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RESEARCH PROJECT INITIATION

Date: July 23, 1974

Project Title: **Survey of Fatal Crash Sites Where Vehicles Struck Fixed
Objects & Comparison Sites.**

Project No: **E-20-655**

Principal Investigator **Dr. Paul H. Wright**

Sponsor: **Insurance Institute for Highway Safety; Washington, D. C. 20037**

Agreement Period: From June 19, 1974 Until September 30, 1975

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Sponsor Contact Person (s):

**Dr. Leon S. Robertson
Research Department
Insurance Institute for Highway Safety
Watergate Six Hundred
Washington, D. C. 20037**

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Office of Contract Administration

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Date: March 13, 1976 *OH*

Project Title: Survey of Fatal Crash Sites Where Vehicles Struck
Fixed Objects and Comparison Sites

Project No: E-20-655

Project Director: Dr. Paul H. Wright

Sponsor: Insurance Institute for Highway Safety; Washington, D. C. 20037

Effective Termination Date: 12/31/75

Clearance of Accounting Charges: 12/31/75

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E-20-655

PRIORITIES FOR ROADSIDE HAZARD MODIFICATION:
A STUDY OF 300 FATAL ROADSIDE OBJECT CRASHES

Paul H. Wright, Ph.D.
Georgia Institute of Technology

Leon S. Robertson, Ph.D.
Insurance Institute for Highway Safety

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Abstract

Surveys of road curvature, superelevation, gradient, and number and distance from the roadway of roadside hazards were conducted at 300 sites in Georgia of fatal crashes into fixed objects and 300 comparison sites 1.6 kilometers (1 mile) away on the road that the vehicle likely had traveled. More than 26 percent of fatal crash sites had curvature greater than 6 degrees combined with downhill gradient of 2 percent or steeper in the roadway at or approaching the sites. Only 8 percent of comparison sites had such roadway characteristics. Half the fatal crashes occurred at or near curves greater than 6 degrees irrespective of gradient. Only 23 percent of comparison sites had such curvature and a state study found only 22 percent of roadway with curvature more than 5.5 degrees throughout the state. Nonlocal roads accounted for 83 percent of the fatal crashes into fixed objects but comprised only 33 percent of the roads in the state. Ninety-eight percent of the objects struck were within 15 meters (50 feet) of the pavement edge. Top priority should be given to roadside hazard modification on and near curves greater than 6 degrees, particularly those accompanied by downhill grades of 2 percent or steeper, on nonlocal roads.

PRIORITIES FOR ROADSIDE HAZARD MODIFICATION:
A STUDY OF 300 FATAL ROADSIDE OBJECT CRASHES

Most roads in the U.S. are lined with rigid structures -- trees, poles, rock cuts, guardrails often improperly installed -- that kill and maim motor vehicle occupants when their vehicles stray even a few feet (sometimes inches) from the travelled roadway.

Because of traditional inappropriate classifications of crashes, the magnitude of the problem is vastly underestimated in commonly used data sources. Most deaths in collisions with roadside hazards are placed in the nonsensical category "noncollision accidents" rather than the "fixed objects" category. In 1974 the National Safety Council estimated 13,500 deaths in "noncollision accidents" and 3600 deaths in "fixed object" crashes (1). A few states have modified their reporting categories to reflect accurately the toll from roadside object collisions. For example, in 1974 Pennsylvania reported 766 occupant fatalities in single vehicle crashes of which 689 (90 percent) resulted from collisions with fixed objects (2). Undoubtedly the vast majority of occupant fatalities in single vehicle crashes (averaging more than 17,000 per year in the U.S.) result from collisions with unyielding structures along the roadside.

The technology is readily available for removing roadside hazards or modifying them or the immediate environment to manage the energy of errant vehicles -- protecting occupants from intolerable energy transfers (3-7). However, the hazards are so numerous that immediate removal or modification of every one is unfeasible. Therefore, it is imperative that those hazards most likely to be struck be identified and given top priority in ameliorative actions. The results of the study reported here provide criteria for identifying road locations where fatalities from collisions with roadside hazards are most likely to

occur as well as the numbers and types of hazards in defined areas contiguous to the crash sites.

METHOD

The study was designed to identify roadway characteristics at sites where one or more vehicle occupants died when the vehicle struck a roadside object compared with roadway characteristics at sites one mile away that the vehicle very likely had passed prior to reaching the fatal site. Differences between the sites can be used to identify sites where such fatalities are more likely to occur, since the exposure to both the crash and comparison sites was usually equal. Comparison of characteristics of these case and comparison sites with available data on characteristics of roadways in the area studied provide additional criteria for selecting sites for modification.

Virtually all of the locations of fatal collisions into roadside objects that occurred in 108 contiguous counties in North and Central Georgia (Figure 1) during a 14 month period ending in April, 1975 were studied. This area includes a variety of land usages (rural, suburban, urban), roadway types, and topography.

Police reports of fatal crashes known to involve fixed objects or vehicles that left the roadway (including not more than 25 for which there was evidence another vehicle was or may have been involved) were routinely mailed to the research team by the Georgia State Patrol. Cases in which an object had not been struck or had not been a significant factor in the fatality were eliminated by review of the police report or in certain cases, by a visit to the crash site. Overturning cases, those not involving significant impact with an object, were excluded.

Engineering surveys were made, usually by three-person teams, at 300 fatal crash locations and at 300 comparison locations. The surveys were

confined to a 0.3 kilometer (0.2 mile) section at each of the locations. The measurements were referenced to the object which likely took the greatest impact and which was most probably responsible for the death. A point along the roadway edge immediately adjacent to the selected object was identified as the "crash site". As Figure 2 illustrates, a point one mile upstream from the crash site was designated as the "comparison site". When locating the comparison sites, choice of turns at T- or Y- intersections were made randomly (by flip of a coin).

