SOME MEASURES FOR IMPROVING NIGHT VISIBILITY AT HIGHWAY INTERSECTIONS

by

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(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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ABSTRACT

Through selected case studies, this report illustrates how the inadequate visibility of road signs and pavement markings at night contributes to wrong-way driving. A concept termed "keg of legibility" for visibility at night has been developed by the author to delineate the limits of night visibility under low beam headlights. The report discusses the application of the keg of legibility to the placement of signs, markings, and additional devices that can be used to help inform the motorist who is to negotiate a four-lane divided highway and to guide him through the intersection. Cases of poor road geometrics are cited to emphasize the need for such information and guidance.

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INTRODUCTION

Wrong-way driving surveys carried out in Virginia since 1970 have shown that most of the wrong-way incidents originate at interchanges and intersections. The driver has to be very carefully guided onto the correct ramp on an interchange or around the nose of the median for a left turn at an intersection on a divided highway. Informational devices such as signs and pavement markings, and other features like curbs, all made conspicuous by a color scheme, are provided with the hope that they will gain the attention of the driver. However, guidance by such devices is not of maximum effectiveness for a person driving under low beam headlights at night, likely because of either improper location of the devices or poor geometrics of the intersection.

PURPOSE AND SCOPE

The purpose of the report is to illustrate the limitations on legibility under which a driver at night negotiates an intersection. The report also describes engineering measures that can be used to help drivers negotiate intersections at night under different geometric conditions.

The report describes a concept termed the "keg of legibility" developed by the author for the placement of signs and other guidance devices.

NEED FOR DESIGN BASED ON NIGHT VISIBILITY

During daylight, the visibility and legibility of roadway elements such as signs, pavement markings, painted curbs, greenery, etc., at an intersection are limited by the longitudinal and transverse distances at which they are viewed. On an unlit intersection

at night, the visibility and legibility are very much curtailed by (1) the limited area covered by the headlights (usually on low beam), (2) the size and shape of the device being viewed and, (3) the luminance of devices and their contrast with the background. Thus it is evident that roadway appurtenances located for visibility and legibility during daytime may not adequately serve their purpose at night. It is, therefore, essential that for full effectiveness highway appurtenances provided for guidance should be designed and located on the basis of their legibility under low beam headlights at night.

When designing intersections between divided highways and crossroads for night visibility, one must differentiate between intersecting roads that are at nearly the same elevations and those that are not. These two cases are discussed in the following sections.

INTERSECTING ROADS AT SAME ELEVATION

The present concept of a driver's vision is based on the cone of vision. Pignataro states that the limit of far clear sight is within a cone of 10° to 12°.(1) Figure 1* shows a 10° cone of vision and the vertical and horizontal distances from the pavement edge within which, according to the cone concept, a sign would have to be placed for optimum visibility. This concept, however, is based on day vision. The horizontal and vertical cone dimensions within which a sign would be visible are shown in the figure.

In this investigation a study was carried out to determine the night and day legibility of a 0.6 m x 0.6 m (2 ft. x 2 ft.) reflectorized diagrammatic sign of engineering grade sheeting. The sign was positioned at distances of 0, 1.5, 3.0, and 4.5 m (0, 5, 10, and 15 ft.) from the pavement edge, with its center at heights of 1.5, 2.4, and 3.3 m (5, 8, and 11 ft.) above the road level. Night-and daytime photographs were taken of the sign at each combination of locations from distances of 15, 30, 45, 60, and 75 m (50, 100, 150, 200, and 250 ft.). The lens of the camera was 1.2 m (4 ft.) above the road surface and 2.7 m (9 ft.) from the pavement edge. At night, low beam headlights were used. These photographs were projected in a darkened room before five persons who graded the legibility of the sign. Four gradings were used: poor, fair, good and excellent. The limits of good legibility in terms of depth, height, and distance from the pavement edge were thus determined and are shown diagrammatically in Figure 2. This diagram shows that the zone of good legibility at night is not conical (as shown in Figure 1) but keg-shaped. Then, for example, at 30 m (100 ft.) from the eye, a sign placed in a

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*All figures are appended.

quadrant of an oval 4.5 m by 3.6 m (15 ft. by 12 ft.) with its axis on the pavement edge should be legible to the driver. (The author, who carried out this study of sign legibility at night and took the photographs, feels that good legibility could also be obtained even when the distance from the pavement edge is increased by 1.5 (5 ft.) over the values given in Figure 2. Also, by use of high intensity sheeting instead of engineering grade sheeting, the horizontal and vertical dimensions of the keg of legibility could be further increased.)

