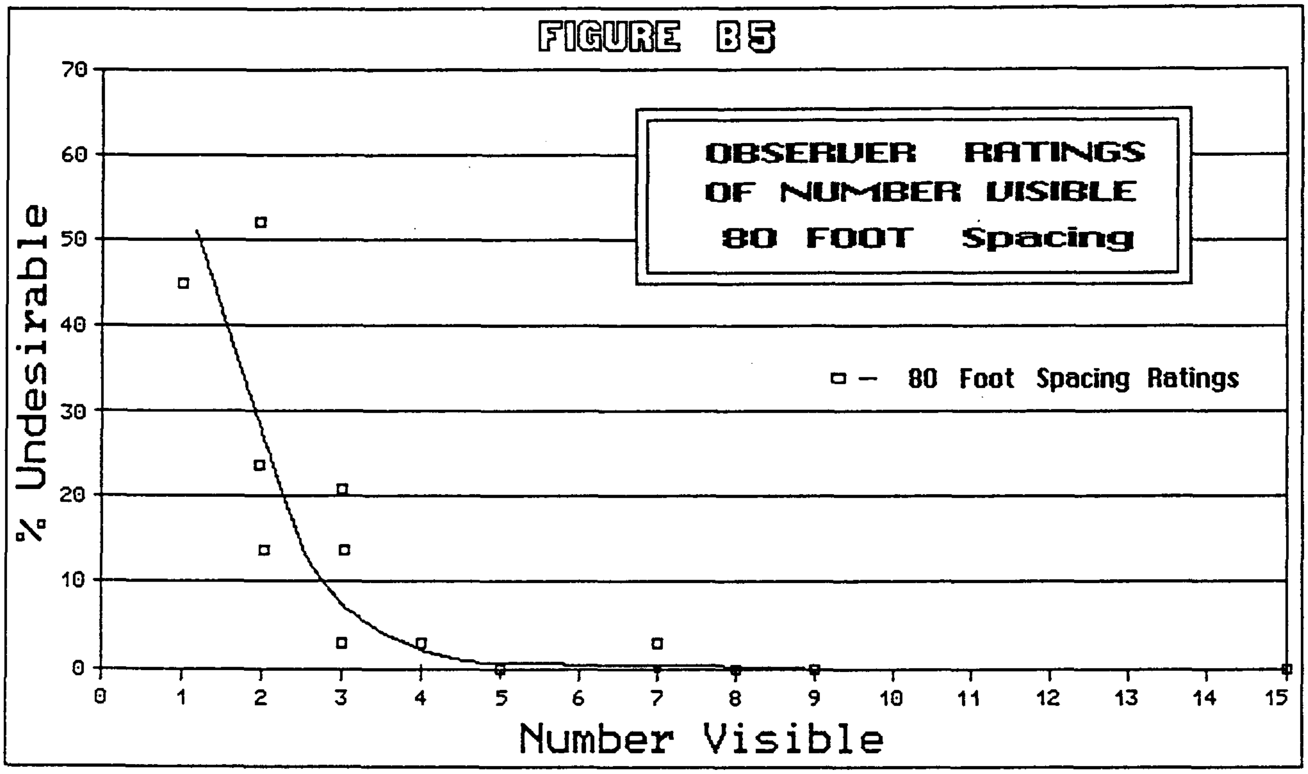
FIGURE B5
OBSERVER RATINGS
OF NUMBER VISIBLE
80 FOOT Spacing
80 Foot Spacing Ratings
% Undesirable
Number Visible
0
10
20
30
40
50
60
70
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

