EVALUATION OF HIGH INTENSITY SHEETING FOR OVERHEAD HIGHWAY SIGNS

by

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SUMMARY

The current practice in Virginia is to reflectorize and illuminate all overhead highway signs because of their important role in the safe and orderly flow of traffic. Reflectorization is obtained by using reflective sheeting as background and legend materials, and diffuse illumination is provided on the sign surface by lighting fixtures. The performance of the high intensity sheeting has shown significant promise and the purpose of this research was to determine the feasibility of using the material on overhead highway signs without external illumination.

Since sign brightness standards have not been established, a comparative technique was employed whereby the brightness of six high intensity overhead signs without illumination was compared to that of six conventional illuminated signs. All experimentation was conducted in the field under the physical and environmental conditions experienced by the highway user. Luminance measurements were made with a telephotometer at the driver's eye position of eleven conventional automobiles. A total of 5,446 luminance measurements were recorded from the travel lanes of illuminated and non-illuminated roadways.

The study concluded that the unlighted high intensity signs were brighter than the lighted conventional signs for the motorist traveling on straight sections of roadways using high beam headlights. For the same motorist using low beams the luminances of the high intensity signs were not as bright as those of adjacent conventional signs. Under stream traffic conditions, the average luminances of the conventional signs were slightly higher than those of the unlighted high intensity signs, however, in many cases there were no statistical differences and the people who viewed the signs stated they preferred the high intensity sign because its uniform brightness provided better legibility.

On a curved approach, where only a limited amount of light from the vehicles was projected upon the overhead signs, the brightness of the unlighted high intensity signs was not sufficient to provide the motorists with sign visibility and legibility equivalent to those obtained from the lighted conventional signs.

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INTRODUCTION

Interstate highways and similar freeways have necessitated the use of many overhead signs. The traffic operational requirements on the Shirley Highway in Northern Virginia were such that all guide signs had to be installed overhead. The overhead sign, like any other, must be visible and legible to the motoring public and the Manual on Uniform Traffic Control Devices states that "all overhead sign installations should be illuminated where an engineering study shows that reflectorization will not perform effectively."[1] The reflectivity of the materials used in the past was not sufficient to fulfill this requirement, therefore, a light source was required to make the signs effective at night.

The current practice in Virginia is to reflectorize and illuminate all overhead signs. Reflectorization is obtained by using enclosed lens reflective sheeting as background and legend materials and diffuse illumination is provided on the sign surface by lighting fixtures. Many of the lighting fixtures are fluorescent, however, the newer overhead sign installations are equipped with mercury vapor fixtures.

Although overhead signs play a significant role in the safe and orderly flow of traffic, they do create problems for traffic engineers and maintenance personnel. The external illumination is one of these problems.

Cost is always an important factor and the expense of the initial light installation is compounded by the great distances to the power sources and unfavorable working conditions on the heavily traveled highways. The maintenance of the lighting has proven to be a regular and continuing process which requires periodic night inspections to locate malfunctioning lights.

Associated with the malfunctioning illumination is the loss of sign service to the motoring public. Overhead signs are usually installed at complex locations on the highway and are most important during the hours of darkness when the driver is unable to see the approaching highway configurations. Several studies have shown that the brightness of conventional signs reduces drastically when the lighting is eliminated, and the level of visibility on the conventional unlighted sign is not sufficient for the average driver.[2,3,4]

The repairs of overhead sign lighting require that equipment and workmen be on the roadway, therefore, a lane must be closed during these operations. Traffic volumes on many freeways, especially in the urban areas, are such that a lane cannot be taken out of service except for a few hours during the off-peak period. Even then, much inconvenience is created for the motoring public, and the exposure of the workmen to traffic is extremely hazardous.

PURPOSE AND SCOPE

Studies have concluded that the brightness of encapsulated lens (high intensity) sheeting is superior to that of the enclosed lens sheeting presently used as faces on overhead traffic signs.[2,3,4,5] The performance of the high intensity sheeting shows significant promise and the purpose of this research was to determine the feasibility of using the material on overhead highway signs without illumination. Since sign brightness standards have not been established, a comparative technique was employed whereby the brightness of high intensity overhead signs without illumination was compared to that of the conventional illuminated signs.

All experimentation was conducted in the field under physical and environmental conditions experienced by the highway user. Luminance measurements were made of the legend and background materials with a telephotometer at the driver's eye position in a variety of conventional automobiles. All measurements were taken from the travel lanes. The major portion of the evaluation was performed on signs installed on non-illuminated freeways; however, several experiments were conducted on signs with ambient lighting because of the trend to illuminate highways, especially in urban areas.

Human factors were incorporated into the study by requesting individuals such as police officers, engineers and highway users to make visual comparisons of the visibility and legibility of the signs.

PHOTOMETRIC INSTRUMENTATION

Luminance measurements were made with a Gamma Scientific, Inc., Model 2009K telephotometer. This instrument was suited for the study as it measures the amount of reflected light from the sign surface. At the outset and at the termination of the tests the instrument was calibrated and over a number of tests it averaged ± 2.0 percent.

Although five acceptance angles were available with the instrument, the 2 minutes of angle sensing probe was chosen as it approaches closely the 20/40 acuity eyesight required for licensing of drivers in Virginia. Further, the generally accepted 50-foot per inch (38.71 m/cm) of letter height criterion(6) for letter legibility and the interstate letter stroke width of 1/5 the letter height yields a stroke width at legibility thresholds for the acuity standards allowed of approximately 2 minutes width.(7) Thus the acceptance angle of the instrument approximates the letter stroke width at the useful legibility distances.

As shown in Figure 1, the instrument was mounted on a tripod above the driver seat back at the driver eye position. In normal use, two operators were required: one to align the optical head with the object in the field of view, the other to record the result.

STUDY SITES

Because of the comparative technique employed in the study, sites were selected where two or more signs were installed on the same overhead structure. At each site, an existing sign was refurbished with enclosed lens sheeting (background and legend) and the adjacent sign was refurbished with high intensity sheeting. The overlay method of sign refurbishment was utilized.

Recording distances were established at each site and marks were applied on the roadway surface on the sign approach at 300-foot (91.44 m) intervals up to a maximum distance of 1,500 feet (457.20 m), as shown in Figure 2. It was felt that these distances encompassed the range of interest accorded detection, identification, and legibility factors.

Six locations representing a variety of geometric configurations of the freeway system were chosen and the design details of the individual sites are related in the following sections.

Figure 1. Telephotometer used to measure sign luminances.

Figure 2. Marking recording distances.

Site 1

The first site selected for study was the overhead signs located over the eastbound lanes of Route 66 at the exit to Route 50 in Fairfax County. As shown in Figure 3 the approach to the signs was straight and downgrade. There were two eastbound lanes on Route 66 at this location and the high intensity sign and the conventional sign were placed over the left and right lanes, respectively. There was no ambient lighting, however fluorescent fixtures provided illumination on the conventional sign.

Site 2

Site 2 was selected because the signs were placed near the crest of a vertical curve on the eastbound lanes of Route 66 near the Route 123 interchange in Fairfax County. The approach was straight on the three-lane section of roadway as shown in Figure 4. The non-illuminated high intensity sign was erected on the right while the conventional sign was placed over the center and left lanes. Illumination was provided on the conventional sign by fluorescent fixtures and there was no ambient lighting.

Site 3

Site 3, located on the northbound lanes of Route 581 at the Route 81 interchange in Roanoke County, was similar to site 2, however the approach grade was steeper. Figure 5 shows that the visibility of the overhead signs was partially restricted by an overpass bridge when it came into the motorist's view. The conventional sign, located over the right lane, was illuminated by fluorescent lights.

Site 4

In order to determine the effects of horizontal alignment on the brightness of overhead signs a site was chosen on the exit ramp from the westbound lanes of Route 66 to Route 123 in Fairfax County as shown in Figure 6. This two-lane facility included a 3° curve, which is the desirable maximum curvature for most interstate and arterial highways in Virginia. The ramp had a posted maximum safe speed limit of 45 miles per hour (2.012 m/s) and sign visibility was restricted to approximately 900 feet (274.32 m) due to geometry and topography. The conventional sign, erected on the right, had fluorescent illumination and no other lighting was present in the vicinity of the signs.

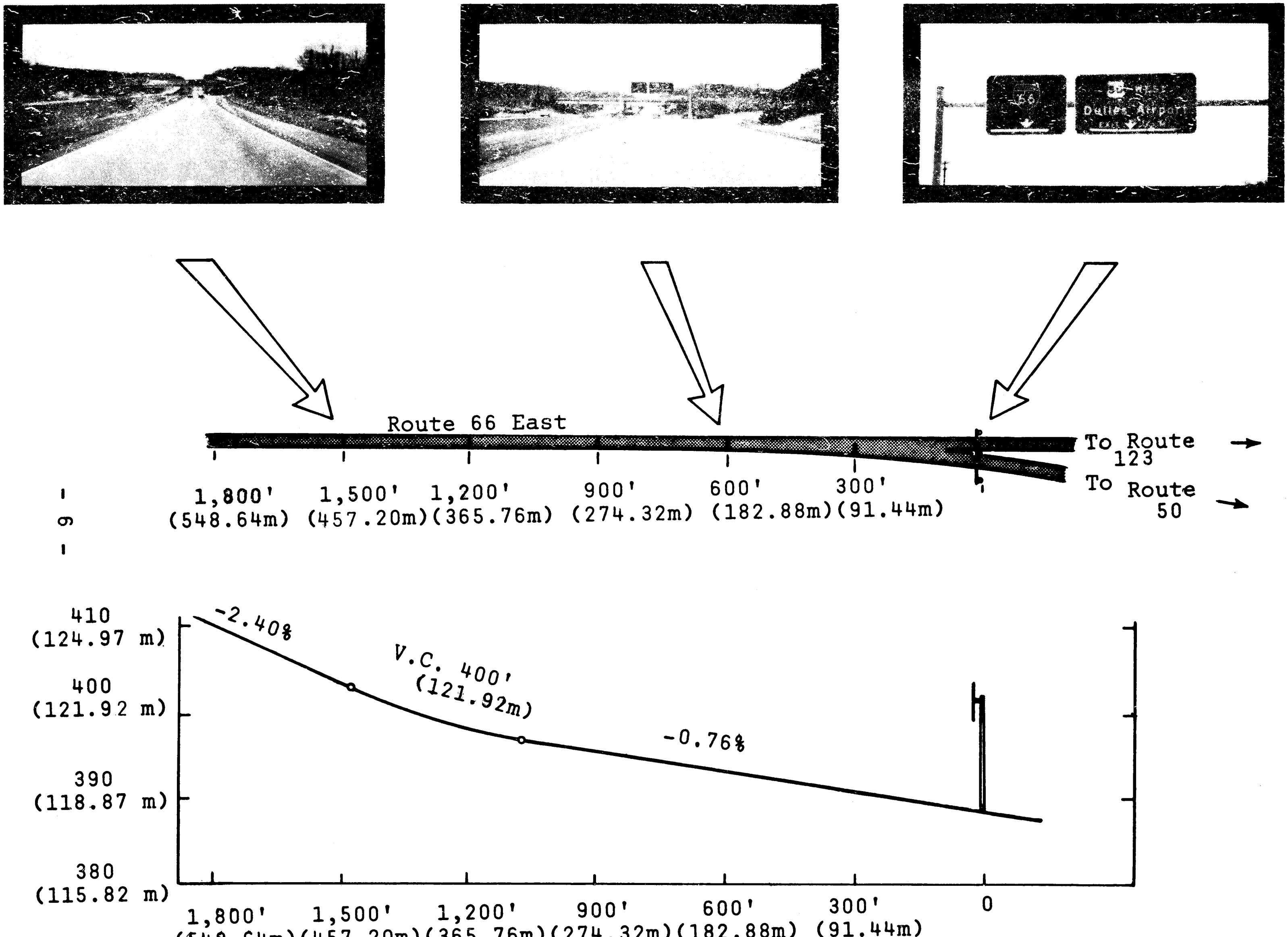

Figure 3. Study site 1 — Route 66 east at Route 50, Fairfax County.

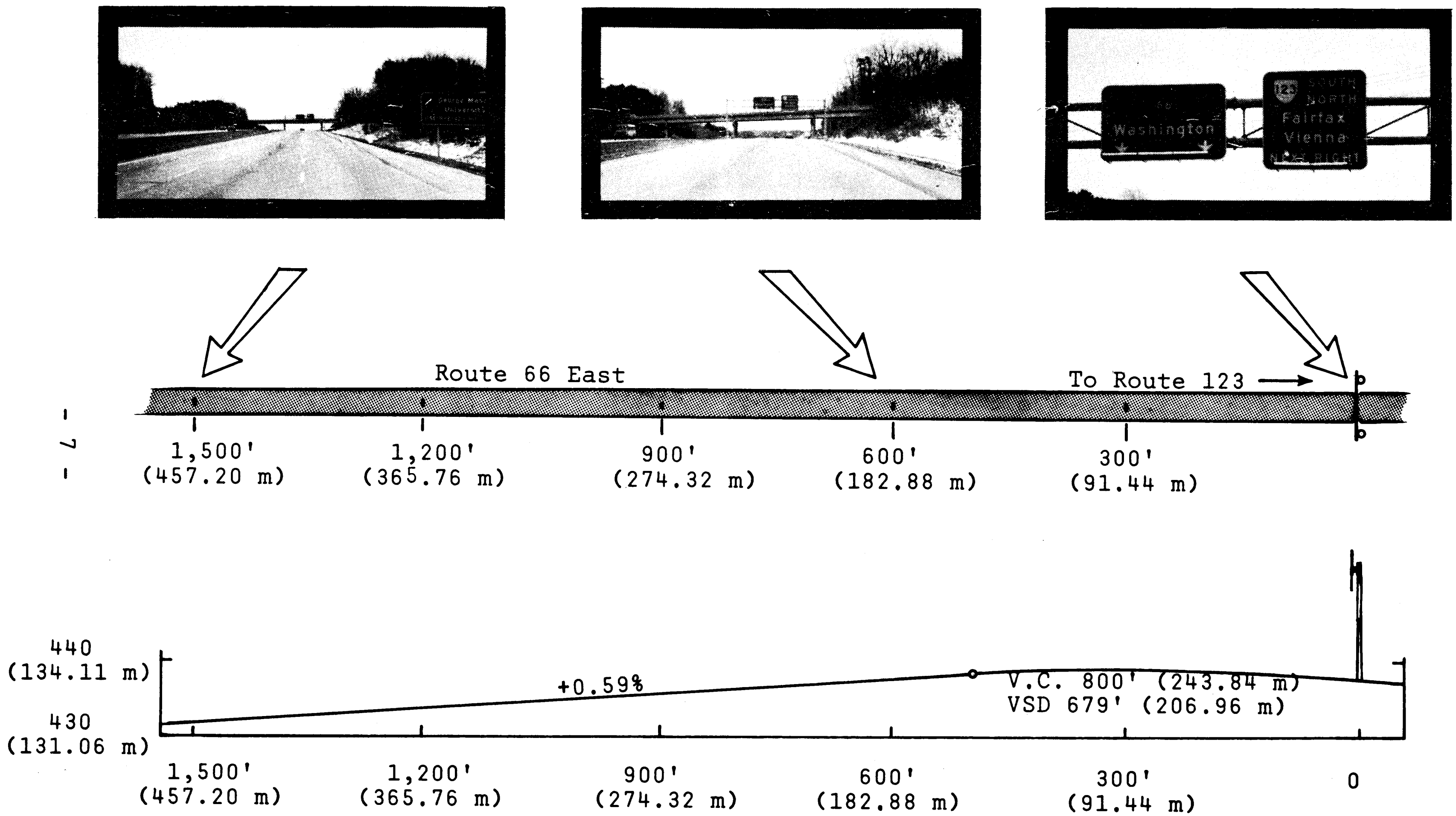

Figure 4. Study site 2 — Route 66 east between Routes 50 and 123, Fairfax County.