Measurements of curvature and superelevation were made beginning 15 meters (50 feet) from the site and at 30 meter (100 foot) intervals for 137 meters (450 feet) both upstream and downstream, respectively, of the crash site and the comparison site. The gradient was measured at every 30 meters (100 feet) for 152 meters (500 feet) both upstream and downstream of the reference sites.

Simple measuring instruments that involved a minimum amount of time at the survey locations were used. A 30-meter (100-foot) cloth tape was used for measuring distances. Horizontal curvatures were measured by the middle ordinate method described by Baker (8). The curve measurements were usually taken on the edge of the roadway. The middle ordinates were converted to degrees of curvature of the centerline of the roadway. Superelevation and gradients were measured at the center of the side of the road that the driver had used when approaching the crash location. Those measurements were made with a specially designed instrument consisting of a four-foot carpenter's level with an adjusted calibrated leg. In the case of Interstate highways, curvature, superelevation and gradient data were taken from plan and profile sheets.

Inventories were taken of various types of fixed objects in 3-meter (10-foot) segments of a 9-meter (30-foot) border 161 meters (0.1 miles) in each direction from the crash and comparison sites respectively along the same side

of the road on which the vehicle crashed. In addition, type of road, number of lanes and widths of pavement and shoulder were recorded.

Data on length of curvature in a 25 percent sample of the entire Georgia public road network, comprising 41,216 kilometers (25,600 miles), were obtained from the Office of Planning, Georgia Department of Transportation. The department also provided mileages by functional class for the complete 161,325 kilometer (100,202 mile) system based on a 1972 functional classification and needs study. These data served as a basis for estimating the amounts and types of roadway in Georgia that would require hazard modification using the criteria developed from the fatal crash sites.

RESULTS

The largest difference between fatal crash and comparison sites was in road curvature. More than 80 percent of the crash locations had curvature within 152 meters (500 feet) of the fatal crash compared with 55 percent of the comparison sites with curvature within 152 meters (Figure 3). More than 50 percent of fatal crash locations had road curvature of greater than 6 degrees within 152 meters (500 feet) of the fatal crash sites but less than 24 percent of comparison locations had curvature greater than 6 degrees within 152 meters of the sites. The difference in distributions of curvature between fatal crash and comparison locations would not occur commonly from chance fluctuations in sampling ($\chi^2 = 80.1$, $df = 7$, $p < 0.001$). Curvature on the 25 percent sample of all Georgia roads was similar to the comparison group. Only 22 percent of the sample of Georgia roads had curvature greater than 5.5 degrees.

The curvature was usually found near the crash site or upstream (the direction from which the vehicle traveled). Figure 4 illustrates the percentage

of road curvature greater than 6 degrees at intervals upstream and downstream from the fatal crash and comparison sites. The largest differences occur in the area from 107 meters (350 feet) upstream to 15 meters (50 feet) downstream of the sites as the vehicle traveled. More than 69 percent of the vehicles crashing on or near curves left the outside of the curve, that is, the right side of a left bending curve or the left side of a right bending curve (Figure 5).

The results for superelevation (not shown) closely paralleled those for curvature. Cases of high curvature and low or nonexistent superelevation were uncommon -- too few to separate the two variables as factors in the identification of likely sites of fatal crashes into fixed objects.

Downhill gradient was found more often characteristic of roadways on which the vehicles approached the fatal crash sites than of roadways on which the vehicles approached the comparison sites. Figure 6 presents the average road gradients at 30 meter (100 foot) intervals within 152 meters (500 feet) of the fatal crash and comparison sites. Fatal crash sites had average decreases in gradient at each distance prior to the crash sites at which measurements were made but none of the measurements at or prior to comparison sites had average decrease in gradient. Extreme uphill gradient was observed more commonly beyond the crash sites than beyond the comparison sites suggesting that the crash sites were often near the points where downhill gradient ended and uphill gradient began. The analysis of variance in Table 1 indicates that the average differences in gradient between fatal crash and comparison sites would not have occurred commonly as a result of random fluctuation in sampling ($p < 0.05$).

Extremes in downhill gradient alone did not discriminate fatal crash and comparison sites substantially more than moderate downhill gradient. Figure 7 presents the minimum gradient observed within 152 meters (500 feet) in the

approaches to the fatal crash and comparison sites. Minimum gradient of minus two percent or less was more frequent in approaches to the fatal crash locations while greater than minus two percent gradient was more frequent in approaches to the comparison sites.

Consideration of maximum road curvature and minimum gradient simultaneously resulted in substantial discrimination of fatal fixed object and comparison locations. Figure 8 presents percent of fatal crash and comparison sites for combinations of maximum curvature and minimum gradient. Only 8 percent of comparison locations had maximum curvature greater than 6 degrees combined with minimum gradient of minus 2 percent or less while 26 percent of fatal fixed object crash sites had such a combination of curvature and gradient.

Since the fatal crash and comparison sites were on the same or similar roads, no difference in number of lanes or pavement width were expected and the average differences in these factors were not significant ($p > 0.40$ in each case). Also, there was no significant difference in width of road shoulder between fatal crash and comparison sites ($p > 0.50$).

For each crash location, the roadways were classified functionally using 10 classifications employed by the State Department of Transportation. Figure 9 shows the percent of fatal crash locations on each class of road compared to percent of all Georgia roads in each class. Only 17 percent of fatal crash sites were on local roads which make up 67 percent of the roads in the state. Thus 83 percent of the fatal crashes occur on nonlocal roads which are only one third of all roads in the state. Each type of nonlocal road had a greater percent of fatal crashes than would be expected from the percent of all roads.