This keg of legibility as developed by the author, should provide good night legibility for a normal person viewing under low beam headlights during good weather conditions on a straight road. The night legibility decreases under defective headlights, increased humidity, and fog and rain. This keg of legibility at night could be used for locating road appurtenances provided for guidance.

Figure 2 shows that according to the keg concept the maximum distances from the pavement edge within which the sign is legible at distances of 15 m and 30 m (50 ft. and 100 ft.) from the driver are 3 m and 3.6 m (10 ft. and 12 ft.) respectively. Hence for intersections at which the distance between the stopping point of the driver and the median (where the signs are located) does not exceed 30 m (100 ft.), the maximum distance from the pavement edge for placement of a sign could be taken as 3 m (10 ft.).

The following two cases in which the drivers entered the exit ramp instead of the entry ramp, and thus made wrong-way entries, resulted from poor visibility of the signs and road markings.

Case No. 1 — Intersection of Interstate Highway Exit Ramp and a Secondary Road

Figures 3 and 4 are day and night photographs of an exit ramp at the intersection of an interstate highway and a secondary road that has experienced a wrong-way entry. Two things are evident from the photographs.

1. As seen in Figure 4, because of the restricted depth and width of vision at night, a driver with low external stimuli is likely to be guided by the pavement edge line, which flares into the right lane. Continuation of the pavement edge line straight across the ramp pavement might discourage a wrong-way entry at night. An alternative for preventing wrong-way entries is

to bring the stop line close enough to the cross-road such that it would be within the zone illuminated by low beam headlights, i.e., within the keg of night legibility. This latter suggestion has been discussed in detail by the author.[2,3] Continuation of the pavement edge line across the exit ramp or provision of the stop line very close to the edge of the crossroad might channelize the movement of drivers, especially drivers with low external stimuli. Either alternative might provide a pseudo-pavement edge effect.

2. A comparison of Figures 3 and 4 shows that the one-way arrow sign, which is visible to the driver during day, is not visible at night. If drivers are able to find their path under poor visibility at night without the benefit of observing a particular sign, it is obvious that this sign has no utility during the daytime when the visibility is much better. Hence the location of signs should be based more on night visibility than on day visibility. This one-way sign should therefore have been located within the zone of the keg of night legibility. The zone of the keg for this intersection is shown in Figure 5.

Case No. 2 — Intersection of Interstate Ramps and a Primary Highway

Figure 6 is a day photograph of a parclo (partial cloverleaf) interchange between an interstate highway and a divided primary highway where a wrong-way driver entered an exit ramp. As seen from the photograph, the nose of the median between the exit and entry ramps is set back from the junction. Figure 7 shows that the nose is not visible at night. If the nose is made visible at night it will show a separation between the exit and the entry ramps, and hence will reduce the probability of the driver entering the exit ramp instead of the entry ramp, which are close together. The following improvements could be recommended for a parclo interchange on which the exit and entry ramps are very close to each other.

1. The nose of the median should be extended up to the edge of the crossroad such that it is within the zone of the keg of night legibility. The nose should be of concrete so that it could be made conspicuous at night by the use of reflective paint. It should be made even more conspicuous by the use of delineators, which

should also be within the zone of the keg of night legibility. Figure 8 shows the suggested improvement. In this photograph the zone of the keg of legibility shows the portion of the nose that would be visible at night. Such a nose would not only provide proper visibility and the separation between the exit and the entry ramps, but also would fully channelize the exit ramp and thus discourage drivers from getting into the exit ramp from the crossroad.

2. A continuous pavement edge line should be used across the exit ramp, or the stop line should be brought very close to the edge of the crossroad such that it is within the keg of night legibility.

3. The pavement edge line should be flared into the entry ramp to encourage drivers to maneuver properly into the entry ramp.

VISIBILITY AT NIGHT ON AN INTERSECTION WITH CROSSROADS AT DIFFERENT ELEVATIONS

The two most common problems involving the geometrics at non-level intersections as shown by the investigations carried out in the reported study are discussed below.

1. The crossroad slopes downward from the divided highway. The slope sometimes is so steep that a driver approaching the divided highway has very little or no light from the headlights of the car falling on the road surface to illuminate the road features. An example is shown in Figure 9.