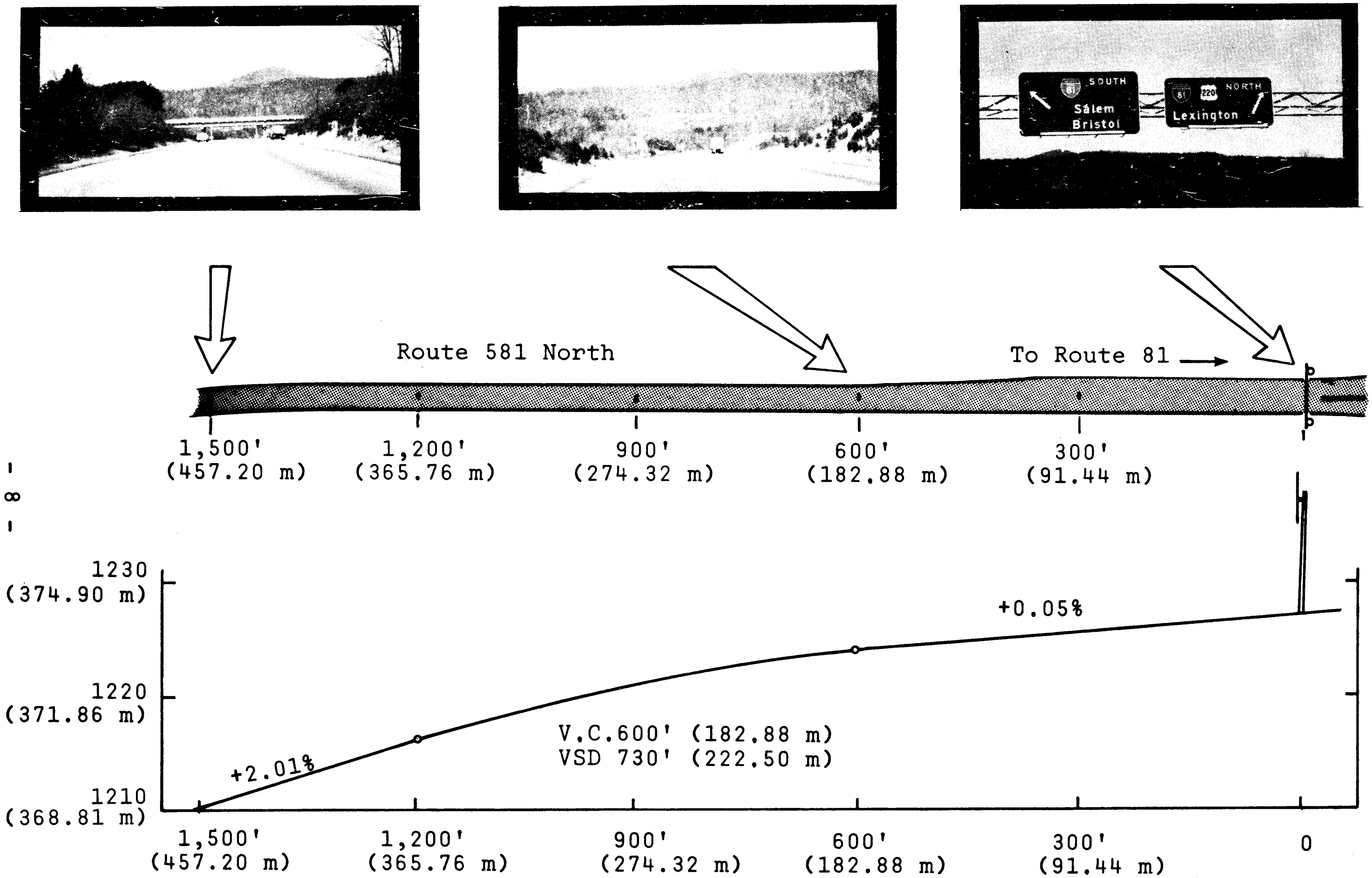

Figure 5. Study Site 3— Route 581 North at Route 81 — Roanoke County.

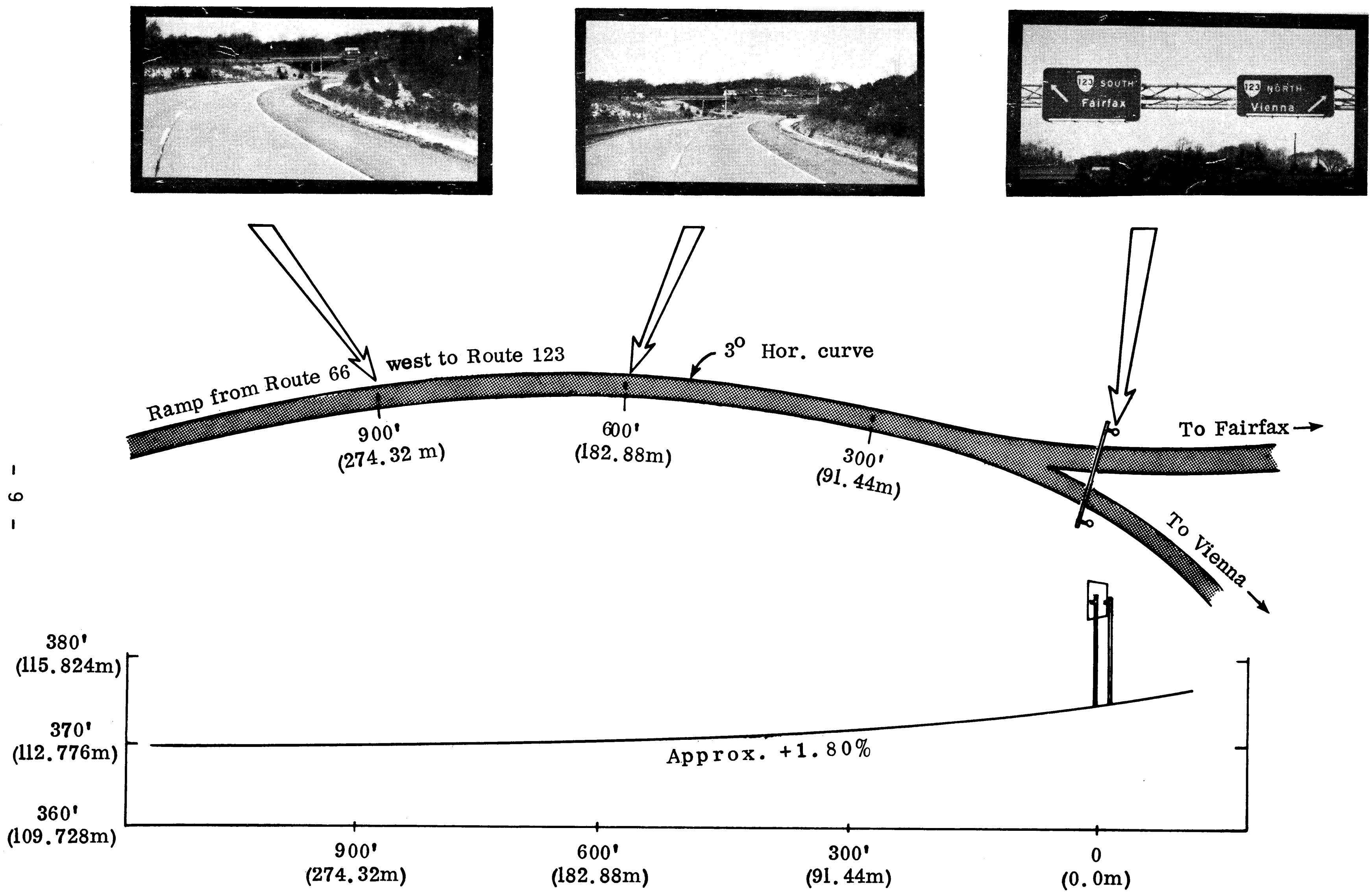

Figure 6. Study site 4 — ramp from Route 66 west to Route 123, Fairfax County.

Site 5

As shown in Figure 7 the approach to the overhead signs at site 5 is on a 2° horizontal curve. The maximum visibility of these signs, erected on Route 581 near Route 81 in Roanoke County, was approximately 900 feet (274.32 m) for the left lane and 750 feet (228.60 m) for the right lane, where in the latter case, signs were mounted on the shoulder and visibility was limited by the roadway geometry. As at the previous sites, the conventional sign (on the left) was illuminated with fluorescent fixtures.

Site 6

Site 6, on Route 95 near the Seminary Road interchange in the city of Alexandria, was chosen because it was provided with roadway lighting. The signs in this area did not need refurbishing, therefore special signs were fabricated and erected for the study as shown in Figure 8. The sign on the left (erected on the existing sign) was fabricated with conventional material and additional illumination was provided by mercury vapor fixtures. The high intensity sign, placed on the right, had no illumination except the roadway lighting.

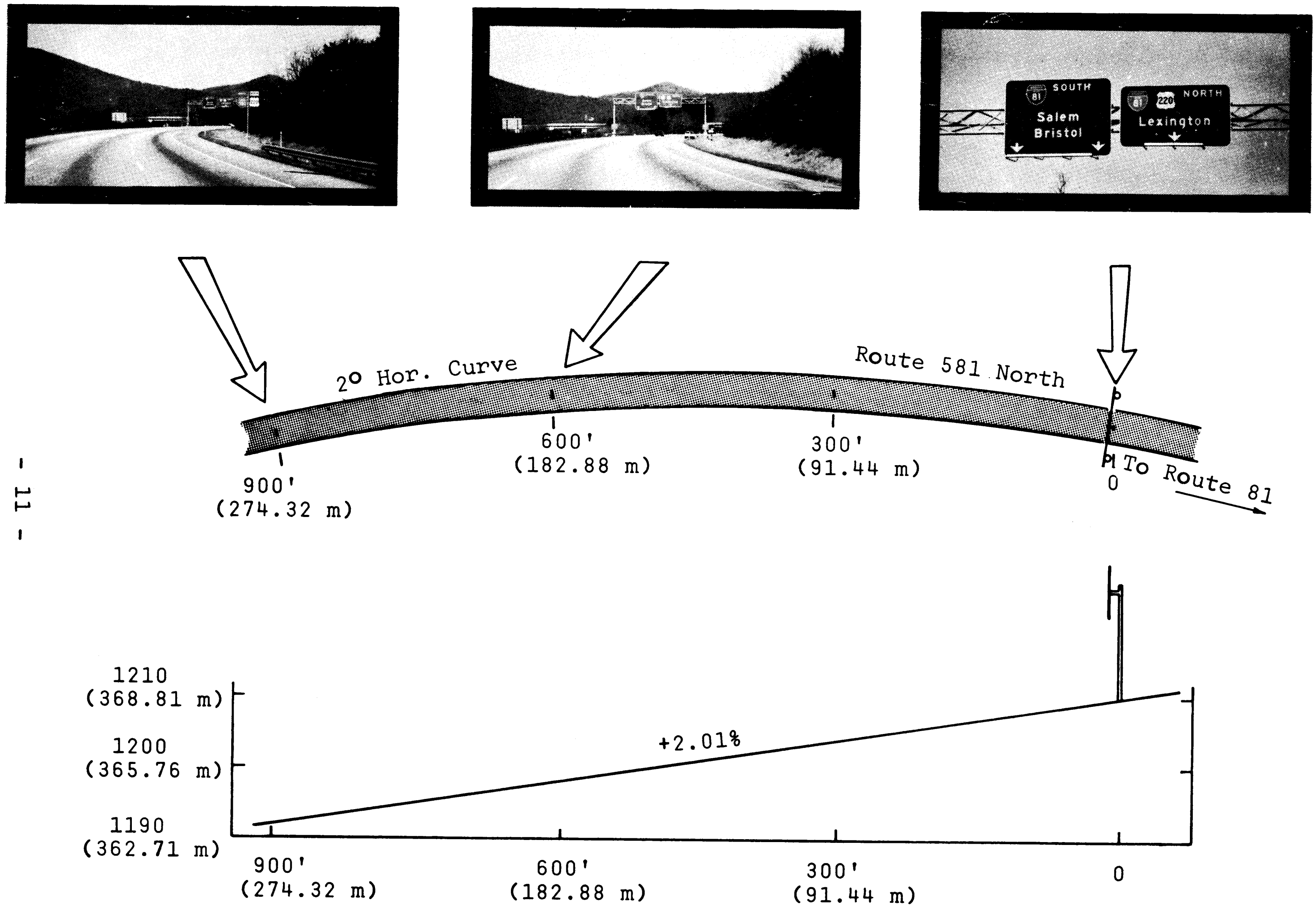

Figure 7. Study site 5 — Route 581 north at Route 81, Roanoke County.