Average of potential hazards near the roadside differed little between fatal crash locations and the comparison locations. Table 2 presents the average numbers or length of potential hazards within 9 meters (30 feet) of the

roadway 161 meters (0.1 mile) upstream from the fatal crash and comparison sites. Trees were somewhat more frequent, on average, at the fatal crash locations but other hazards were about equally frequent at both locations. The same result was observed within 9 meters (30 feet) of the roadway 161 meters (0.1 mile) downstream from the fatal crash and comparison sites (Table 3). On average, the fatal crash sites had about 15 narrow potential hazards and 111 meters (365 feet) of elongated potential hazards within 9 meters (30 feet) of the roadway per 161 meters (0.1 miles) adjacent to the crash sites. An average of 13 narrow objects and 104 meters (341 feet) of elongated potential hazards were in a like area adjacent to comparison sites.

About 90 percent of the objects apparently taking the brunt of the impacts were within 11 meters (35 feet) from the pavement edge (Figure 10) and 98 percent were within 15 meters (50 feet). The objects struck and the percentage of fatal crashes involving them are: trees -- 39 percent; embankments and ditches -- 23 percent; utility poles -- 14 percent; guardrail -- 7 percent; signs -- 5 percent; bridge abutments -- 3 percent; other -- 19.3 percent (including parked vehicles, brick walls, buildings, fences, bridge columns, curbs, fire hydrants, billboards, guywires, dumpsters, median barriers, and luminary poles).

Table 4 presents the average number of objects in a path 5 meters (15 feet) to each side and 27 meters (90 feet) beyond the fatal crash site in the direction the vehicle traveled. On average, five to six narrow potential hazards and 15 feet of elongated potential hazards were found in this area.

DISCUSSION

The results of this study suggest a clear set of priorities for removing roadside hazards or modifying them or the roadway to manage the energy of errant vehicles to protect vehicle occupants. Road locations with curvature

greater than 6 degrees and negative (downhill) gradient of two percent or steeper in or prior to the curves should be modified first. More than 26 percent of the fatal crash locations fell within these criteria compared to only eight percent of comparison locations. That task completed, the remainder of road locations with curvature greater than six degrees should then be modified. More than 50 percent of fatal crash locations had such curvature compared to less than 24 percent of the comparison locations. Following these in priority are locations with more than three degrees curvature combined with less than two percent gradient and, then, the remainder of locations with more than three degrees curvature.

The most probable locations of fatal crashes can be further narrowed by concentrating on nonlocal roads. Although the available state road data did not allow degree of curvature and gradient to be assessed by type of roadway, it was clear that fatal crashes into roadside objects occurred mostly on nonlocal roads. The obvious approach to roadside hazard amelioration is to identify the types of roads in a given state that have a history of "noncollision" and fixed object fatalities and to apply the noted curvature and gradient criteria to identify the most likely sites along those roads. Although the number and types of hazards on a particular road in a particular area may differ because of climate, land use and other factors, the involvement of curves and gradient in likelihood of impacting hazards is undoubtedly similar in all areas.

A number of researchers have attempted to relate road characteristics to crashes with some success (9-13). However, a clear set of factors that can be used to identify likely locations of crashes into roadside hazards has not emerged prior to the present study. Prior studies have included nonhomogeneous sets of crashes, have failed to distinguish severity of injury, and/or have

used arbitrarily defined road segments. Studying only fatal crashes into fixed objects, and referencing the roadway characteristics to specific crash sites resulted in a clear profile of hazardous locations in the present study.

The modifications at a particular location depend on a number of factors: number and types of hazards, width of right-of-way, cooperation of utility companies and others who erect and maintain objects on or off the right-of-way, and costs of alternative means of modification. In some cases it may be possible to reduce or eliminate curvature and gradient while at the same time removing or modifying hazards. In other cases only removal or modification of the hazards may be feasible.

Attention must also be given to characteristics of the location that might contribute to vehicle rollover in the absence of fixed objects. Ditches, culverts, curbs, or embankments that might contribute to rollover must be modified as well as fixed objects. If fixed objects are removed or modified but roadside characteristics contributing to rollover remain, a subset of the fatalities will continue to occur. In every case, the goal should be a clear recovery area for vehicles that leave the road or, if objects can not be entirely cleared, application of energy management principles that eliminate the lethal transfer of crash forces to vehicle occupants (3-7).

The data also provide guidelines for the types of fixed objects and other roadside characteristics that can be expected, on average, and their distribution at the locations to be modified. Most of the fatal crashes occurred in curves or a few hundred meters beyond the maximum curvature. Apparently control of the vehicle is usually lost in or coming out of curves rather than in anticipation of difficulty with a curve. The vast majority of the fatalities in the crashes studied would not have occurred had a 15 meter (50 foot) roadside area 137 meters (450 feet) before and after the maximum

curvature been clear of fixed objects and characteristics contributing to rollover. Ninety-eight percent of the objects struck were within 15 meters (50 feet) of the pavement.

On average, a 161 meter (0.1 mile) long, 9 meter (30 foot) wide roadside area at the fatal crash locations had 9 trees, 1 utility pole, 1 traffic sign or signal post, and 5 other such relatively narrow objects. Relatively elongated objects, potentially hazardous, averaged in feet, included guard rail -- 24, curbs -- 39, embankments -- 115, banks and cuts -- 63, ditches -- 117, median barriers -- 4. Some of these, such as guard rails and median barriers, may be protective or hazardous depending on their designed ability to gently absorb or redirect the energy of a moving vehicle as well as their proper construction and installation (3-7).

Since almost 70 percent of the fatal crashes that occurred on or near curves were on the outside of the curves, that side of the road should take precedence in ameliorative efforts when resources do not allow such efforts on both sides of the road at every available site. It is not known how often running off the inside of curves occurred to avoid objects on the outside of curves. Eventually both sides of the road must be modified for maximum benefit.

Relatively few objects were found in a 9 by 27 meter (30 by 90 foot) path that the vehicles would likely have traveled had they not struck the lethal object. The potential for relatively large reductions in human damage by relatively small efforts in modifying roadside hazards is clear. Failure to act promptly in ameliorative efforts could provide grounds for legal liability (14).