2. The opposing lanes of the divided highway are at different elevations. The driver coming from the crossroad is not able to see both sides of the lanes under low beam headlights and hence considers the divided highway to be a 2-lane road with the median being the opposite edge of the road.

The problem of poor geometrics is compounded when the situations above are combined at one intersection. The steeper the downward slopes of the crossroads or the greater the difference between the elevations of the two opposite lanes of the divided highway, the poorer is the visibility.

Case No. 3 — Intersection of a Divided Primary Highway and a Secondary Road

The intersection indicated in Figure 9 by a cross section sketch is a site of two wrong-way entries, both by non-drunken drivers; one during the day from the northern end and the other during dark from the southern end of the secondary road. As is evident from this figure, the northern end of the crossroad slopes downward from the divided highway. Also there is a considerable difference in elevation between the eastbound and the westbound lanes of the divided highway. The southern end of the crossroad is, however, level with the eastbound lane of the divided highway.

As was observed at the site and also as is evident from Figure 9, a driver approaching the intersection from the northern end of the crossroad is not able to see any portion of the two westbound lanes. The intersection could be improved as described below.

1. The driver must be informed of the geometry of the roadways before he enters the intersection. This can best be achieved by a diagrammatic sign depicting a divided highway intersection, and placed in such a way that it is visible to the driver using low beam headlights at night and at the time he most needs to know the geometry. The best location is below the stop sign on the same pole as shown in Figure 10. This sign would be within 3 m (10 ft.) of the lane edge and hence, as per the keg concept, visible at night. Such signs have been installed on an experimental basis at intersections for 92 km (57 miles) of primary highways in Virginia. This sign has been used in Delaware, where it is claimed wrong-way entries have been reduced.[4] It is not an international sign nor has it yet been approved for incorporation in the Manual on Uniform Traffic Control Devices by the U. S. Department of Transportation.

2. At intersections like the one shown in Figure 9, the nose of the median that the driver has to negotiate to complete a left turn is not visible to him at night. In such a case, it may be necessary to provide guidance for this maneuver. The needed information would be additional to the divided highway intersection sign, and could be provided by a diagrammatic sign as shown in Figure 10.

RECOMMENDATIONS

1. The locations of road signs and pavement markings should be designed on the basis of night visibility rather than day visibility.

2. At intersections with very bad geometric design such as differences in elevations between the opposite lanes of 4-lane divided highways, crossroads sloping downward from divided highways, or wide crossovers that could lead to wrong-way entries, diagrammatic signs would provide additional guidance. A diagrammatic sign depicting a divided highway intersection placed at the junction of the crossroad and the divided highway below the stop sign would inform the driver of the geometry of the intersection during the day and night. A diagrammatic turn sign placed at the nose of the median would inform the driver of the location of the left median nose and the need for turning around it.

3. The application of the "cone of vision" concept for the placement of signs needs to be modified. The "keg of night legibility" as developed in this investigation for the night legibility of signs seems to be more applicable.

4. To discourage a driver from entering an exit ramp at night when his depth of vision is low, the pavement edge marking should be continued across the exit ramp or the stop line should be brought closer to the edge of the crossroad such that it is within the keg of night legibility.

5. On parclo interchanges with the exit and entry ramps very close together, the median should be extended up to the edge of the crossroad and its nose should be of concrete with reflective painting. This feature will make the nose conspicuous in the zone of the keg of legibility to show the separation between the exit and entry ramps near the crossroad. It will also channelize traffic from the exit ramp.

ACKNOWLEDGEMENT

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REFERENCES

1. Pignataro, L. J., Traffic Engineering, Theory and Practice. Prentice-Hall, Inc., 1973.

2. Vaswani, N. K., "Engineering Measures for Reducing Wrong-way Driving," Virginia Highway & Transportation Research Council, October 1975.

3. _____, "Case Studies of Wrong-way Entries at Highway Interchanges in Virginia," Transportation Research Record No. 514, Transportation Research Board, Washington, D. C.

4. Letter dated August 7, 1976, from Raymond S. Pusey,Chief, Bureau of Traffic, State of Delaware to the Federal Highway Administration.