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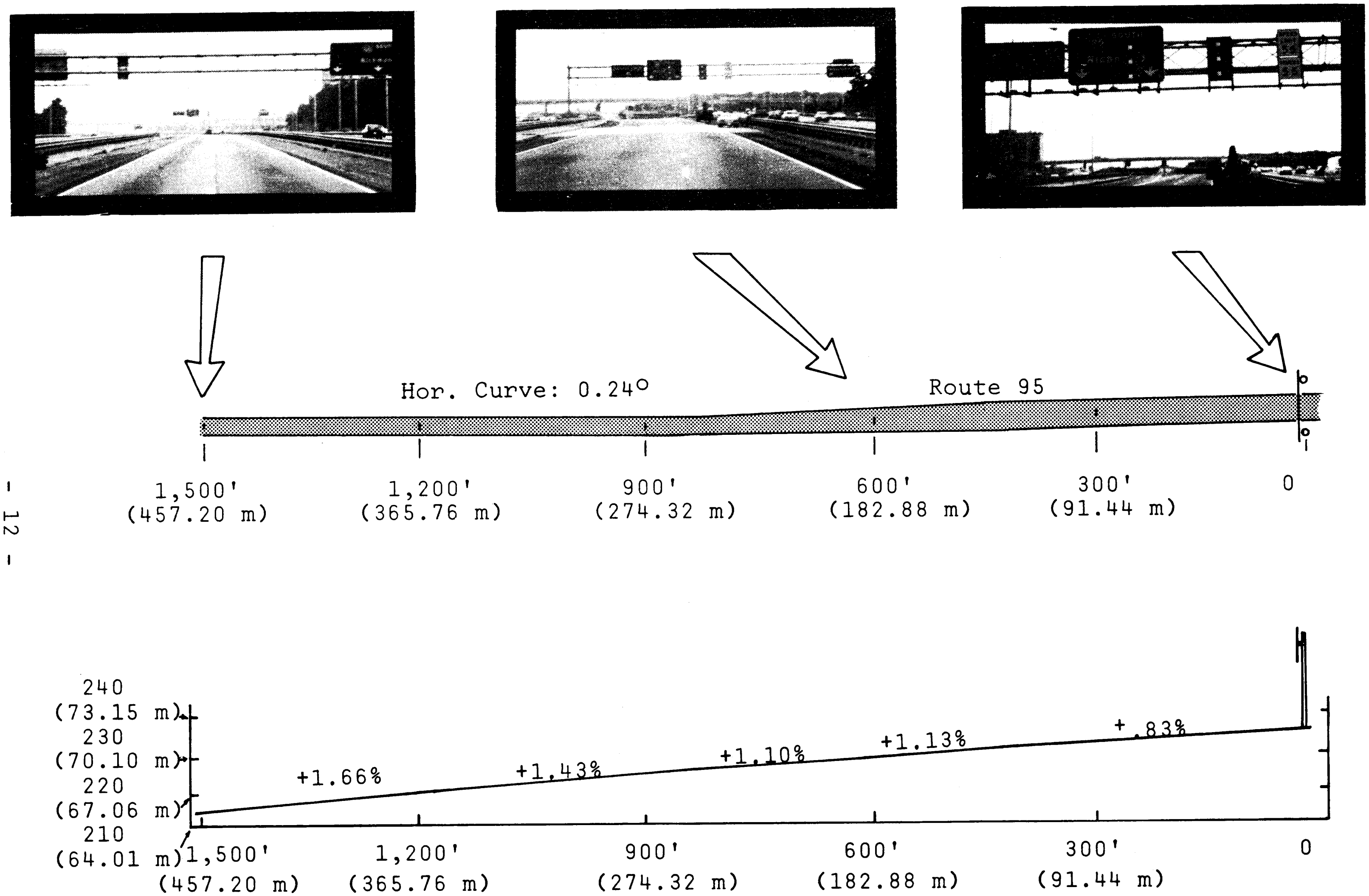


Figure 8. Study site 6 — Route 95 near Seminary Road, City of Alexandria.

TEST VEHICLES

The automobiles used for data collection were domestic passenger cars or station wagons as noted in Table 1. The eleven vehicles used had tinted windshields. The vehicles were equipped with the photometric instruments and needed accessories. The fuel tanks were filled and the vehicles taken to an official inspection station for a check of the headlamp alignment. The intent was to procure an automobile representative of the late-model car population that had headlamp adjustment in conformance with state requirements. Prior to the readings, all windshield and headlamp surfaces were cleaned.

In commencing the luminance measurements, care was taken to align the vehicles in the travel lanes with the lane line pavement markings. This was accomplished by traveling several hundred feet in approaching the recording position and stopping without last-second steering wheel alignment.

Table 1

Vehicles Used in Study

Year	Make and Model	No. of Headlights	No. of Vehicles	Site	Tinted Windshield
1970	Plymouth; 4-door sedan	4	1	1,2,4,6	Yes
1974	Vega; 2-door coupe	2	3	1,2,3,4,5	Yes
1974	Mercury; 4-door sedan	4	1	4,6	Yes
1970	Ford Station Wagon	4	2	1,3,5	Yes
1971	Plymouth; 4-door sedan	4	1	3,5	Yes
1972	Ambassador; 4-door sedan	4	2	1,2,3,5	Yes
1973	Plymouth; 4-door sedan	4	1	2,4	Yes
		TOTAL VEHICLES	11		

DATA RECORDED

At sites 1 through 5, the instrument was used to measure sign luminances as shown in Figure 9. Background measurements were

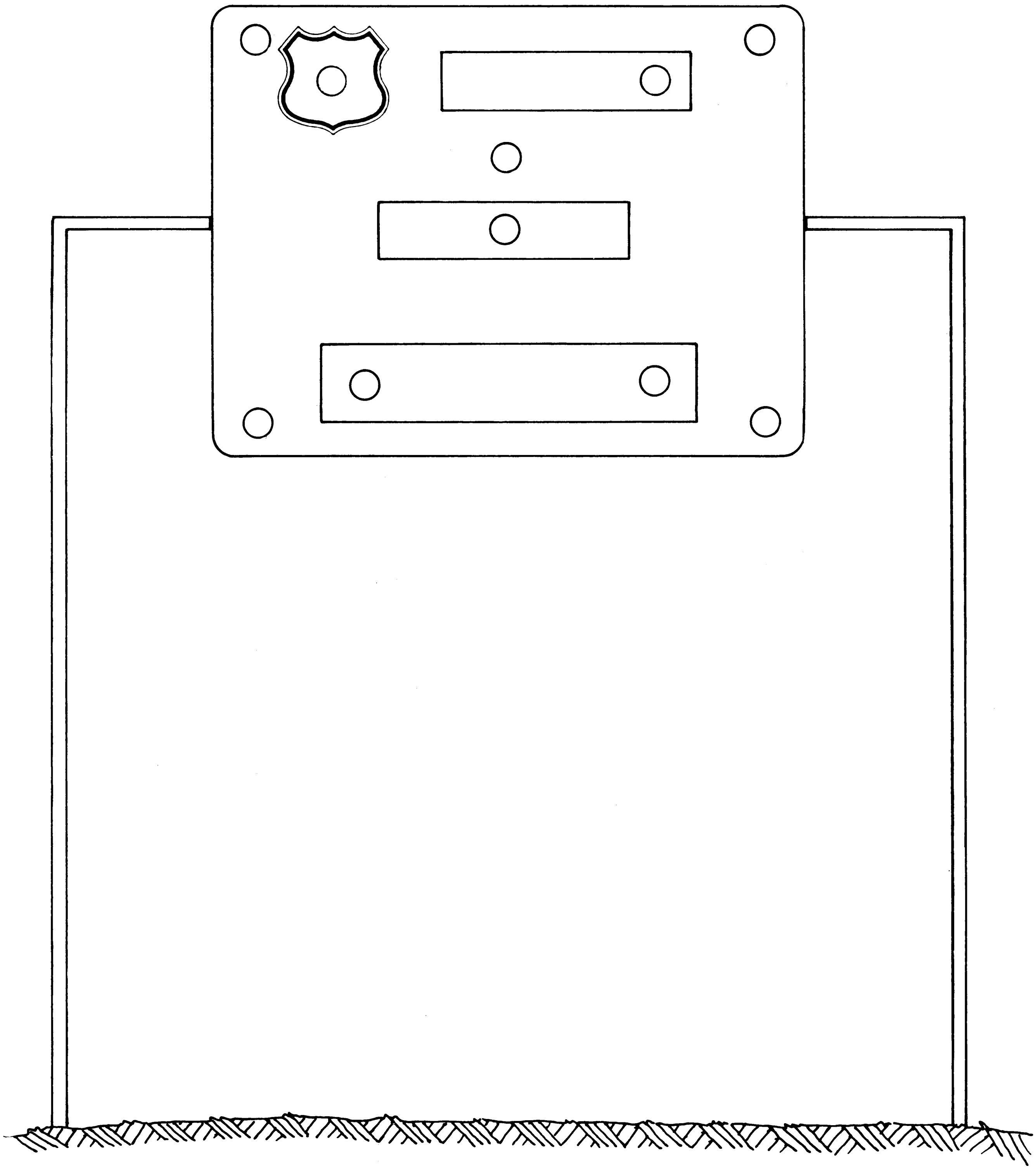


Figure 9. Brightness measurement locations.

taken in available spaces of the sign at the center and four corners at 300-foot (91.44 m) intervals up to a maximum distance of 1,500 feet (457.20 m). The sign legend luminance measurements were limited to distances of 300, 600 and 900 feet (91.44, 182.88, and 274.32 m) because of the 2-minute probe used on the telephotometer. At greater distances the letter strokes were not of ample size to allow measurements. Whenever possible the legend readings were secured as shown in Figure 9, but for some signs, complete data could not be gathered due to message placement. Measurements for these signs were taken at the top, center and bottom to obtain average luminances of the legend materials.

Readings were taken from the left and right lanes of the roadway using low and high beam headlights. Also, in an attempt to determine the effects of stream traffic, measurements were taken when other vehicles were adjacent to the observation vehicle. All vehicles in the traffic stream as well as the observation vehicle used low-beam headlights.

At site 6, the average luminances of the special signs were obtained by taking readings of the background and legend materials at the top, center, and bottom. Data were secured from vehicles in the right lane of the roadway as shown in Figure 8, under high beams, low beams, and stream traffic conditions. Another complete set of data was recorded from vehicles which approached the signs on a straight course. This was done by placing the centerline of the approaching vehicles perpendicular to the sign faces at 1,500 feet (457.20 m), the reticle of the optical head being aligned on a reference target and locked into place. Thereafter, the vehicle was moved and stopped at the next reading distances by alignment of the vehicle while the reticle was sighted on the target.

In all cases the probe was held to the area intended and particular care was taken with the legend readings to measure that portion of the sign face exclusively. For the 12 signs under study, 5,446 readings were recorded under various weather conditions. Inclement weather affects the luminance of many sign materials, and at each site an attempt was made to secure readings during one evening while dew formations were present. Measurements could not be made during rainfall, but they were taken under icy conditions at sites 3 and 5.

The roadway illumination in the vicinity of the signs was measured by a mobile illumination recording system developed by the Research Council.[8]

In addition to the luminance readings, facts were recorded at all sites including information on materials utilized for legend and background, sky cover, ambient lighting, presence of external illumination, position of sign, sign dimensions, vehicle description, and position of vehicle. A detailed description of each sign is given in Appendix A.

At each site, a group of people were requested to view the signs and express their opinions on the effectiveness of each sign. Individuals such as engineers, clerks, secretaries, policemen, and general highway users were included in these groups. Because of the hazards involved in stopping on the traveled lanes, these observations were made from a parked vehicle on the right shoulder. On each visit the signs were first viewed at 1,200 feet (365.76 m), or at the maximum visibility distance, under the various lighting conditions. At this location the panel members were asked questions relative to "attention" or "target value." The individuals responded to questions such as, "Which sign did you observe first?" "What sign characteristic attracted your attention?" and "Do you feel that both signs have sufficient brightness to gain the attention of the motoring public at this distance?"

After the group's comments were recorded, the vehicle was moved forward and stopped at 600 feet (182.88 m). Questions were asked relative to legibility and degree and uniformity of brightness. Upon leaving the site each individual was requested to express a preference between the two traffic signs.

ANALYSIS

To adequately serve the motoring public, a sign must be visible and legible, and the approach distances at which the signs are visible and legible were of importance in this analysis.

It is generally accepted that the legibility distance is 50 feet per inch (38.71 m/cm) of letter height.[6] A review of Appendix A reveals that the letters on the signs under study had a height of 12 and 16 inches (30.48 and 40.64 cm); therefore, the signs were legible in the 600- to 800-foot range (182.88 - 243.84 m). A study has shown that the visibility distance is a function of the sign dimension, the brightness contrast of the letters to the sign, and the contrast of the sign to the background terrain.[9] Considering the size of the sign letters and the brightness values of the sign materials and surrounding terrain, the visibility recognition distance for the signs erected on non-illuminated roadways (sites 1-5) was in the 1,100- to 1,200-foot (335.28 - 365.76 m) range. At site 6 the visibility distance of the signs on the illuminated roadway was in the 800- to 1,000-foot (243.84 - 304.8 m) range.

Since the brightness, or luminance, of a sign placed on the highway is a function of the characteristics of the sign material; the trigonometric relationship between the car, the sign, and the roadway; and the illumination reaching the sign from the headlights, it is necessary to discuss each site separately as the roadway geometrics vary.

A review of the data has been conducted and is presented in this section. The data, including the number of readings, computed averages, standard deviations, statistical test values and statistical significance at 95% confidence limits, are given in Appendix B.

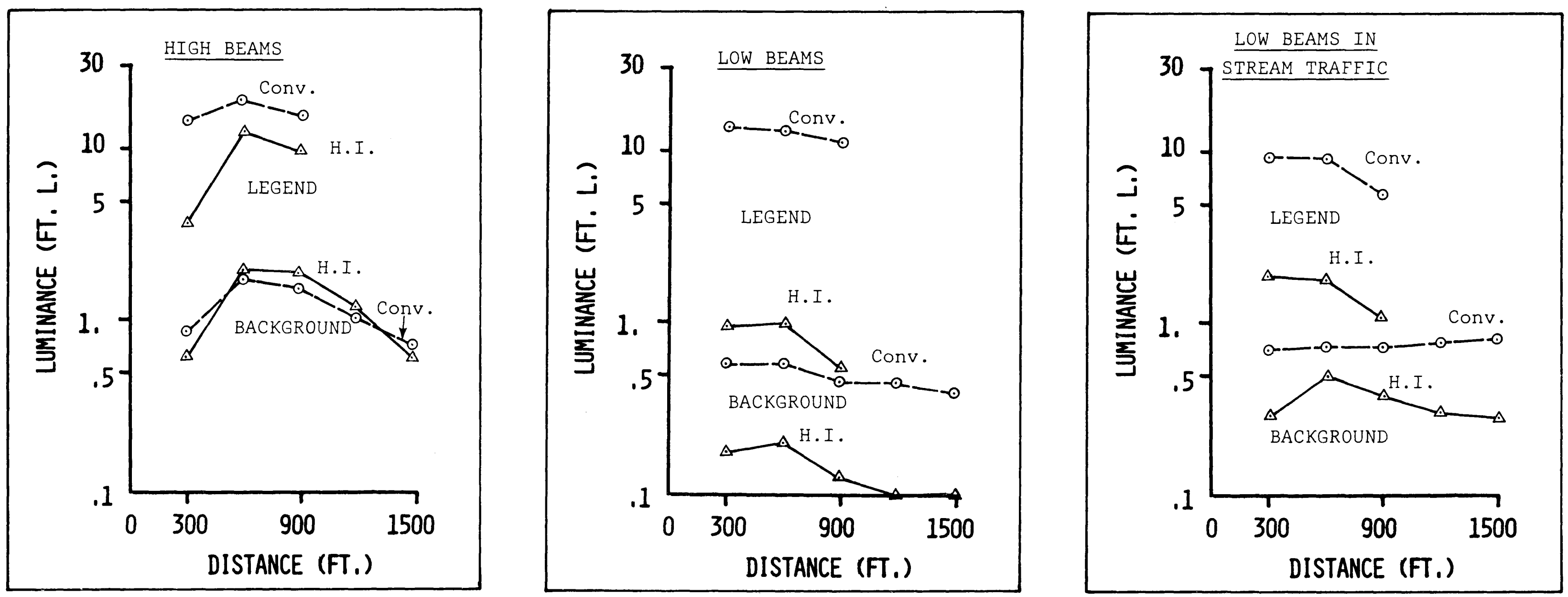
The luminance readings recorded while dew was on the signs did not reveal any adverse effects on the brightness of the signs; therefore these will not be discussed for each site.