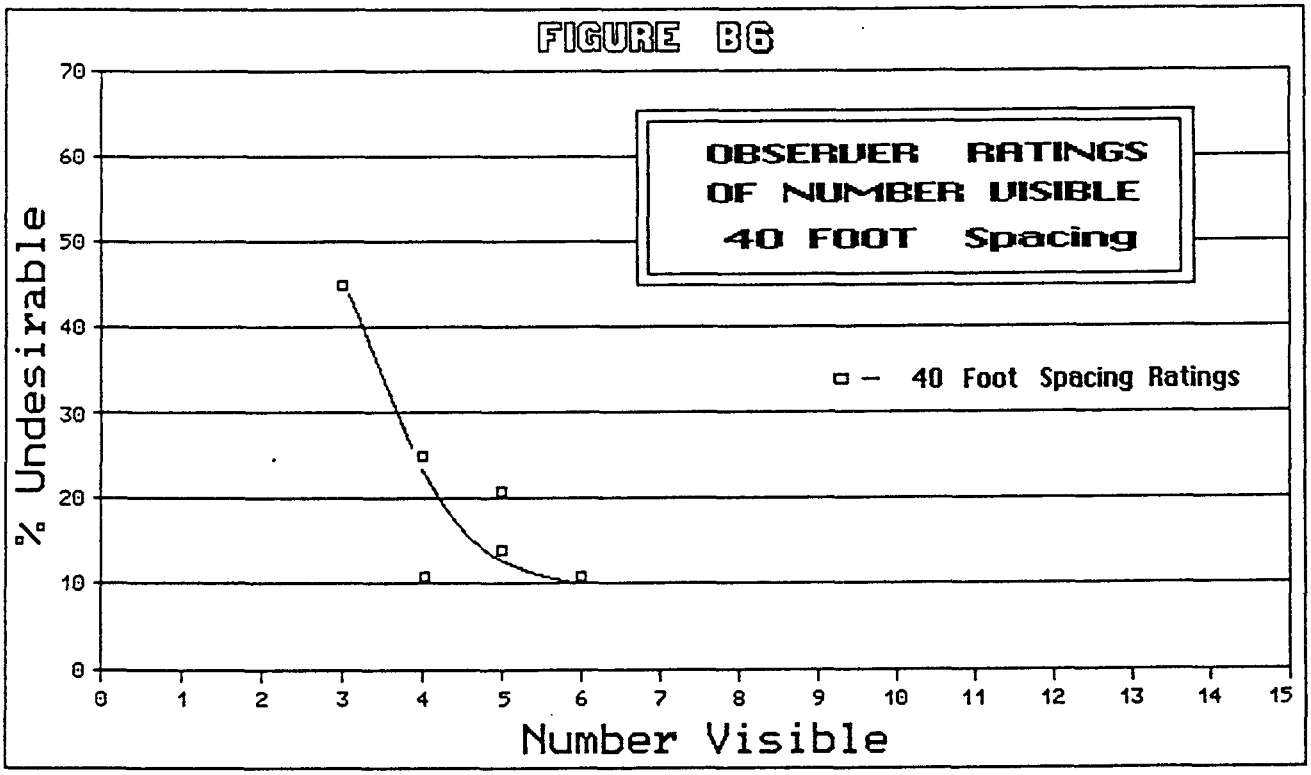
FIGURE B6
OBSERVER RATINGS
OF NUMBER VISIBLE
40 FOOT Spacing
40 Foot Spacing Ratings
% Undesirable
Number Visible
0
10
20
30
40
50
60
70
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Appendix C

Maintenance Inventories

Maintenance Inventories

-Rt 80, Mp 0.0 to Mp 4.1

This installation was finished by December of 1977. As part of a pilot test of mounting procedures, ethylene vinyl acetate mounts were placed at over 400 locations along this 4 mile stretch. (Reference 2) This material is flexible and remains so with time. Three inch round reflectors were mounted, generally on both faces of each mount. The barrier was primed and butyl pads were placed under each mount. Each mount was also bolted to the barrier top. The system was assembled from individually supplied parts.

When surveyed in May of 1987, 113 of the 432 mounts needed maintenance to either replace the entire mount or merely to reinstall one or both reflectors. The total loss of 26 % across 9.5 years yields a yearly rate of 2.8 % of the installation needing maintenance.

-Rt 1, Mp 23.7 to 24.2

Delineators were placed at this location to test the use of construction adhesives being recommended for use with acrylic mounts. The mounts at this location were quite rigid. Some 40 mounts were installed prior to July of 1983. One mount was removed in 1984 to examine the adhesive bond, which was excellent. Of the remaining 39, 24 were in need of maintenance as of May 1987. The loss of 38 % across almost 4 years yields a yearly rate of about 10 % of the installation.

-Rt 1 Freeway, Mp 3 to 5.5

This installation, also utilizing construction adhesive, was completed in August of 1985. It was also the test site for determining spacing recommendations found elsewhere in this report. The delineator mounts are considered flexible, although not nearly as flexible as those used on Route 80. When inventoried in May of 1987, 28 of the 308 mounts were in need of maintenance. This 9 % loss in just under 2 years translates to about 5 % of the installation lost per year.

TABLE J

MAINTENANCE NEEDS OF CENTER BARRIER DELINEATORS
Results of May 1987 Survey

Installation	Mileposts	Years	- Installed - Total	/Mile	----- Lost ------ Total	%	%/Year
Rt 1 Freeway	3.0 - 5.5	1.8	308	123	28	9.1%	5.1%
Rt 1 New Brunswick	23.7 - 24.2	4.0	39	78	15	38.5%	9.6%
Rt 80 Water Gap	0.0 - 4.1	9.5	432	105	113	26.2%	2.8%

Installation	----- Lost ----- Total	2+	% 2+	Sites	Lost / Site
Rt 1 Freeway	28	19	67.9%	6	3.2
Rt 1 New Brunswick	15	7	46.7%	2	3.5
Rt 80 Water Gap	113	79	69.9%	23	3.4

Installation	----- Lost ----- Total	3+	% 3+	Sites	Lost / Site
Rt 1 Freeway	28	13	46.4%	3	4.3
Rt 1 New Brunswick	15	5	33.3%	1	5.0
Rt 80 Water Gap	113	53	46.9%	10	5.3