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TABLES

1. ANALYSIS OF VARIANCE OF GRADIENT \pm 152 METERS (500 FEET) OF FATAL FIXED OBJECT AND COMPARISON SITES
2. AVERAGE NUMBER OF NARROW POTENTIAL HAZARDS AND METERS⁺ OF ELONGATED POTENTIAL HAZARDS AT FATAL FIXED OBJECT AND COMPARISON SITES 9 METERS OFF THE PAVEMENT AND 161 METERS IN THE DIRECTION FROM WHICH THE VEHICLE TRAVELED
3. AVERAGE NUMBER OF NARROW POTENTIAL HAZARDS AND METERS⁺ OF ELONGATED POTENTIAL HAZARDS AT FATAL FIXED OBJECT AND COMPARISON SITES 9 METERS OFF THE PAVEMENT AND 161 METERS BEYOND THE SITES IN THE DIRECTION THE VEHICLE WAS TRAVELING
4. AVERAGE NUMBER OF OBJECTS 4.6 METERS⁺ TO EACH SIDE AND 27 METERS BEYOND THE CRASH SITE IN THE DIRECTION OF THE FATAL VEHICLES MOVEMENT

TABLE 1. ANALYSIS OF VARIANCE OF GRADIENT \pm 152 METERS
(500 FEET) OF FATAL FIXED OBJECT AND COMPARISON SITES

Source of Variation	Degrees of Freedom	Mean Squares	Variance Ratio, F	Significance
Fatal - Comparison Differences	1	40.873	4.905	p < 0.05
Differences Among Measuring Points	20	11.294	1.355	
Residual	6.490	8.333		

TABLE 2. AVERAGE NUMBER OF NARROW POTENTIAL HAZARDS AND METERS⁺ OF ELONGATED POTENTIAL HAZARDS AT FATAL FIXED OBJECT AND COMPARISON SITES 9 METERS OFF THE PAVEMENT AND 161 METERS IN THE DIRECTION FROM WHICH THE VEHICLE TRAVELED

Meters from Pavement	Fatal Sites				Comparison Sites			
	0-3	3-6	6-9	Total	0-3	3-6	6-9	Total
<u>Narrow Potential Hazards (Number)</u>								
Trees	0.7	2.7	3.9	7.3*	0.7	1.8	3.0	5.5
Utility Poles	0.6	0.4	0.3	1.3	0.6	0.5	0.3	1.4
Traffic/Signal Posts	0.7	0.2	0.1	1.0	0.6	0.2	0.1	0.9
Street Luminary Poles	0.1	**	**	0.1	**	**	**	0.1
Other Narrow Objects	1.3	2.0	1.7	5.0	1.6	2.0	1.0	4.6
Total	3.3	5.3	6.0	14.7*	3.5	4.5	4.4	12.5
<u>Elongated Potential Hazards (In Meters)</u>								
Guard Rail	3.3	3.4	0.5	7.2	3.2	1.2	**	4.4
Curbs	9.7	1.7	0.5	11.9	11.2	1.6	0.1	12.9
Embankments	11.1	19.1	4.8	35.0	8.6	16.6	3.8	29.0
Banks - Cuts	4.5	9.9	4.7	19.1	4.7	9.5	4.2	18.4
Ditches	13.1	18.1	4.4	35.6	14.9	13.4	3.0	31.3
Median Barriers	0.5	0.7	0.0	1.2	1.2	0.1	**	1.3
Total	42.2	53.0	14.9	110.1	43.8	42.4	11.1	97.3

+ 1 meter = 3.28 feet

* Significantly different ($p < 0.05$, two-tailed) from comparison sites

** < 0.05 but not 0.00

TABLE 3. AVERAGE NUMBER OF NARROW POTENTIAL HAZARDS AND METERS⁺ OF ELONGATED POTENTIAL HAZARDS AT FATAL FIXED OBJECT AND COMPARISON SITES 9 METERS OFF THE PAVEMENT AND 161 METERS BEYOND THE SITES IN THE DIRECTION THE VEHICLE WAS TRAVELING

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Meters from Pavement	Fatal Sites				Comparison Sites			
	0-3	3-6	6-9	Total	0-3	3-6	6-9	Total
<u>Narrow Potential Hazards (Number)</u>								
Trees	1.0	3.1	4.9*	9.0*	0.5	2.8	3.4	6.7
Utility Poles	0.6	0.4	0.2	1.2	0.8	0.4	0.2	1.4
Traffic Sign/Signal Posts	0.6	0.2	0.1	0.9	0.7	0.2	**	0.9
Street Light Poles	**	**	**	**	**	**	**	0.1
Other Narrow Objects	1.4	1.7	1.5	4.6	1.8	1.2	1.1	4.1
Total	3.6	5.4	6.7	15.7	3.8	4.6	4.7	13.2
<u>Elongated Potential Hazards (In Meters)</u>								
Guard Rail	4.9	3.0	**	7.9	2.4	3.0	**	4.4
Curbs	9.8	1.9	0.1	11.8	11.7	2.4	0.3	14.4
Embankments	9.7	18.7	5.2	33.6	8.3	20.7	4.3	33.3
Banks - Cuts	5.0	11.9	5.9	22.8	5.7	12.6	3.6	21.9
Ditches	15.8	15.6	3.7	35.1	12.6	18.3	4.7	35.6
Median Barriers	0.5	**	0.5	1.0	0.9	0.1	0.1	1.1
Total	45.7	51.1	15.5	112.3	41.5	57.1	13.0	110.7

+ 1 meter = 3.28 feet

* Significantly different ($p < 0.05$, two-tailed) from comparison sites

** < 0.05 but not 0.00

Wright

TABLE 4. AVERAGE NUMBER OF OBJECTS 4.6 METERS⁺ TO EACH SIDE AND 27 METERS BEYOND THE CRASH SITE IN THE DIRECTION OF THE FATAL VEHICLES MOVEMENT