Site 1

Figure 10 shows the measured average luminances of the background and legend materials of the two signs under high beams, low beams, and stream traffic conditions. For high beam headlights, the average luminance of the unlighted high intensity background material was brighter than that for the conventional material at 600, 900 and 1,200 feet (182.88, 274.32, and 365.76 m). A review of the statistical analysis revealed that while the luminance of the high intensity background at 300 feet (91.44 m) was below that of the conventional material, there was no statistical difference between the two. Although the average brightness of the conventional legend material was greater than that for the high intensity legend, the difference was not statistically significant within the legibility distance.

For a motorist traveling alone on the highway and using low beams, the average luminance of the lighted conventional material was greater than that for the unlighted high intensity material.

Under stream traffic conditions, the average luminances of the conventional materials were slightly higher than those for the high intensity materials; however the differences were not statistically significant within the visibility and legibility distances. As shown by the standard deviations, the brightness of the high intensity sign was much more uniform than that of the lighted conventional sign.



Basic Conversion Units: 1 Foot = .3048 meter
1 Foot Lambert = 3.426 candela/meter^2

Figure 10. Site 1 — Nighttime average luminance versus distance.

The majority of the eleven people viewing these signs stated that they first observed the conventional sign because of the bright spot created by the exterior lighting. However, they unanimously agreed that at 600 feet (182.88 m) the luminance appeared greater and more uniform for the high intensity sign and stated it was more legible than the conventional sign. Upon leaving the site, each stated he would prefer the high intensity sign.

Site 2

Due to the roadway geometrics at site 2, more illumination from the headlights could reach the signs than at site 1 and, as expected, the average luminance readings of the signs were greater. Figure 11 shows that with high beams the high intensity material was brighter than the conventional material except at 300 feet (91.44 m), where the white legend material was significantly brighter.

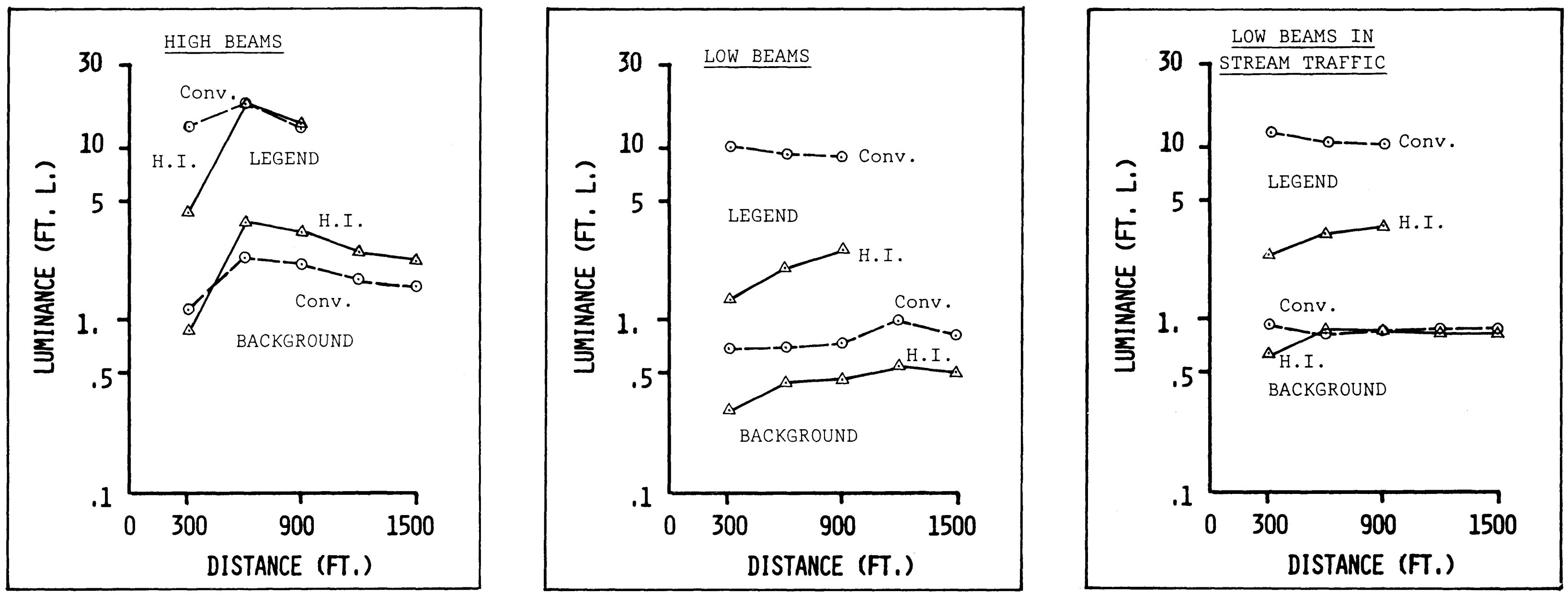
With low beams, the lighted conventional sign was much brighter than the unlighted high intensity sign as insufficient headlamp illumination reached the overhead signs.

In stream traffic, the average luminances of the two background materials were practically the same, while the brightness of the conventional legend material was greater than that of the high intensity material.

The thirteen people visiting this site responded in a similar manner to those who visited site 1, with the exception that one-third of the individuals stated that they first observed the high intensity sign rather than the conventional sign.

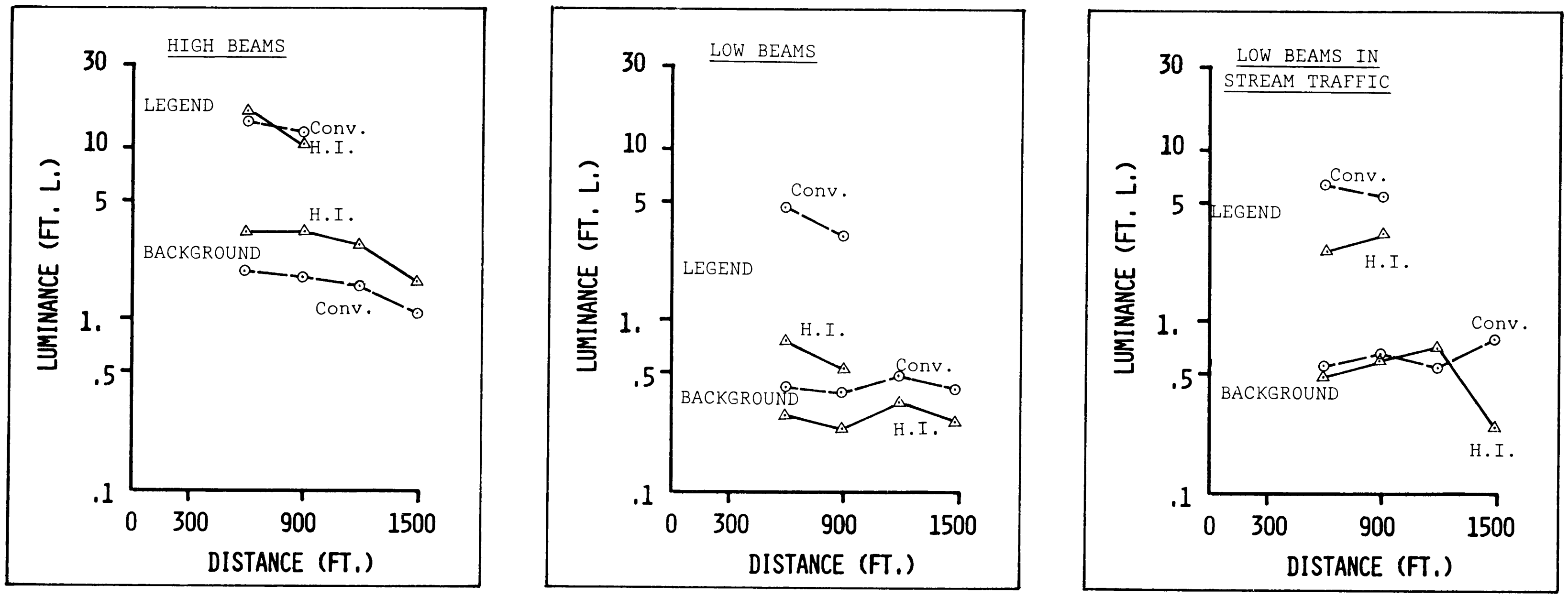
Site 3

The signs at site 3 were erected over the gore area; therefore no measurements were recorded at 300 feet (91.44 m) due to the hazards created by the weaving traffic. The luminance readings at this site, as shown in Figure 12, were similar to those for the previous two sites, which had straight approaches. Under low beam conditions, the luminances of the conventional materials were statistically brighter while the high intensity materials were brighter and relatively equivalent under high beams and stream traffic conditions, respectively. An examination of the standard deviations revealed that the brightness of the high intensity sign was much more uniform than that of the conventional sign.



Basic Conversion Units: 1 Foot = .3048 meter
1 Foot Lambert = 3.426 candela/meter^2

Figure 11. Site 2 — Nighttime average luminance versus distance.



Basic Conversion Units: 1 Foot = .3048 meter
1 Foot Lambert = 3.426 candela/meter^2

Figure 12. Site 3 — Nighttime average luminance versus distance.

Six people viewed the signs and stated they first observed the conventional sign because of the bright spot at the bottom created by the external illumination. They further stated that they preferred the high intensity sign because it was more legible and uniform in brightness. They were of the opinion that the high intensity sign would adequately serve the motoring public.

Additional readings were taken of the conventional sign under non-illuminated conditions, which are occasionally viewed by the motorist during electrical malfunctions. At 600 feet (182.88 m) with high beam headlights, there were reductions of 40 and 50 percent in the brightness of the background and legend materials, respectively. For the motorist traveling alone using low beams, these reductions were 61 and 90 percent.

Readings were taken when the signs were covered with ice, and the brightness of the conventional sign, even under non-illuminated conditions, increased while the luminance of the high intensity sign was not affected.

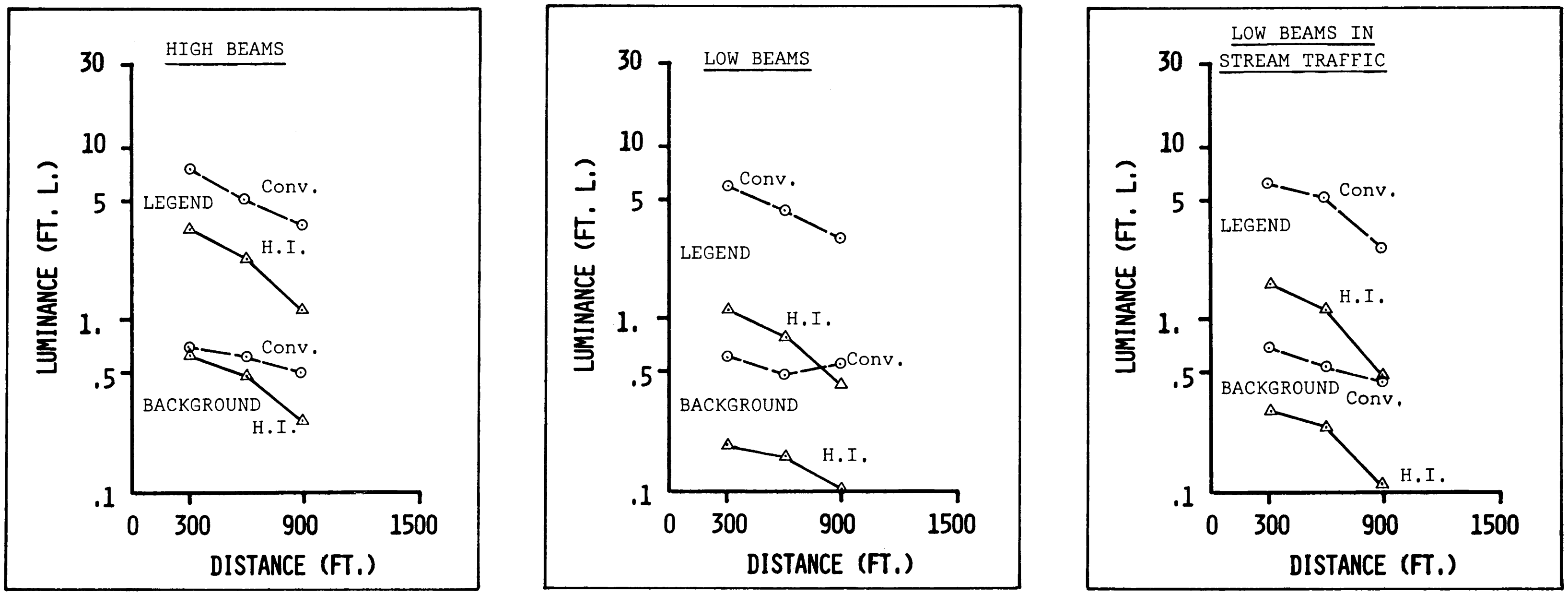
Site 4

The nighttime luminance data for site 4 are shown in Figure 13. The measurements were restricted to a maximum of 900 feet (274.32 m) because of a cut slope on the inside of the 3° horizontal curve. Generally, the luminance readings for these signs were lower than those recorded at the previous three sites. The degree of illumination reaching the signs from the vehicle headlamps was limited because of the horizontal curve, and at all observation locations the brightness of the conventional sign was superior to that of the high intensity sign.

The thirteen people who viewed these signs stated unanimously that the lighted conventional sign provided better visibility and legibility.