APPENDIX

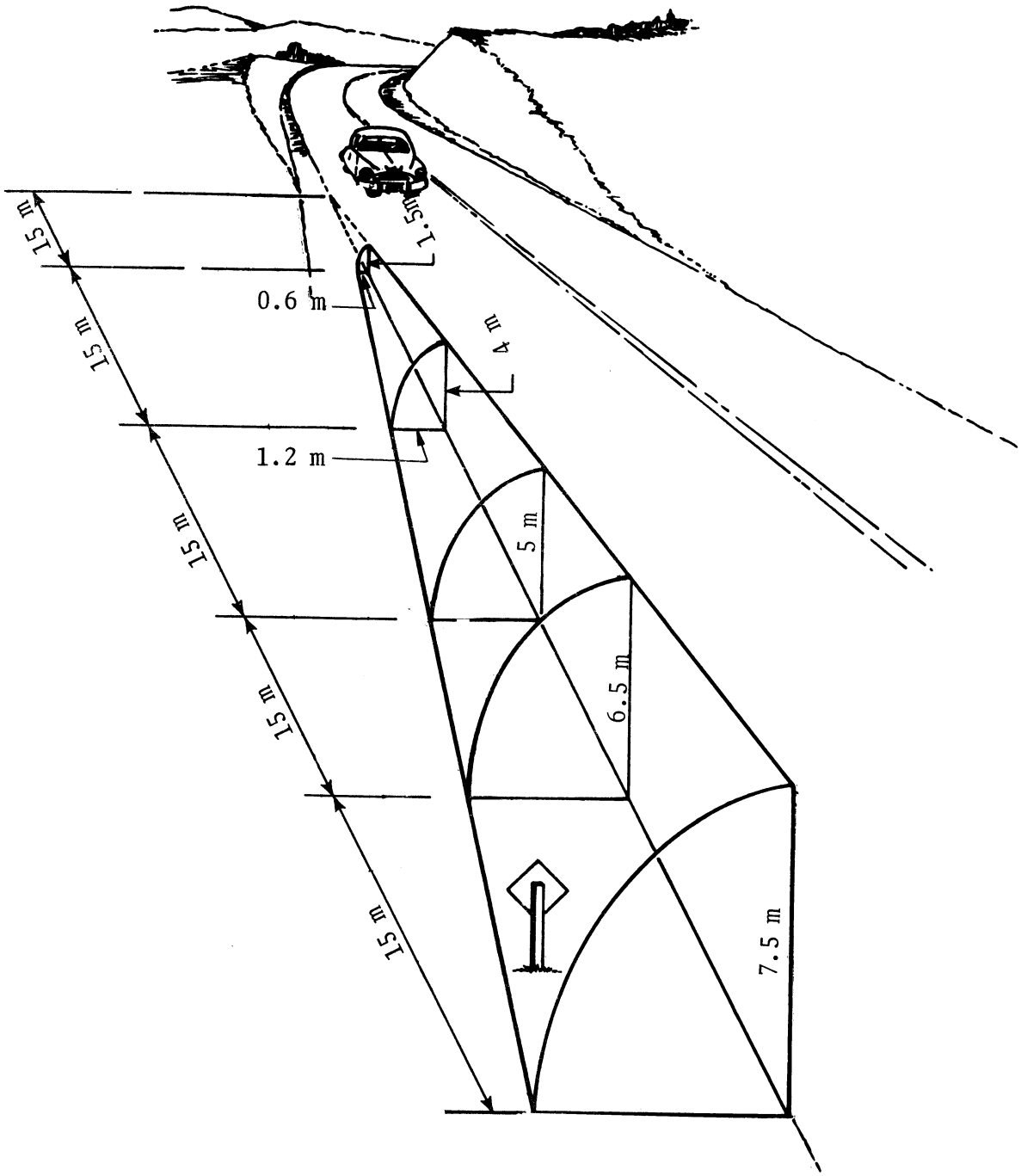

Figure 1. Ten degree cone of vision.