	Vehicle Path Beyond the Fatal Site (Meters)			
	0-9	9-18	18-27	Total
<u>Narrow Potential Hazards (Number)</u>				
Trees	1.2	1.3	1.4	3.9
Utility Poles	0.1	**	0.1	0.1*
Traffic Sign/Signal Posts	0.1	**	**	0.1
Street Luminary Poles	0.0	**	0.0	**
Other	0.6	0.5	0.3	1.4
Total	2.0	1.8	1.8	5.5
<u>Elongated Potential Hazards (Meters)</u>				
Guard Rails	0.5	0.2	0.2	0.9
Curbs	0.2	0.1	0.1	0.4
Embankments	0.6	0.3	0.4	1.3
Banks - Cuts	0.3	0.4	0.4	1.1
Ditches	0.5	0.4	0.2	1.1
Median Barriers	0.0	0.0	0.0	0.0
Total	2.1	1.4	1.3	4.8

+ 1 meter = 3.28 feet

* Total not equal to sum because of rounding

** < 0.05 but not 0.00

FIGURES

1. AREA STUDIED (SHADED)
2. HYPOTHETICAL FATAL CRASH AND COMPARISON SITES
3. MAXIMUM ROADWAY CURVATURE UP TO 152 METERS FROM FATAL FIXED OBJECT CRASH AND COMPARISON SITES
4. PERCENT OF ROAD CURVATURE > 6 DEGREES UP TO 152 METERS FROM FATAL FIXED OBJECT AND COMPARISON SITES
5. PERCENT OF FATAL CRASHES INTO ROADSIDE OBJECTS BY TYPE OF CURVATURE
6. AVERAGE GRADIENT OF ROADWAY UP TO 152 METERS FROM FATAL FIXED OBJECT CRASH AND COMPARISON SITES
7. MINIMUM GRADE 152 METERS UPSTREAM FROM FATAL FIXED OBJECT CRASH AND COMPARISON SITES
8. PERCENT OF FATAL CRASH AND COMPARISON SITES WITH COMBINATIONS OF MAXIMUM CURVATURE AND MINIMUM GRADIENT
9. PERCENT OF FATAL FIXED OBJECT CRASH LOCATIONS AND ENTIRE GEORGIA ROADWAY BY FUNCTIONAL CLASSIFICATION OF ROADWAYS
10. DISTANCE FROM ROADSIDE OF OBJECTS IN FATAL CRASHES

FIGURE 1.
AREA STUDIED (SHADED)