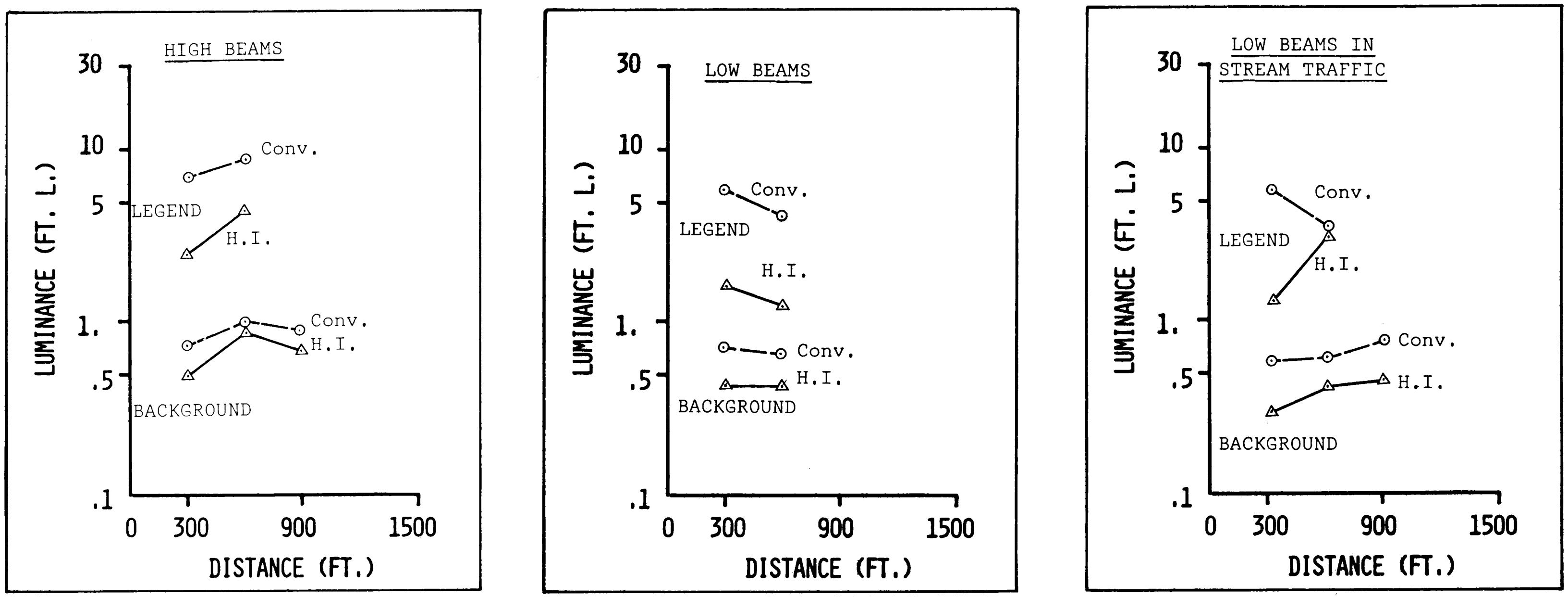
Site 5

A review of Figure 14 indicates that the luminances of the signs at site 5 were similar to those measured at site 4. The luminances of both signs were generally low, with the conventional being brighter than the high intensity one. The six persons who viewed the signs agreed that the conventional sign provided the better service.



Basic Conversion Units: 1 Foot = .3048 meter
1 Foot Lambert = 3.426 candela/meter^2

Figure 13. Site 4 — Nighttime average luminance versus distance.



Basic Conversion Units: 1 Foot = .3048 meter
1 Foot Lambert = 3.426 candela/meter^2

Figure 14. Site 5 — Nighttime average luminance versus distance.

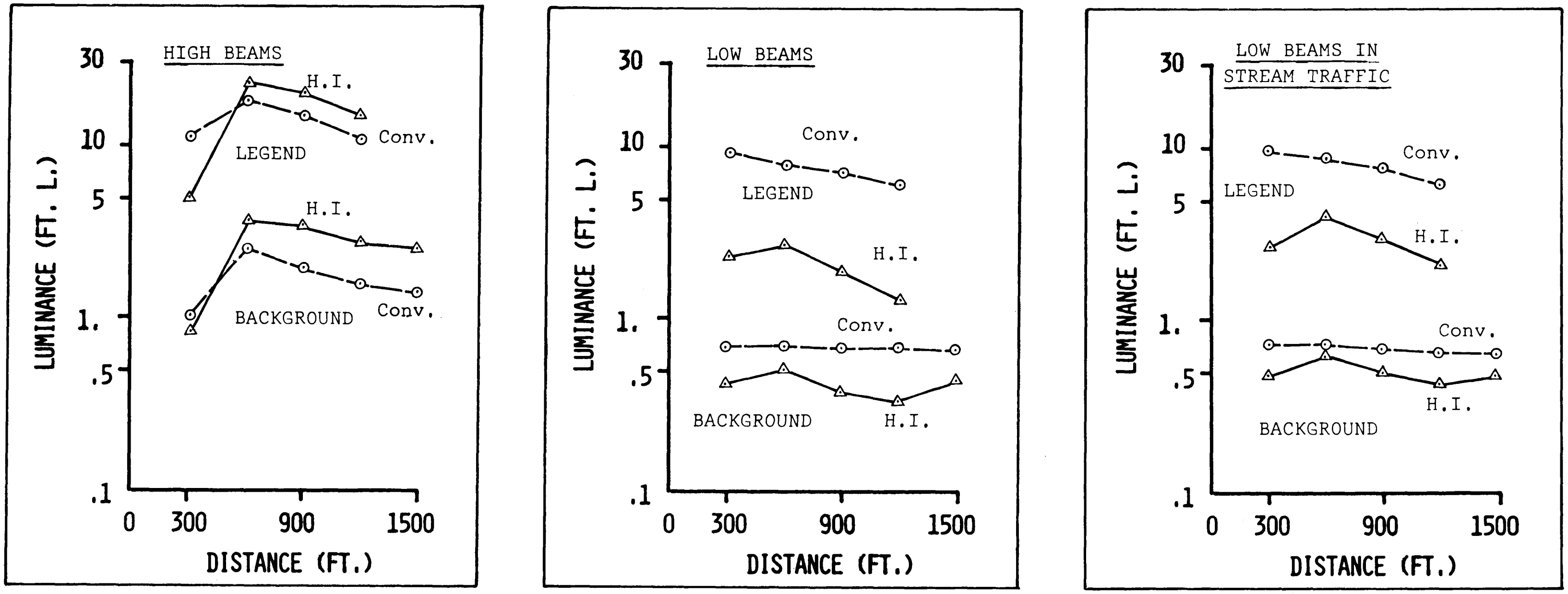
Additional measurements were made of the conventional sign without exterior illumination to determine the effect of an electrical malfunction on the brightness of the sign. At 600 feet (182.88 m), with high beam headlamps, there were brightness reductions of 23 and 53 percent for the background and legend materials, respectively. On low beams the motorist would experience a reduction of 83 percent in the luminance of background material, while the brightness of legend decreased by 90 percent when the external lighting was absent on the conventional sign.

Site 6

The luminances of the overhead signs at site 6, the only location studied which had roadway lighting, are shown in Figures 15 and 16. Figure 15 shows the data recorded when the signs were approached on a curve and Figure 16 indicates the brightness of the sign when the vehicle traveled directly toward the signs on a straight approach.

On the curved approach, under high beam conditions, the luminances of the high intensity background and legend materials exceeded those of the conventional materials within the legibility and visibility distances. Although the luminance readings of the conventional materials were greater than those of the high intensity materials for low beam and stream traffic conditions, there were no statistical differences between the green background materials. On the straight approach (Figure 16) the special sign luminances within the legibility range were basically equivalent to those recorded on the curved approach; however, the brightness did increase at greater distances from the signs, which were within the visibility distance range.

Six people viewed the special signs erected for the study and each expressed difficulty in observing the signs at 1,500 feet (457.20 m); this fact emphasized the validity of the shorter computed visibility distances on illuminated roadways. For high beam and stream traffic conditions, the unanimous preference of these people was for the high intensity sign. The majority of the same individuals stated that they observed no difference in the brightness of the two signs for low beam headlamps.



Basic Conversion Units: 1 Foot = .3048 meter
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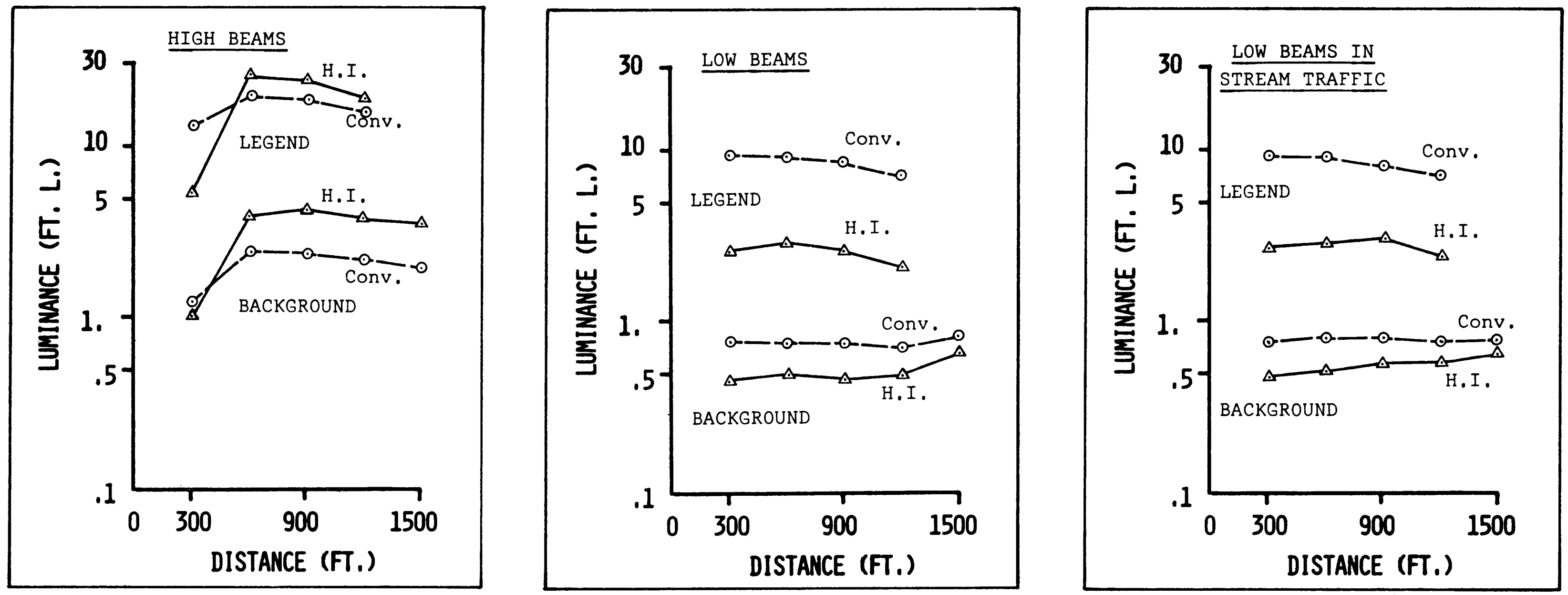
Figure 15. Site 6 — (Curved Approach) — Nighttime average luminance versus distance.



Basic Conversion Units: 1 Foot = .3048 meter
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Figure 16. Site 6 — (Straight Approach) — Nighttime average luminance versus distance.

CONCLUSIONS

Previous studies of sign brightness have reported essentially laboratory findings of calculated luminance in the absence of reliable and sensitive instruments for field work. It has been only in recent times that satisfactory photometers have been developed to make in situ luminance measurements of signs. The objective of this study was to compare the field brightness of high intensity overhead signs without external illumination to that of the lighted conventional signs. The sign luminances measured and reported in this study should not be interpreted as luminescent standards. The NCHRP is funding a project which hopefully will establish these requirements. However, earlier investigators have suggested luminance levels for signs and several of the measurements taken on the evaluated signs were below these levels.[10]

The analysis revealed a resemblance in the luminances of signs erected on roadways with similar configurations. The conclusions based on the findings from signs erected on straight, curved and illuminated roadways are presented in the following sections.

Non-illuminated Straight Roadways

For signs erected on straight sections of roadway there were no statistical differences in the brightnesses of the background materials of the two signs for the motorists traveling in stream traffic. Although the average luminances of the high intensity legend materials were not as bright as those of the illuminated conventional sign, the people who viewed the signs stated that the uniform brightness of the high intensity sign provided greater legibility than the illuminated sign with the uneven light distribution. For a single vehicle traveling with high beam lights the high intensity signs were much brighter; however, for the same vehicle using low beams the luminance of the high intensity signs was not as bright as that of the adjacent conventional signs. It should be pointed out that as a matter of observation the people who conducted the study are of the opinion that there are only limited occasions when it is feasible for the "lone" motorist to utilize low beams on a freeway. In fact, it was not possible to collect the low beam data at any of the study sites until after 1 a.m., when traffic volumes were low.

The high intensity materials provided constant service whereas the brightness of conventional materials was governed by the external lighting. During electrical malfunctions the luminances of the conventional materials reduced drastically and the brightness was insufficient to provide the motorist proper service.

Non-illuminated Curved Roadway

On a curved approach, where only a limited amount of light from the vehicles was projected upon the overhead signs, the luminances of the unlighted high intensity materials were not sufficient to provide the motorists with the equivalent sign legibility and visibility obtained from the conventional signs.

Although the luminance readings of the unlighted high intensity sign were more uniform than those of the conventional sign, the persons who viewed the signs on the curved approaches unanimously concurred that the lighted sign provided better service.

While external lighting was required to provide high luminance measurements on the curved sections of roadway, the use of the brighter materials was also beneficial in view of the brightness reduction experienced during electrical malfunctions. Under non-illuminated conditions the high intensity signs were two to three times brighter than the conventional signs.

Illuminated Roadways

The presence of roadway lighting reduces the maximum visibility distance and thus increases the probability that the sign will not be seen even though the legibility distance may be adequate. Furthermore, the findings of this study indicated that roadway illumination did not significantly increase the luminances of overhead signs.

When approaching the signs on a straight course and using high beam headlights, it was concluded that the luminances of the high intensity materials exceeded those of the conventional materials within the legibility and visibility distances. For stream traffic conditions, the non-illuminated high intensity sign was preferred. For the same signs when approached on a slight curve (0.24° of curve) using high beams, the luminances of the high intensity signs were greater; however, at distances within the visibility range the luminance levels decreased at a greater rate than they did on the straight approach.

Under low beam conditions the conventional materials were brighter than the high intensity materials on the straight and curved approaches.

At 1,500 feet (457.20 m) the signs did have poor "attention value" characteristics but after the persons visiting the site moved to within the legibility distance range they concurred that the high intensity sign provided better service than the lighted conventional sign under high beam and stream traffic conditions.

RECOMMENDATIONS

The conclusions of this study indicate that the external lighting can be eliminated on many overhead signs through the use of high intensity sheeting without adversely affecting the service to the motoring public.

It is recommended that consideration be given to disconnecting or removing the illumination on existing and proposed high intensity overhead signs on roadways that are susceptible to high beam and stream traffic lighting conditions and which have a straight approach equal to or greater than the visibility recognition distance. Generally the maximum visibility distances in Virginia are approximately 1,000 and 1,200 feet (304.80 and 365.76 m) for illuminated and non-illuminated roadways, respectively. This recommendation should not be applied to signs on roadways where the "lone" motorist is required to use low beam headlights, such as narrow median facilities where state law requires the motorist to dim his headlights to prevent the projection of glare into the oncoming driver's eyes.

The Department should continue to provide external lighting on all overhead signs which are erected on curved sections of illuminated and non-illuminated roadways. Although lighting is required, the policy of using high intensity signs on the interstate and limited access systems should be maintained. The high intensity signs are beneficial at these restricted visibility locations, especially during electrical malfunctions.

ACKNOWLEDGMENTS

The author acknowledges the contributions of a number of people from the Virginia Department of Highways and Transportation who contributed to this research. D. B. Hope and M. E. Wood, Jr., district engineers in the Culpeper and Salem Districts, respectively, authorized the refurbishment of the signs used in the study. L. C. Taylor II, J. W. Nicholson, and H. E. Carpenter coordinated and implemented the sign refurbishments, illumination modifications, and the handling of traffic during data collection. Sincere appreciation is extended to the members of the maintenance forces who assisted in the sign work and provided traffic control and safety. Without their assistance, completion of the project would have been impossible.