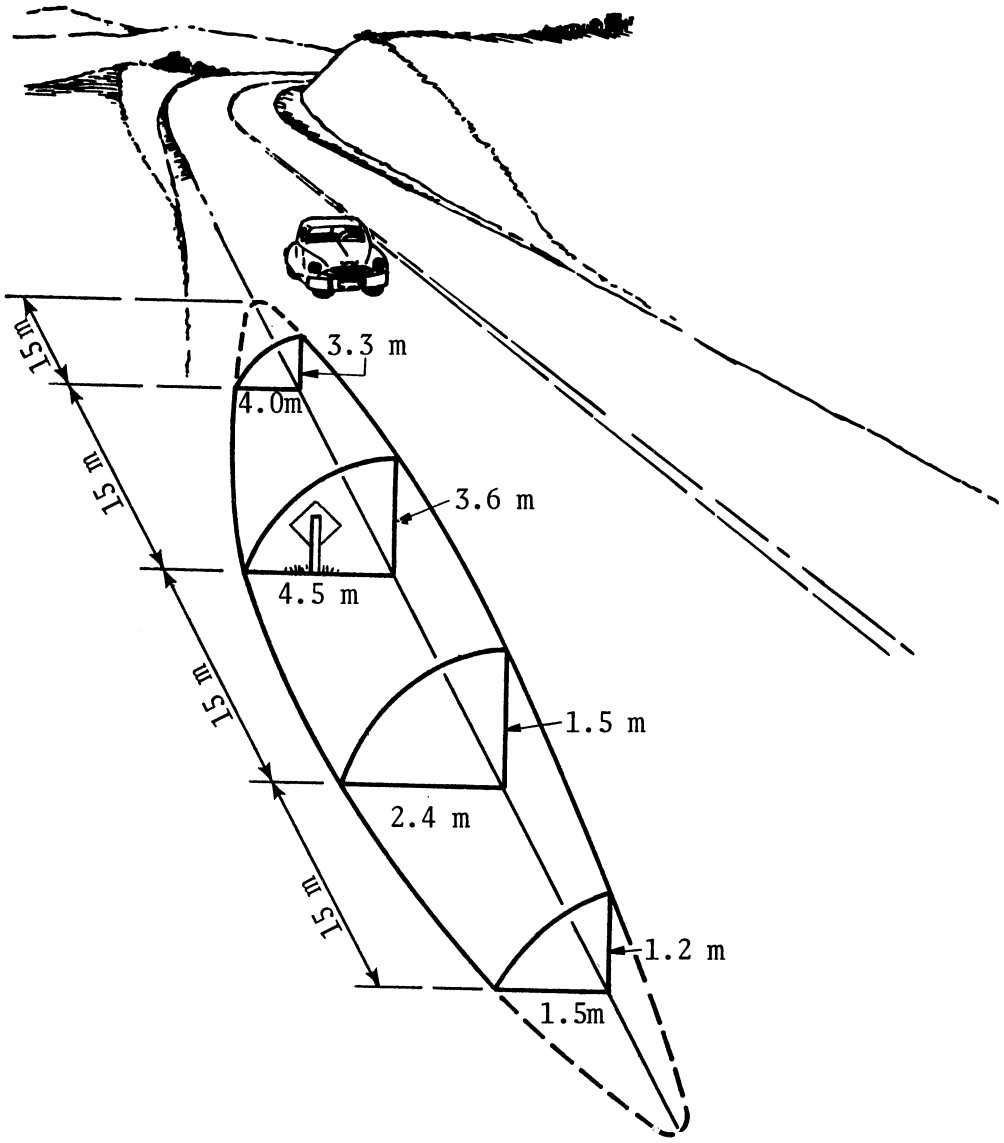

Figure 2. Keg of good legibility of 0.6 m x 0.6 m (1 m = 3.3 ft.) diagrammatic reflective sign under low beam headlights.

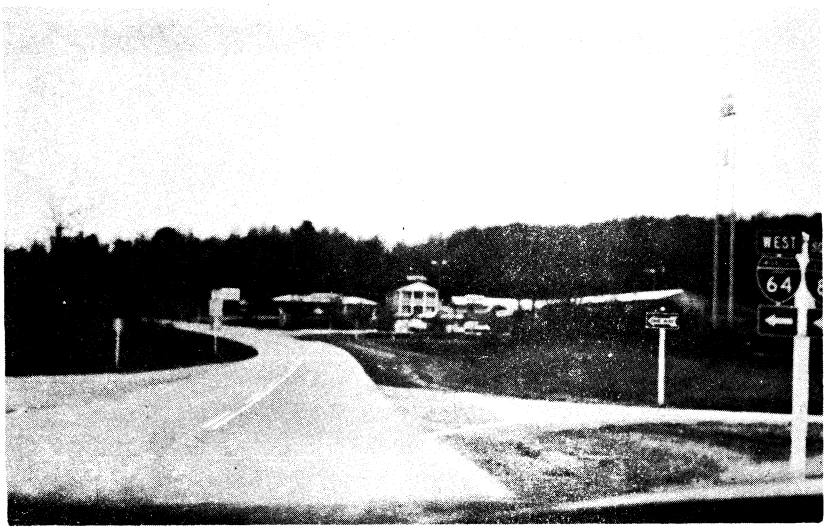

Figure 3. Intersection of interstate exit ramp and secondary road. Day photograph showing one-way arrow sign and stop line.