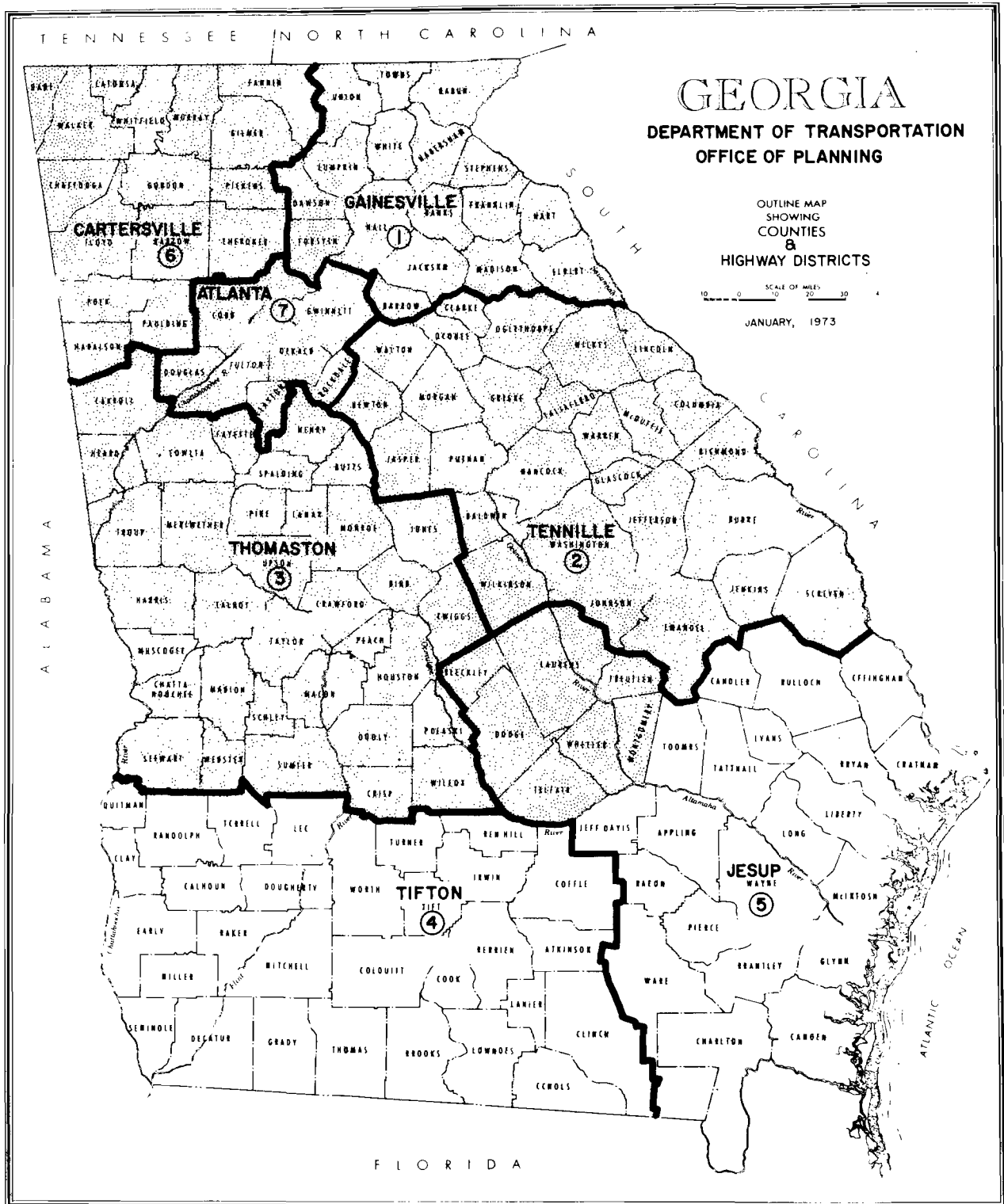
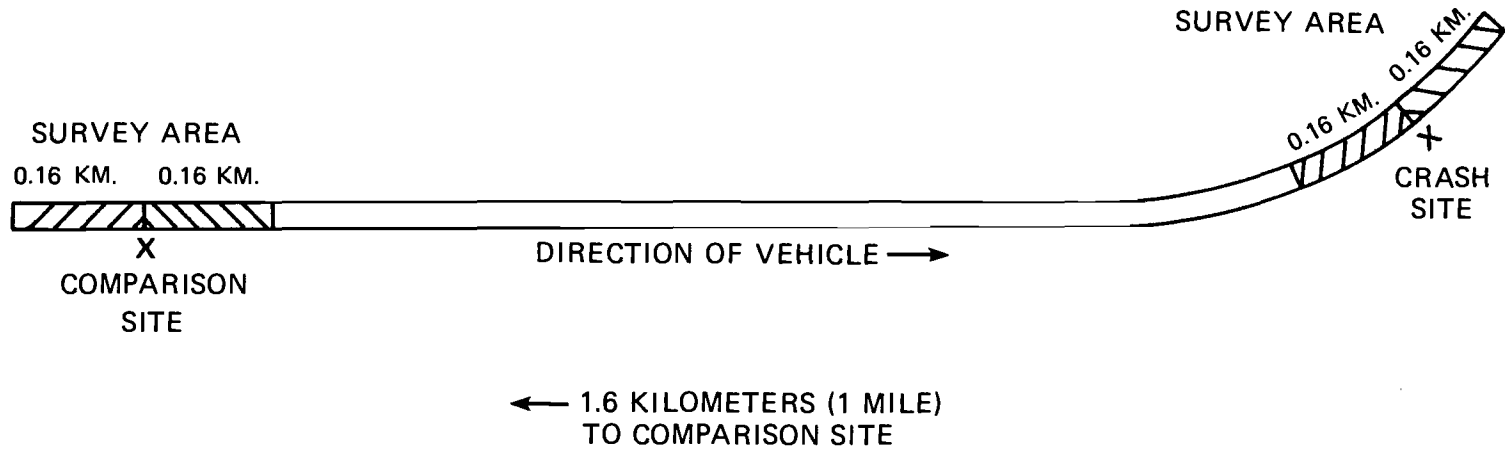
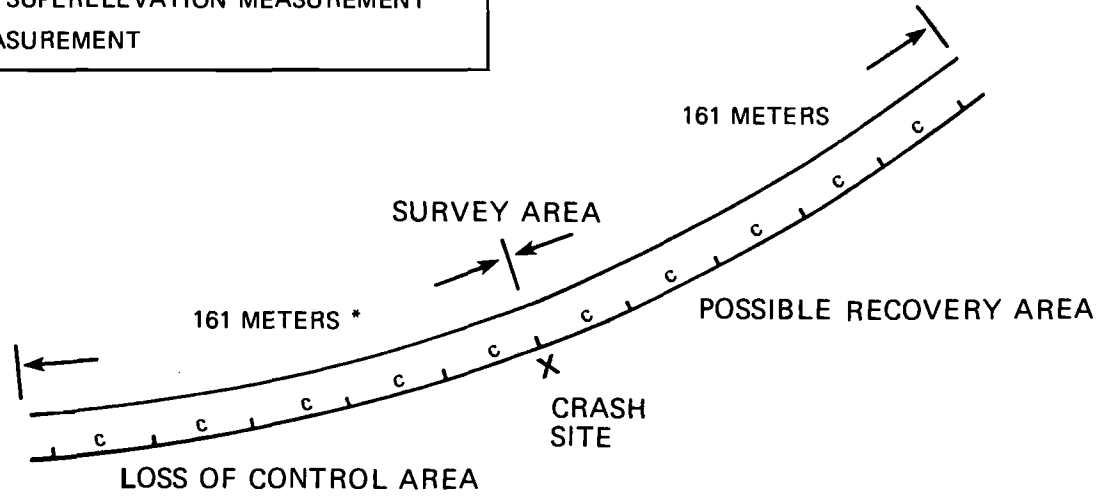