Much gratitude goes to John Shelor, traffic technician, for his help throughout the project, and especially his assistance on the long and tiring nights when the sign luminances were measured.

Finally, acknowledgment goes to Jim Benson, student helper, for his contribution in analyzing the data and to all the individuals who so freely offered information for this research.

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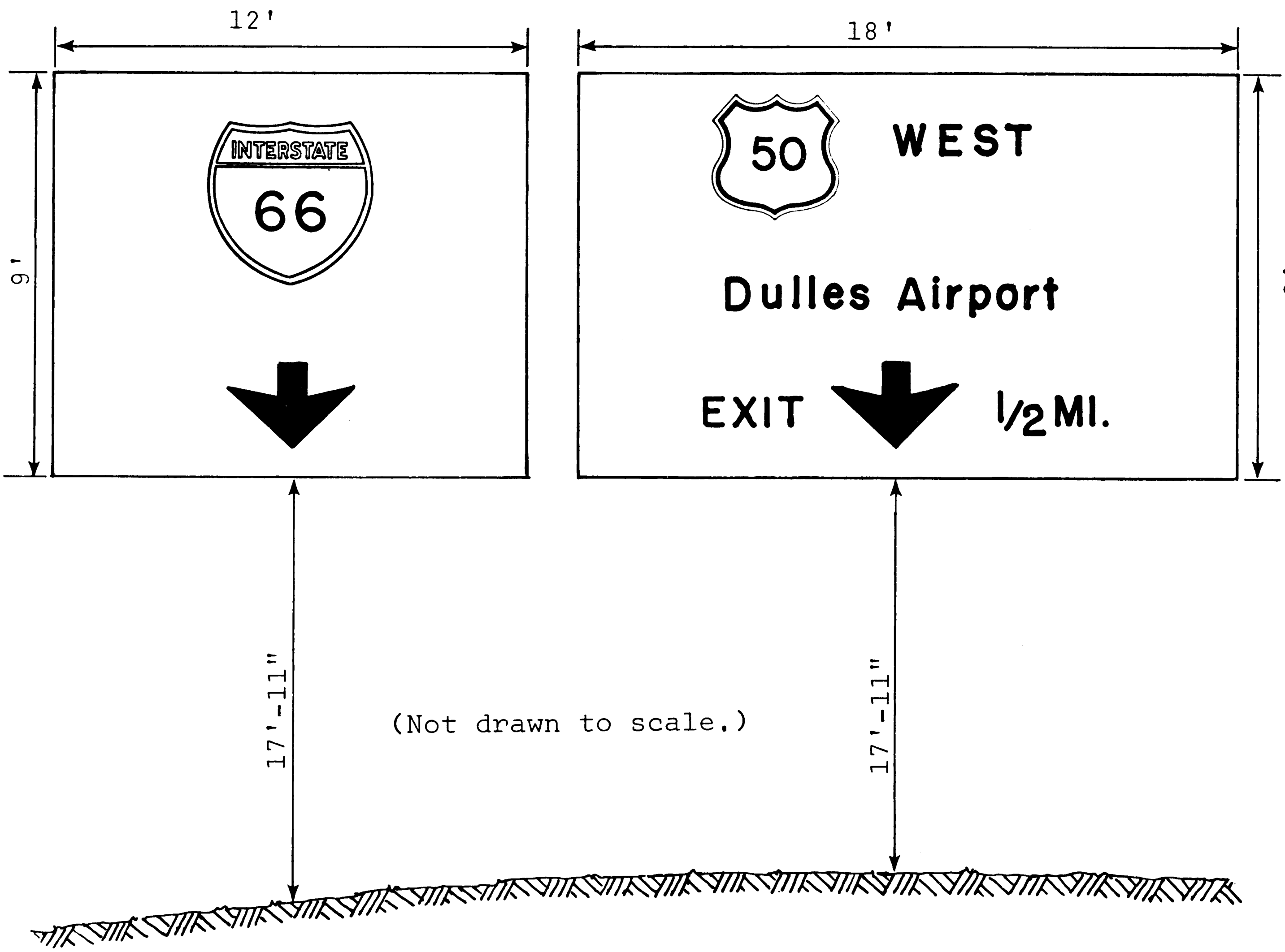
APPENDICES

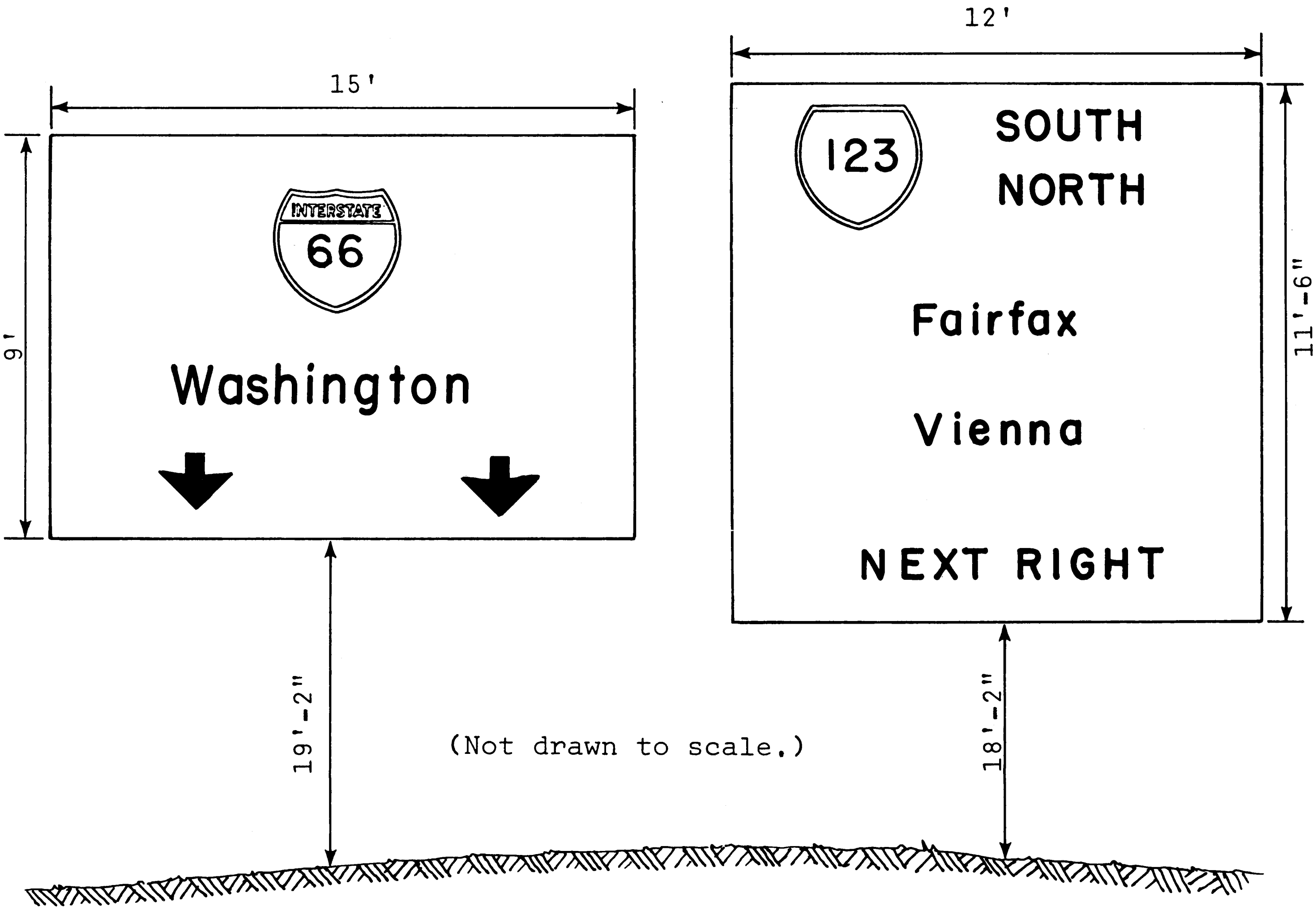
APPENDIX A



Message:	Line 1:	Shields	
		Route 66	48"
		Route 50	36"
		Capitals	12" Mod. E.
	Line 2:	Capitals	16" Mod. E.
		Lower Case	12" Mod. E.
	Line 3:	Capitals	10" Mod. E.
Arrows:			22"

Basic Conversion Units — 1 inch = 2.54 centimeters
1 foot = .3048 meter

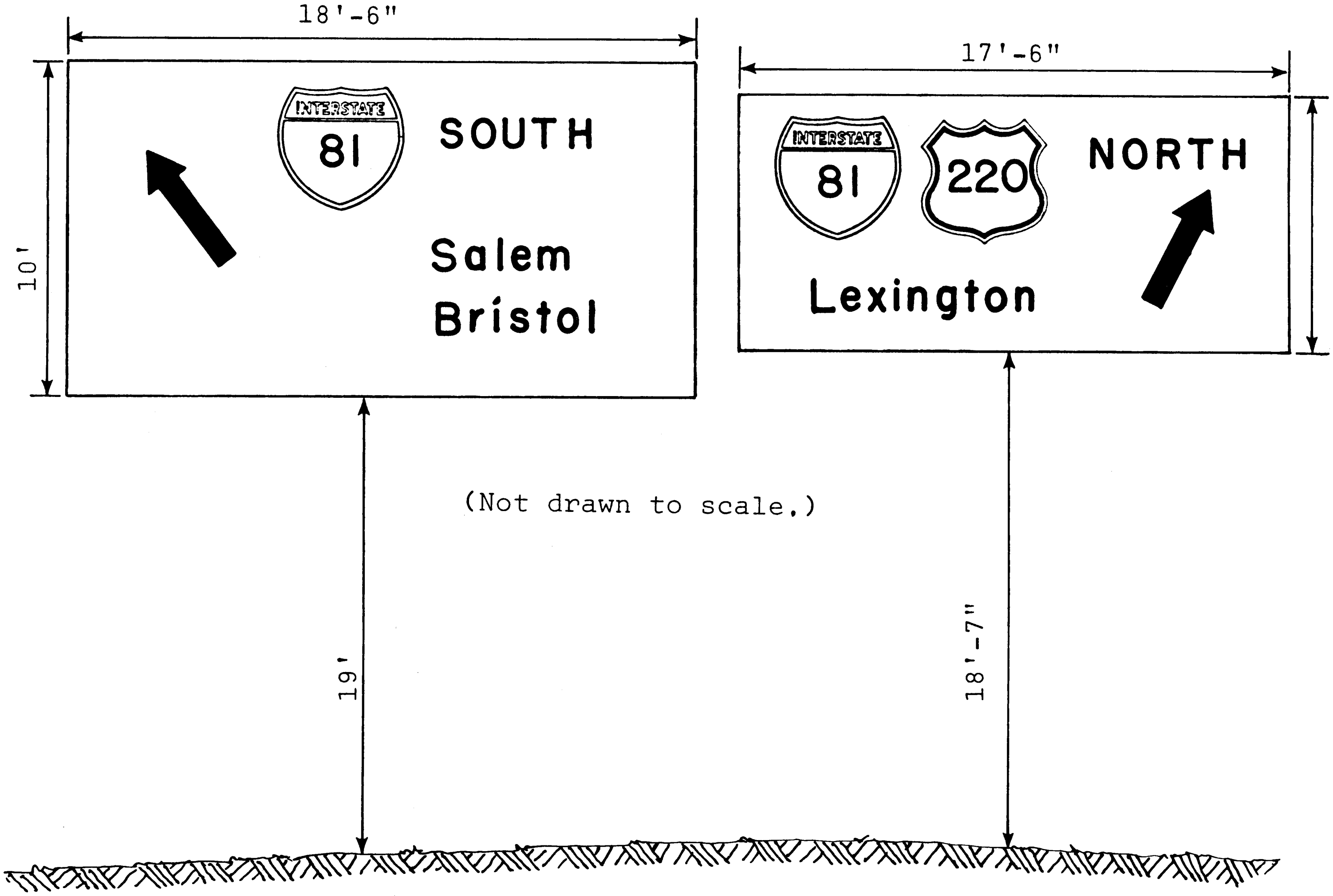
Site 1. Sign design details.



Message:	Line 1:	Shields	36"
		Capitals	12" Mod. E.
	Line 2:	Capitals	16" Mod. E.
		Lower Case	12" Mod. E.
	Line 3:	Capitals	16" Mod. E.
		Lower Case	12" Mod. E.
	Line 4:	Capitals	12" Mod. E.
Arrows:			22"

Basic Conversion Units: 1 inch = 2.54 centimeters
1 foot = .3048 meter

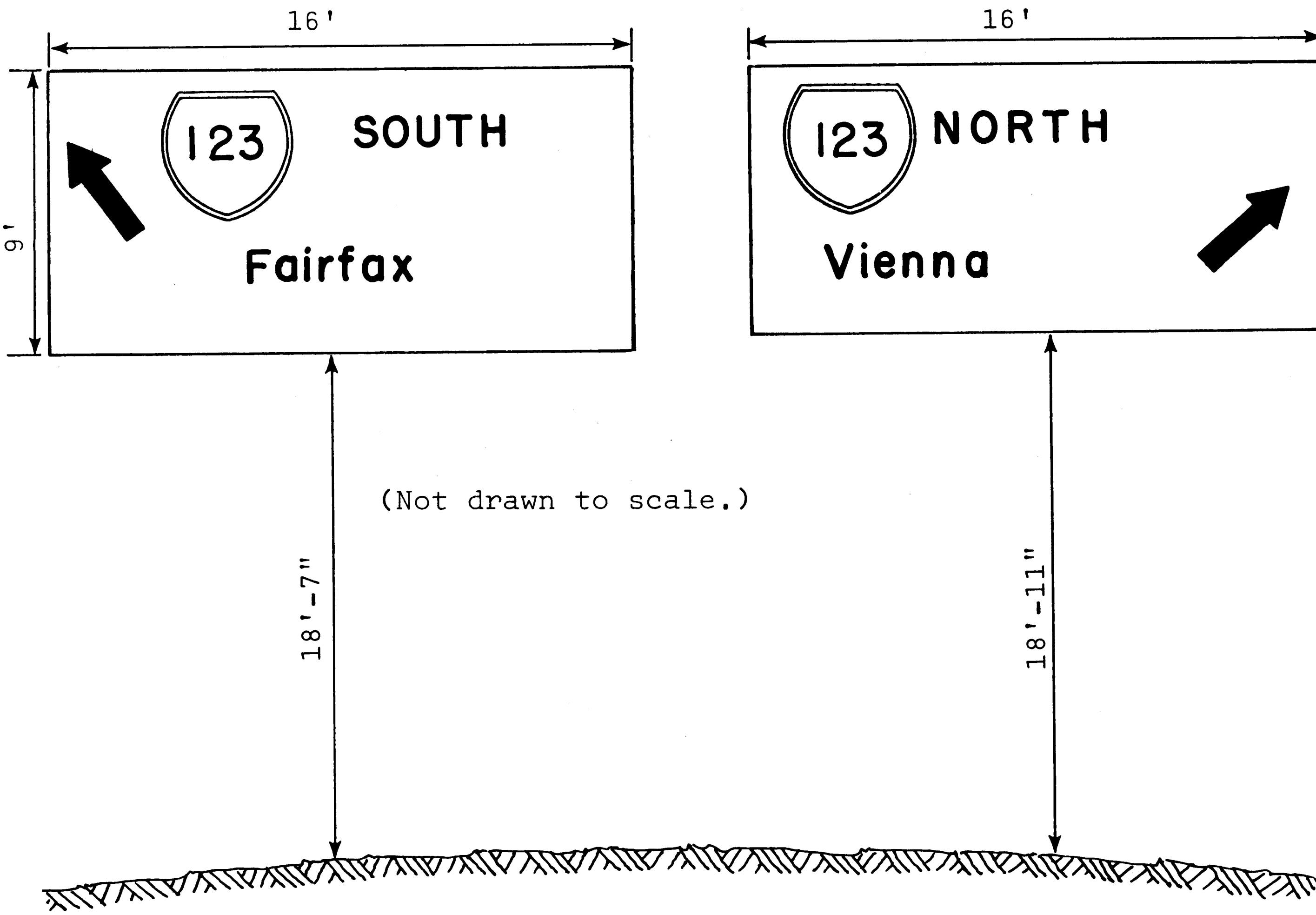
Site 2. Sign design details.