Figure 4. Night photograph of the same intersection shown in Figure 3. The one-way arrow sign and stop line are not now visible.

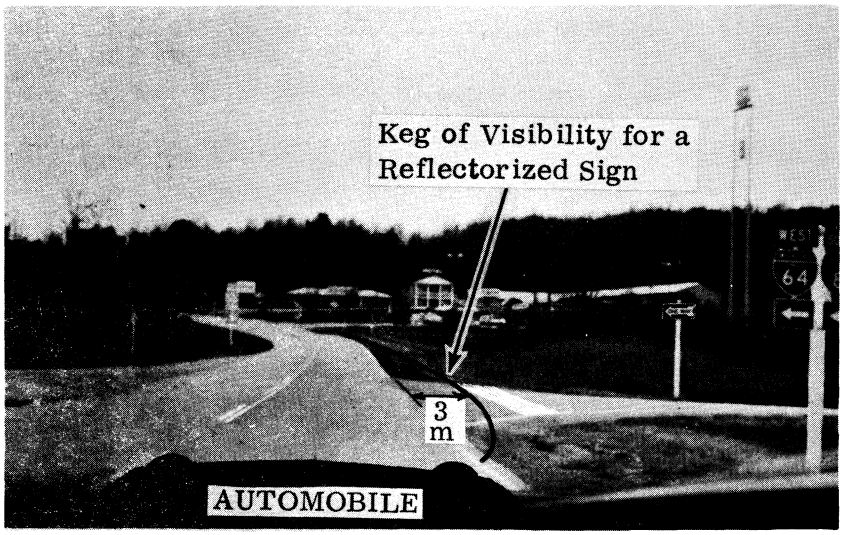

Figure 5. The zone of keg of visibility shows that the one-way sign and stop line would not be visible at night and hence both are redundant. (1 m=3.3 ft.)

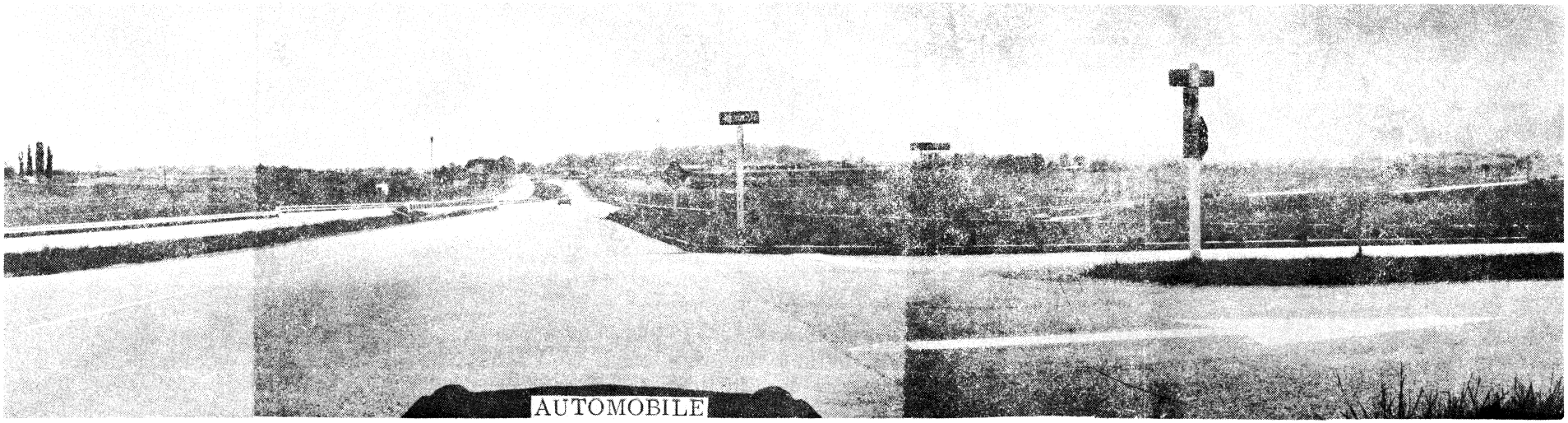

Figure 6. Partial cloverleaf intersection of interstate and primary highway.