FIGURE 2
HYPOTHETICAL FATAL CRASH AND COMPARISON SITES



c DENOTES CURVATURE & SUPERELEVATION MEASUREMENT
| DENOTES GRADIENT MEASUREMENT



* 1 METER = 3.28 FEET

FIGURE 3.
MAXIMUM ROADWAY CURVATURE UP TO 152 METERS FROM FATAL
FIXED OBJECT CRASH AND COMPARISON SITES

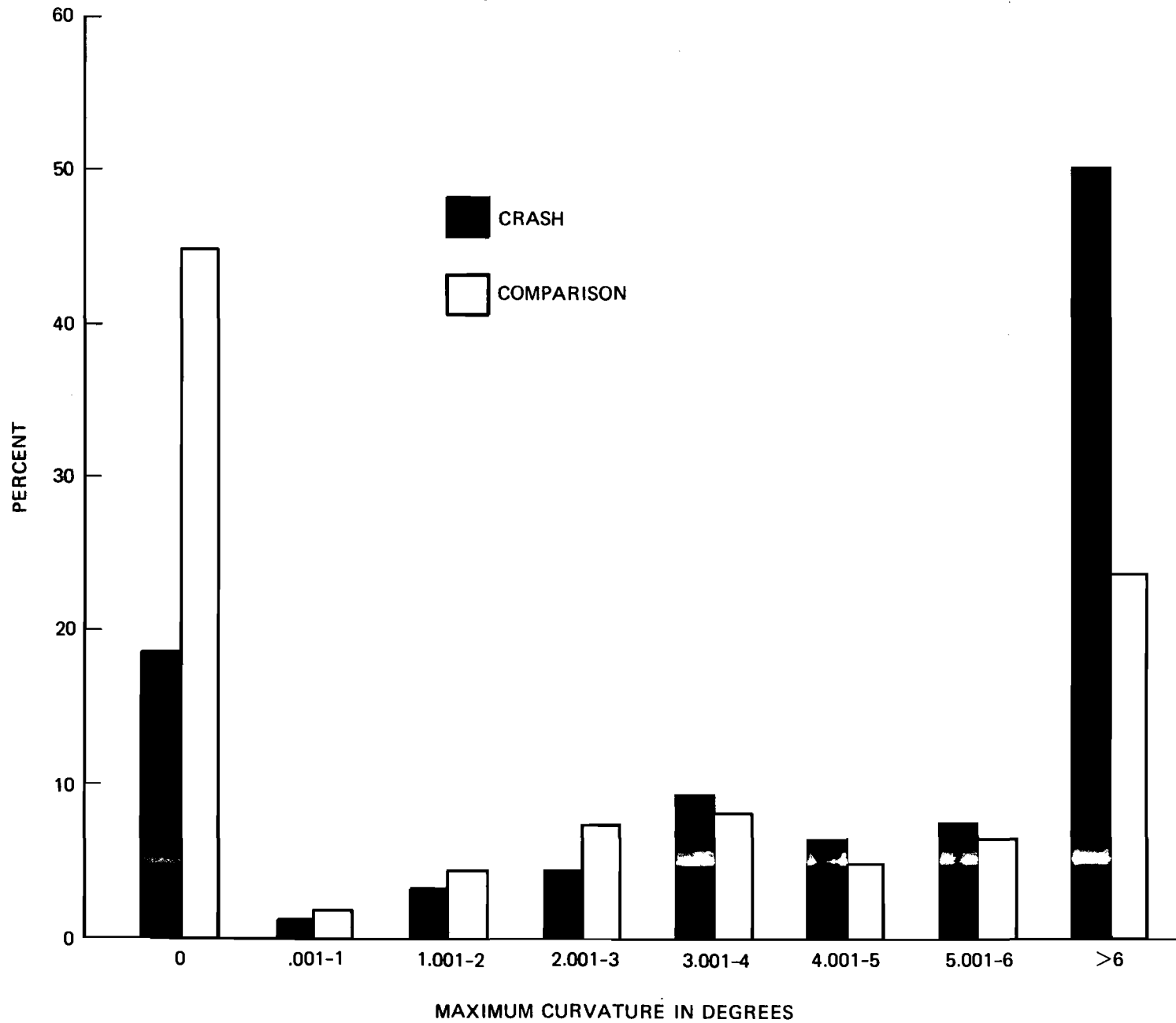


FIGURE 4
PERCENT OF ROAD CURVATURE >6 DEGREES UP TO 152 METERS FROM