Message:	Line 1:	Shields	36"
		Capitals	12" Mod. E.
	Line 2:	Capitals	16" Mod. E.
		Lower Case	12" Mod. E.
	Line 3:	Capitals	16" Mod. E.
		Lower Case	12" Mod. E.
Arrows:			48"

Basic Conversion Units: 1 inch = 2.54 centimeters
1 foot = .3048 meter

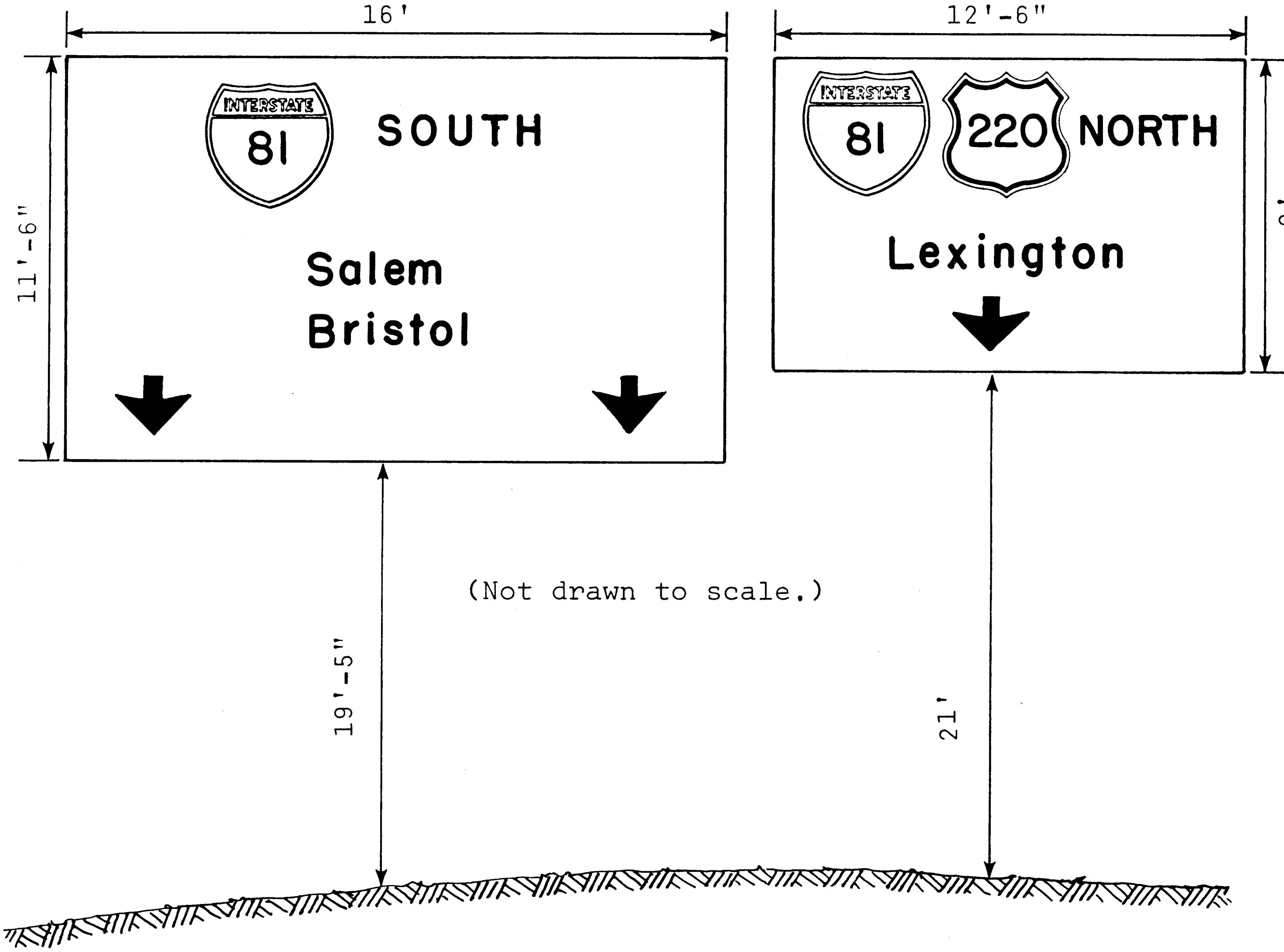
Site 3. Sign design details.



Message:	Line 1:	Shields	36"
		Capitals	12" Mod. E.
	Line 2:	Capitals	16" Mod. E.
		Lower Case	12" Mod. E.
Arrows:			48"

Basic Conversion Units: 1 inch = 2.54 centimeters
1 foot = .3048 meter

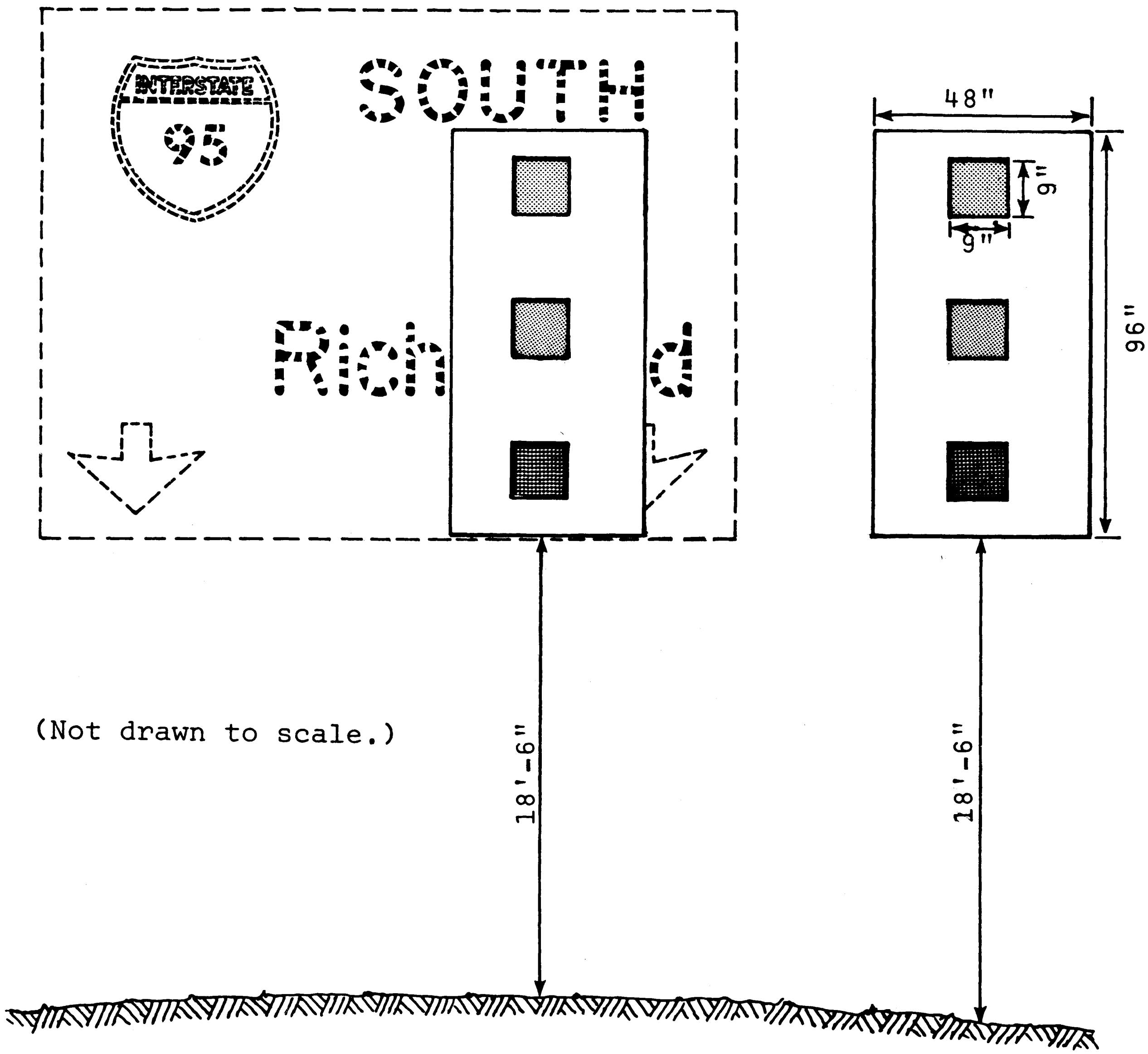
Site 4. Sign design details.



Message:	Line 1:	Shields	36"
		Capitals	12" Mod. E.
	Line 2:	Capitals	16" Mod. E.
		Lower Case	12" Mod. E.
	Line 3:	Capitals	16" Mod. E.
		Lower Case	12" Mod. E.
Arrows:			22"

Basic Conversion Units: 1 inch = 2.54 centimeters
1 foot = .3048 meter

Site 5. Sign design details.



(Not drawn to scale.)

Basic Conversion Units: 1 inch = 2.54 centimeters
1 foot = .3048 meter

Site 6. Special sign design details.

APPENDIX B

Site 1

Summary of Luminance Data and Statistical Tests

Sign	Distance (ft.)	Luminance (ft.-lamberts)	Number of Readings	Standard Deviation	t Value	Significance
Sign Background — High Beams						
High Intensity	300	.629	35	.331	-2.311	Yes
Conventional	300	.845	35	.442		
High Intensity	600	1.997	40	.507		
Conventional	600	1.710	40	.589	2.335	Yes
High Intensity	900	1.905	40	.562		
Conventional	900	1.507	40	.543	3.222	Yes
High Intensity	1,200	1.212	40	.435		
Conventional	1,200	1.007	40	.364	2.287	Yes
High Intensity	1,500	.605	30	.201		
Conventional	1,500	.709	30	.268	-1.704	No
Sign Legend — High Beams						
High Intensity	300	3.690	19	1.868		
Conventional	300	14.479	30	9.239	-5.007	Yes
High Intensity	600	12.360	8	3.380		
Conventional	600	18.600	22	9.580	-1.780	No
High Intensity	900	9.377	8	5.050		
Conventional	900	16.080	18	7.314	-2.343	Yes
Sign Background — Low Beams						
High Intensity	300	.182	25	.057		
Conventional	300	.579	25	.271	-7.177	Yes
High Intensity	600	.207	25	.083		
Conventional	600	.570	25	.260	-6.646	Yes
High Intensity	900	.131	30	.043		
Conventional	900	.453	30	.264	-6.598	Yes
High Intensity	1,200	.092	30	.034		
Conventional	1,200	.448	30	.229	-8.429	Yes
High Intensity	1,500	.088	20	.048		
Conventional	1,500	.395	20	.189	-7.029	Yes
Sign Legend — Low Beams						
High Intensity	300	.970	11	.477		
Conventional	300	13.920	20	9.199	-4.630	Yes
High Intensity	600	.985	6	.499		
Conventional	600	13.030	16	9.811	-2.960	Yes
High Intensity	900	.537	6	.204		
Conventional	900	11.170	14	6.521	-3.932	Yes
Sign Background — Low Beams in Stream Traffic						
High Intensity	300	.286	20	0.07		
Conventional	300	.688	20	.27	-2.350	Yes
High Intensity	600	.465	20	0.16		
Conventional	600	.674	20	.25	-1.113	No
High Intensity	900	.363	20	.09		
Conventional	900	.687	20	.32	-1.818	No
High Intensity	1,200	.292	20	.09		
Conventional	1,200	.754	20	.44	-2.491	Yes
High Intensity	1,500	.276	20	.13		
Conventional	1,500	.773	20	.43	-2.643	Yes
Sign Legend — Low Beams in Stream Traffic						
High Intensity	300	1.91	4	.50		
Conventional	300	9.31	12	7.02	-1.477	No
High Intensity	600	1.82	4	.46		
Conventional	600	9.11	8	6.46	-1.447	No
High Intensity	900	1.01	4	.15		
Conventional	900	5.79	8	4.13	-1.496	No

Basic Conversion Units — 1 foot = .3048 meter
1 foot lambert = 3.426 candela/meter^2

APPENDIX B (cont.)

Site 2

Summary of Luminance Data and Statistical Tests

Sign	Distance (ft.)	Luminance (ft.-lamberts)	Number of Readings	Standard Deviation	t Value	Significance
Sign Background — High Beams						
High Intensity	300	.898	35	.662		
Conventional	300	1.144	35	.860	-1.339	No
High Intensity	600	3.824	40	1.002		
Conventional	600	2.328	40	.967	6.794	Yes
High Intensity	900	3.386	35	.896		
Conventional	900	2.119	35	1.000	5.583	Yes
High Intensity	1,200	2.566	30	.771		
Conventional	1,200	1.736	30	.924	3.778	Yes
High Intensity	1,500	2.291	28	.910		
Conventional	1,500	1.575	30	.800	3.189	Yes
Sign Legend — High Beams						
High Intensity	300	4.371	32	2.996		
Conventional	300	13.820	26	10.010	-5.076	Yes
High Intensity	600	18.560	26	5.368		
Conventional	600	18.380	18	12.350	.066	No
High Intensity	900	14.410	14	5.419		
Conventional	900	13.490	10	8.198	.332	No
Sign Background — Low Beams						
High Intensity	300	.316	35	.205		
Conventional	300	.697	35	.467	-4.422	Yes
High Intensity	600	.448	35	.236		
Conventional	600	.707	35	.467	-2.926	Yes
High Intensity	900	.464	35	.293		
Conventional	900	.736	35	.509	-2.740	Yes
High Intensity	1,200	.554	20	.379		
Conventional	1,200	1.014	20	.752	-2.444	Yes
High Intensity	1,500	.495	33	.273		
Conventional	1,500	.807	35	.658	-2.522	Yes
Sign Legend — Low Beams						
High Intensity	300	1.344	29	.677		
Conventional	300	10.490	21	7.901	-6.227	Yes
High Intensity	600	2.098	25	1.084		
Conventional	600	9.576	13	8.794	-4.242	Yes
High Intensity	900	2.622	12	1.370		
Conventional	900	9.059	8	7.348	-2.997	Yes
Sign Background — Low Beams in Stream Traffic						
High Intensity	300	.672	20	.641		
Conventional	300	.967	20	.720	-1.368	No
High Intensity	600	.939	25	.546		
Conventional	600	.869	25	.549	.450	No
High Intensity	900	.930	25	.498		
Conventional	900	.903	25	.531	.185	No
High Intensity	1,200	.871	10	.270		
Conventional	1,200	.915	10	.733	- .179	No
High Intensity	1,500	.884	23	.458		
Conventional	1,500	.916	25	.748	- .176	No
Sign Legend — Low Beams in Stream Traffic						
High Intensity	300	2.528	16	1.913		
Conventional	300	12.950	12	8.994	-4.528	Yes
High Intensity	600	3.305	19	1.169		
Conventional	600	11.500	11	9.336	-3.823	Yes
High Intensity	900	3.711	11	.783		
Conventional	900	11.132	11	7.411	-3.303	Yes

Basic Conversion Units: 1 foot = .3048 meter
1 foot lambert = 3.426 candela/meter^2

APPENDIX B (cont.)