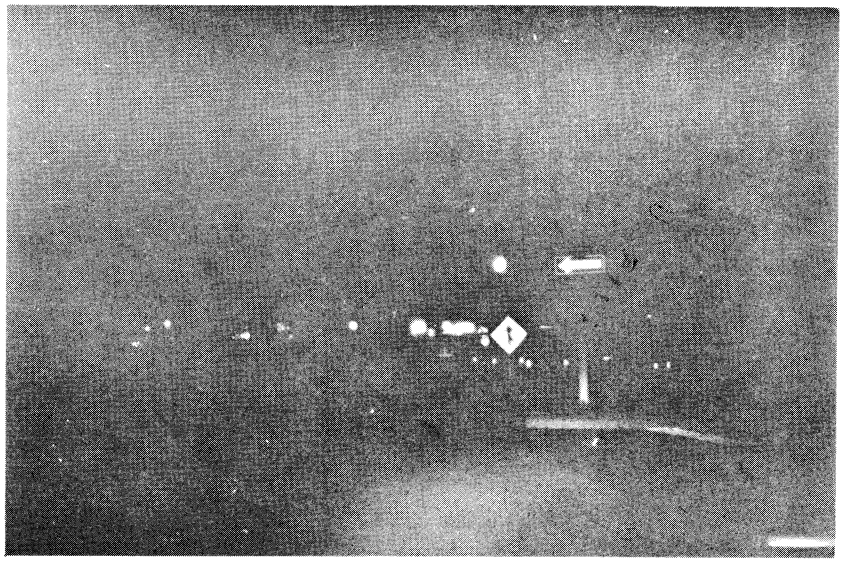

Figure 7. Visibility at night under low beam headlights of the site shown in Figure 6.

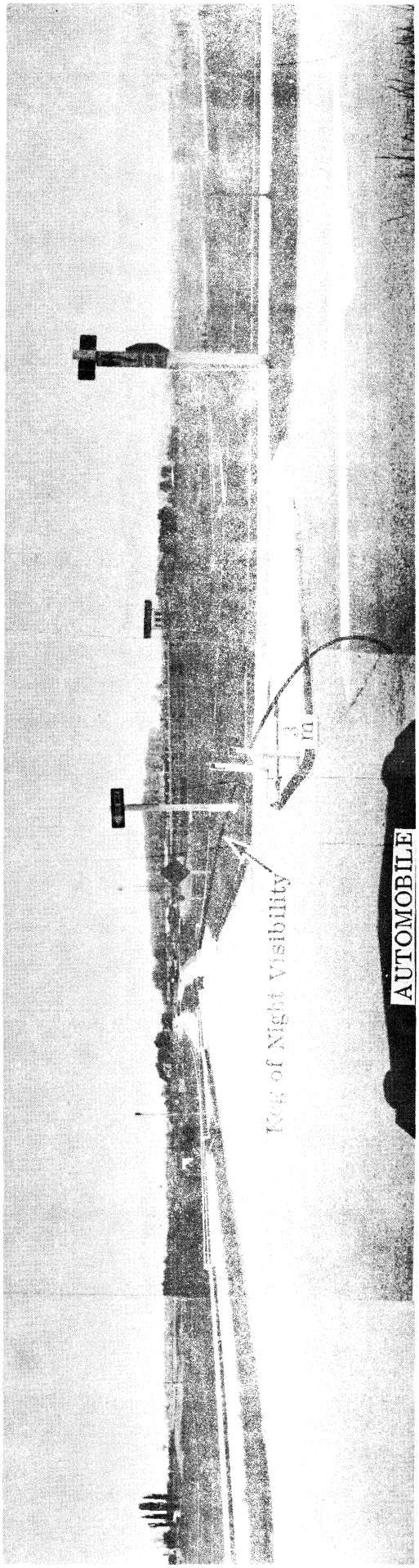

Figure 8. The zone of keg of visibility shows that one-way sign is visible, and that to be visible at night the median should be extended as shown. (1 m = 3.3 ft.)