Site 3

Summary of Luminance Data and Statistical Tests

Sign	Distance (ft.)	Luminance (ft.-lamberts)	Number of Readings	Standard Deviation	t Value	Significance
		Sign Background — High Beams				
High Intensity	600	3.247	30	1.638		
Conventional	600	1.877	30	.692	4.220	Yes
High Intensity	900	3.223	25	1.041		
Conventional	900	1.733	25	.506	6.436	Yes
High Intensity	1,200	2.724	25	.342		
Conventional	1,200	1.566	25	.236	13.940	Yes
High Intensity	1,500	1.643	3	.172		
Conventional	1,500	1.077	3	.309	2.772	Yes
		Sign Legend — High Beams				
High Intensity	600	17.430	20	8.570		
Conventional	600	14.920	21	3.697	1.228	No
High Intensity	900	10.020	6	5.565		
Conventional	900	10.920	6	1.932	- .374	No
		Sign Background — Low Beams				
High Intensity	600	.283	30	.059		
Conventional	600	.410	30	.173	- 3.810	Yes
High Intensity	900	.233	25	.131		
Conventional	900	.374	25	.178	- 3.208	Yes
High Intensity	1,200	.340	20	.052		
Conventional	1,200	.473	20	.127	- 4.338	Yes
High Intensity	1,500	.260	3	.036		
Conventional	1,500	.390	3	.165	- 1.333	No
		Sign Legend — Low Beams				
High Intensity	600	.781	24	.203		
Conventional	600	4.640	26	1.984	- 9.476	Yes
High Intensity	900	.522	4	.234		
Conventional	900	3.057	3	.484	- 9.331	Yes
		Sign Background — Low Beams in Stream Traffic				
High Intensity	600	.471	25	.174		
Conventional	600	.558	25	.261	- 1.382	No
High Intensity	900	.659	23	.336		
Conventional	900	.649	25	.395	.093	No
High Intensity	1,200	.724	25	.434		
Conventional	1,200	.547	25	.241	1.781	No
High Intensity	1,500	.250	3	.020		
Conventional	1,500	.792	3	.219	- 4.269	Yes
		Sign Legend — Low Beams in Stream Traffic				
High Intensity	600	2.548	16	.996		
Conventional	600	6.447	16	2.252	- 6.333	Yes
High Intensity	900	3.045	4	.619		
Conventional	900	5.437	3	1.396	- 3.118	Yes

Basic Conversion Units: 1 foot = .3048 meter
1 foot lambert = 3.426 candela/meter^2

APPENDIX B (cont.)

Site 4

Summary of Luminance Data and Statistical Tests

Sign	Distance (ft.)	Luminance (ft.-lamberts)	Number of Readings	Standard Deviation	t Value	Significance
		Sign Background — High Beams				
High Intensity	300	.651	40	.465		
Conventional	300	.713	40	.435	- .612	No
High Intensity	600	.492	40	.285		
Conventional	600	.625	40	.361	- 1.840	No
High Intensity	900	.265	25	.150		
Conventional	900	.495	17	.273	- 3.509	Yes
		Sign Legend — High Beams				
High Intensity	300	3.423	28	1.948		
Conventional	300	8.105	26	4.671	- 4.870	Yes
High Intensity	600	2.311	26	1.386		
Conventional	600	5.276	26	3.023	- 4.546	Yes
High Intensity	900	1.143	11	.395		
Conventional	900	3.762	11	.887	- 8.947	Yes
		Sign Background — Low Beams				
High Intensity	300	.190	40	.113		
Conventional	300	.621	40	.391	- 6.698	Yes
High Intensity	600	.161	40	.105		
Conventional	600	.491	40	.313	- 6.321	Yes
High Intensity	900	.097	25	.102		
Conventional	900	.552	17	.577	- 3.876	Yes
		Sign Legend — Low Beams				
High Intensity	300	1.155	28	.746		
Conventional	300	6.244	24	3.213	- 8.142	Yes
High Intensity	600	.787	26	.466		
Conventional	600	4.472	24	2.284	- 8.055	Yes
High Intensity	900	.420	11	.146		
Conventional	900	3.033	11	.851	-10.041	Yes
		Sign Background — Low Beams in Stream Traffic				
High Intensity	300	.301	30	.076		
Conventional	300	.711	30	.391	- 5.634	Yes
High Intensity	600	.243	30	.062		
Conventional	600	.547	30	.341	- 4.803	Yes
High Intensity	900	.110	25	.100		
Conventional	900	.447	17	.273	- 5.663	Yes
		Sign Legend — Low Beams in Stream Traffic				
High Intensity	300	1.627	22	.555		
Conventional	300	6.512	20	3.364	- 6.719	Yes
High Intensity	600	1.162	20	.459		
Conventional	600	5.442	22	2.458	- 7.659	Yes
High Intensity	900	.453	11	.154		
Conventional	900	2.665	11	1.009	- 7.189	Yes

Basic Conversion Units: 1 foot = .3048 meter
1 foot lambert = 3.426 candela/meter^2

APPENDIX B (cont.)

Site 5

Summary of Luminance Data and Statistical Tests

Sign	Distance (ft.)	Luminance (ft.-lamberts)	Number of Readings	Standard Deviation	t Value	Significance
Sign Background — High Beams						
High Intensity	300	.488	25	.204		
Conventional	300	.694	25	.288	- 2.915	Yes
High Intensity	600	.894	30	.212		
Conventional	600	.971	30	.395	- .935	No
High Intensity	900	.678	10	.462		
Conventional	900	.866	10	.470	- .903	No
Sign Legend — High Beams						
High Intensity	300	2.374	24	.720		
Conventional	300	6.619	21	4.124	- 4.965	Yes
High Intensity	600	4.417	22	.849		
Conventional	600	8.073	12	3.059	- 5.304	Yes
Sign Background — Low Beams						
High Intensity	300	.443	10	.063		
Conventional	300	.727	10	.315	- 2.796	Yes
High Intensity	600	.433	10	.059		
Conventional	600	.657	10	.260	- 2.657	Yes
Sign Legend — Low Beams						
High Intensity	300	1.671	10	.415		
Conventional	300	6.060	10	4.065	- 3.397	Yes
High Intensity	600	1.262	6	.064		
Conventional	600	4.190	2	.014	-61.088	Yes
Sign Background — Low Beams in Stream Traffic						
High Intensity	300	.305	25	.187		
Conventional	300	.603	25	.345	- 3.795	Yes
High Intensity	600	.419	29	.210		
Conventional	600	.609	29	.277	- 2.944	Yes
High Intensity	900	.472	10	.394		
Conventional	900	.782	10	.504	- 1.532	No
Sign Legend — Low Beams in Stream Traffic						
High Intensity	300	1.229	21	.478		
Conventional	300	5.846	21	3.605	- 5.818	Yes
High Intensity	600	3.348	21	2.941		
Conventional	600	3.416	5	2.539	- .048	No

Basic Conversion Units: 1 foot = .3048 meter
1 foot lambert = 3.426 candela/meter^2

Site 6 (Curved Approach)

Summary of Luminance Data and Statistical Tests

Sign	Distance (ft.)	Luminance (ft.-lamberts)	Number of Readings	Standard Deviation	t Value	Significance
Sign Background — High Beams						
High Intensity	300	.854	6	.693		
Conventional	300	1.046	6	.636	- .500	No
High Intensity	600	3.812	6	2.086		
Conventional	600	2.704	6	1.565	1.041	No
High Intensity	900	3.517	6	2.082		
Conventional	900	1.972	6	1.060	1.620	No
High Intensity	1,200	2.851	6	2.068		
Conventional	1,200	1.578	6	.843	1.396	No
High Intensity	1,500	2.648	6	1.658		
Conventional	1,500	1.421	6	.658	1.685	No
Sign Legend — High Beams						
High Intensity	300	4.900	6	3.459		
Conventional	300	11.400	6	4.941	- 2.640	Yes
High Intensity	600	24.050	6	14.240		
Conventional	600	18.290	6	9.302	.830	No
High Intensity	900	20.530	6	12.700		
Conventional	900	14.860	6	6.351	.978	No
High Intensity	1,200	15.150	6	10.734		
Conventional	1,200	10.890	6	4.614	.893	No
Sign Background — Low Beams						
High Intensity	300	.424	6	.331		
Conventional	300	.700	6	.276	- 1.569	No
High Intensity	600	.515	6	.249		
Conventional	600	.703	6	.264	- 1.269	No
High Intensity	900	.388	6	.168		
Conventional	900	.689	6	.234	- 2.560	Yes
High Intensity	1,200	.337	6	.107		
Conventional	1,200	.703	6	.182	- 4.246	Yes
High Intensity	1,500	.459	6	.063		
Conventional	1,500	.687	6	.158	- 3.283	Yes
Sign Legend — Low Beams						
High Intensity	300	2.309	6	1.570		
Conventional	300	9.343	6	3.539	- 4.450	Yes
High Intensity	600	2.770	6	1.692		
Conventional	600	8.090	6	2.226	- 4.661	Yes
High Intensity	900	1.962	6	.672		
Conventional	900	7.230	6	2.110	- 5.827	Yes
High Intensity	1,200	1.399	6	.623		
Conventional	1,200	6.137	6	1.482	- 7.219	Yes
Sign Background — Low Beams in Stream Traffic						
High Intensity	300	.489	6	.296		
Conventional	300	.731	6	.292	- 1.426	No
High Intensity	600	.645	6	.295		
Conventional	600	.734	6	.218	- .594	No
High Intensity	900	.513	6	.171		
Conventional	900	.692	6	.196	- 1.686	No
High Intensity	1,200	.435	6	.107		
Conventional	1,200	.656	6	.198	- 2.405	Yes
High Intensity	1,500	.492	6	.064		
Conventional	1,500	.648	6	.165	- 2.159	No
Sign Legend — Low Beams in Stream Traffic						
High Intensity	300	2.690	6	1.515		
Conventional	300	9.657	6	3.459	- 4.519	Yes
High Intensity	600	4.002	6	1.869		
Conventional	600	8.707	6	2.270	- 3.920	Yes
High Intensity	900	2.987	6	.947		
Conventional	900	7.612	6	2.087	- 4.943	Yes
High Intensity	1,200	2.095	6	.187		
Conventional	1,200	6.163	6	1.532	- 6.456	Yes

Basic Conversion Units: 1 foot = .3048 meter
1 foot lambert = 3.426 candela/meter^2

Site 6 (Straight Approach)

Summary of Luminance Data and Statistical Tests

Sign	Distance (ft.)	Luminance (ft.-lamberts)	Number of Readings	Standard Deviation	t Value	Significance
		Sign Background — High Beams				
High Intensity	300	1.010	6	.780		
Conventional	300	1.215	6	.778	- .456	No
High Intensity	600	3.815	6	1.772		
Conventional	600	2.366	6	1.360	1.589	No
High Intensity	900	4.122	6	2.496		
Conventional	900	2.294	6	1.532	1.529	No
High Intensity	1,200	3.738	6	2.570		
Conventional	1,200	2.183	6	1.407	1.300	No
High Intensity	1,500	3.434	6	2.545		
Conventional	1,500	1.884	6	1.268	1.335	No
		Sign Legend — High Beams				
High Intensity	300	5.123	6	3.485		
Conventional	300	12.580	6	5.691	-2.737	Yes
High Intensity	600	24.700	6	12.050		
Conventional	600	18.790	6	8.739	.973	No
High Intensity	900	23.230	6	15.040		
Conventional	900	17.790	6	9.078	.759	No
High Intensity	1,200	17.620	6	12.220		
Conventional	1,200	15.080	6	7.730	.430	No
		Sign Background — Low Beams				
High Intensity	300	.451	6	.373		
Conventional	300	.749	6	.313	-1.499	No
High Intensity	600	.495	6	.394		
Conventional	600	.724	6	.277	-1.165	No
High Intensity	900	.464	6	.347		
Conventional	900	.727	6	.232	-1.543	No
High Intensity	1,200	.485	6	.264		
Conventional	1,200	.687	6	.246	-1.371	No
High Intensity	1,500	.661	6	.341		
Conventional	1,500	.804	6	.228	- .854	No
		Sign Legend — Low Beams				
High Intensity	300	2.451	6	1.669		
Conventional	300	8.797	6	2.731	-4.857	Yes
High Intensity	600	2.726	6	1.865		
Conventional	600	8.480	6	2.682	-4.315	Yes
High Intensity	900	2.465	6	1.553		
Conventional	900	7.893	6	2.193	-4.948	Yes
High Intensity	1,200	1.932	6	1.233		
Conventional	1,200	6.490	6	1.743	-5.229	Yes
		Sign Background — Low Beams in Stream Traffic				
High Intensity	300	.481	6	.375		
Conventional	300	.736	6	.311	-1.282	No
High Intensity	600	.519	6	.338		
Conventional	600	.761	6	.252	-1.406	No
High Intensity	900	.572	6	.279		
Conventional	900	.776	6	.234	-1.372	No
High Intensity	1,200	.580	6	.278		
Conventional	1,200	.742	6	.225	-1.110	No
High Intensity	1,500	.655	6	.268		
Conventional	1,500	.734	6	.224	- .554	No
		Sign Legend — Low Beams in Stream Traffic				
High Intensity	300	2.618	6	1.772		
Conventional	300	8.685	6	2.293	-5.128	Yes
High Intensity	600	2.865	6	1.849		
Conventional	600	8.535	6	2.293	-4.715	Yes
High Intensity	900	3.007	6	1.310		
Conventional	900	7.498	6	2.123	-4.410	Yes
High Intensity	1,200	2.335	6	1.131		
Conventional	1,200	6.578	6	1.552	-5.412	Yes

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