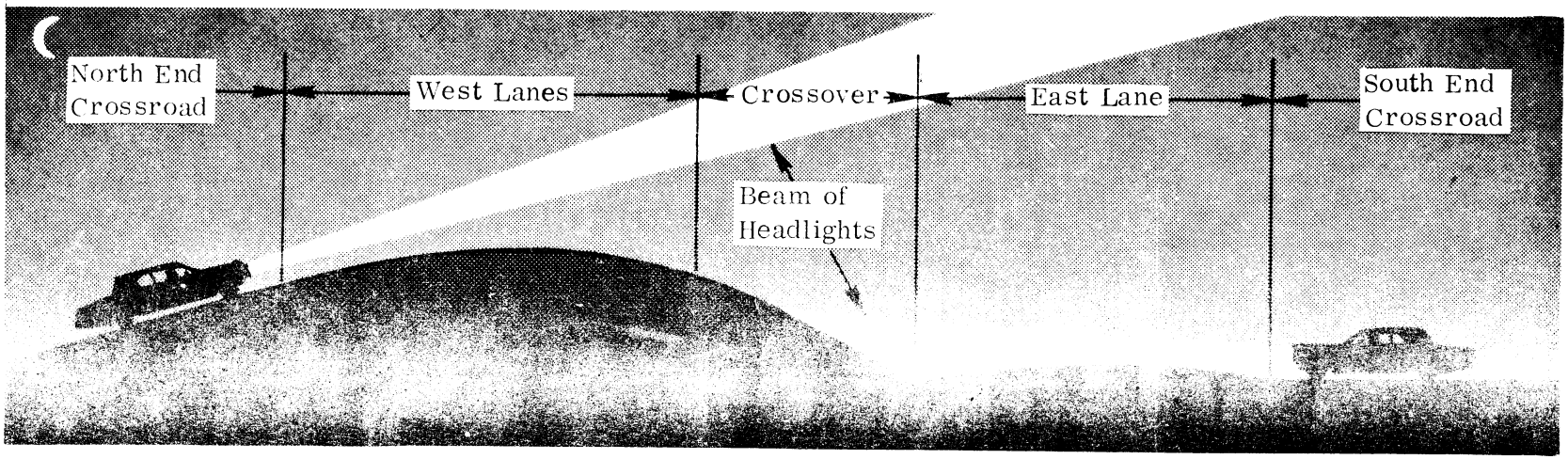

Figure 9. Intersection of a 4-lane divided highway and a crossroad at which, because of a difference in levels of the lanes, headlights do not properly illuminate the median.

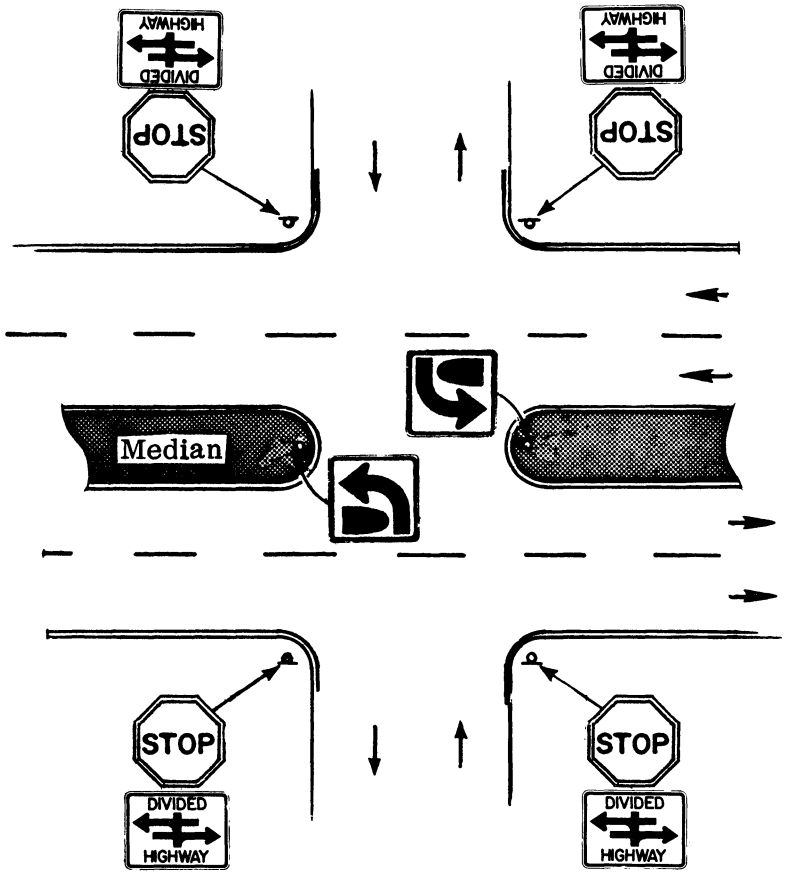

Figure 10. Recommended traffic signs for discouraging wrong-way entry.