FATAL FIXED OBJECT AND COMPARISON SITES

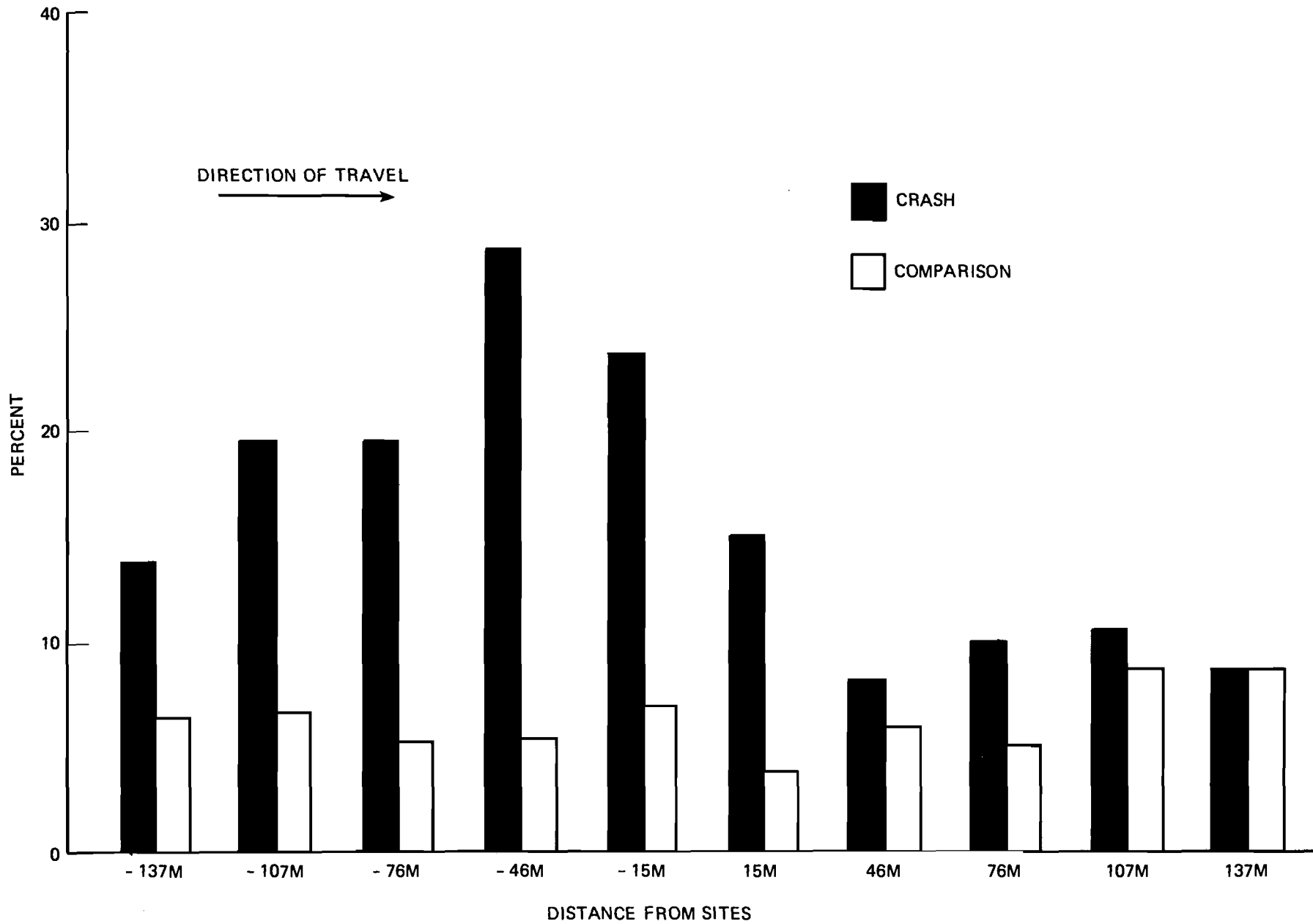
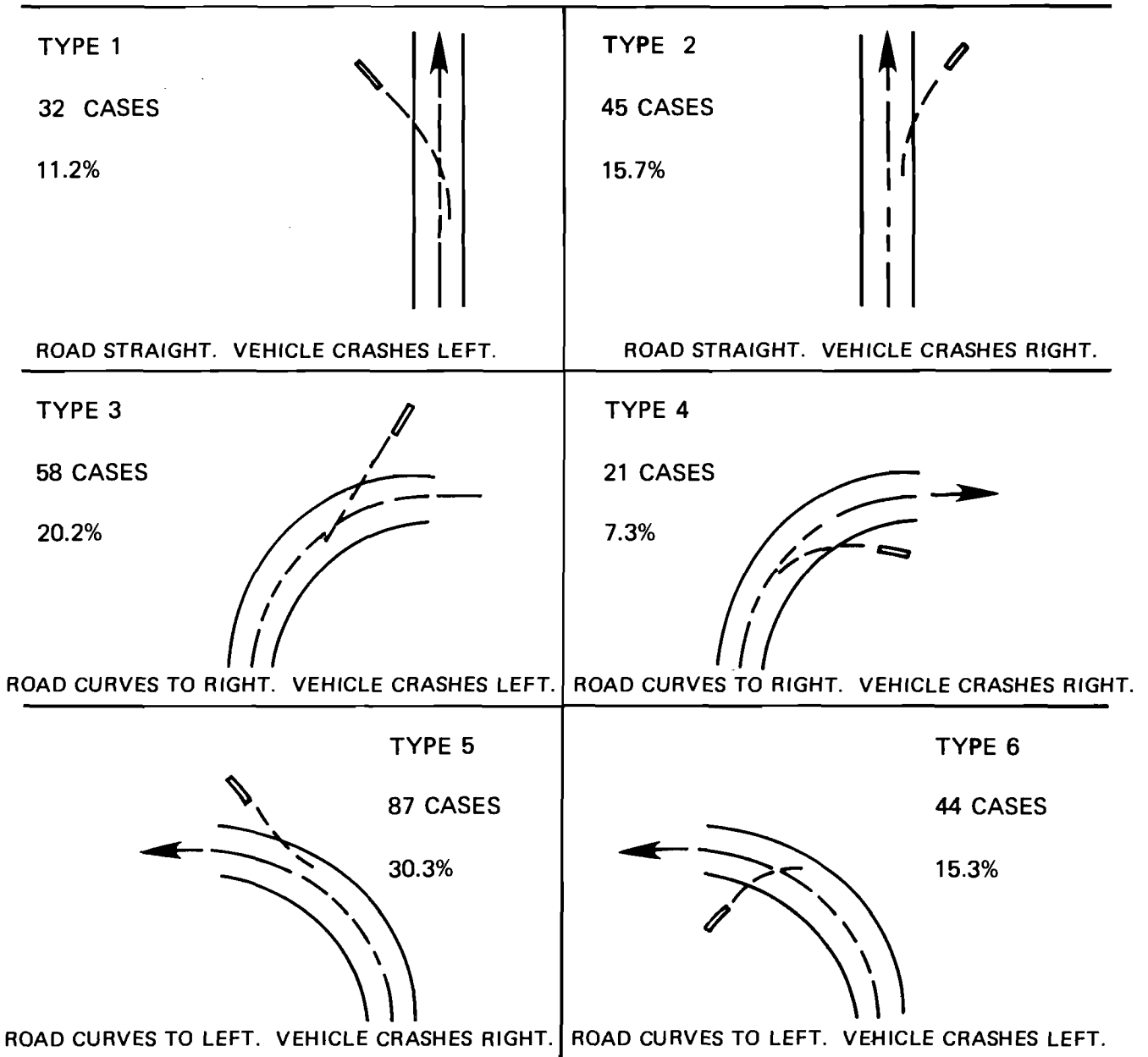


FIGURE 5

PERCENT OF FATAL CRASHES INTO ROADSIDE OBJECTS
BY TYPE OF CURVATURE



* EXCLUDES 13 CASES WHERE CURVES HAD MORE THAN 1 TYPE OF BEND
OR INFORMATION WAS MISSING

FIGURE 6
AVERAGE GRADIENT OF ROADWAY UP TO 152 METERS FROM FATAL
FIXED OBJECT CRASH AND COMPARISON SITES

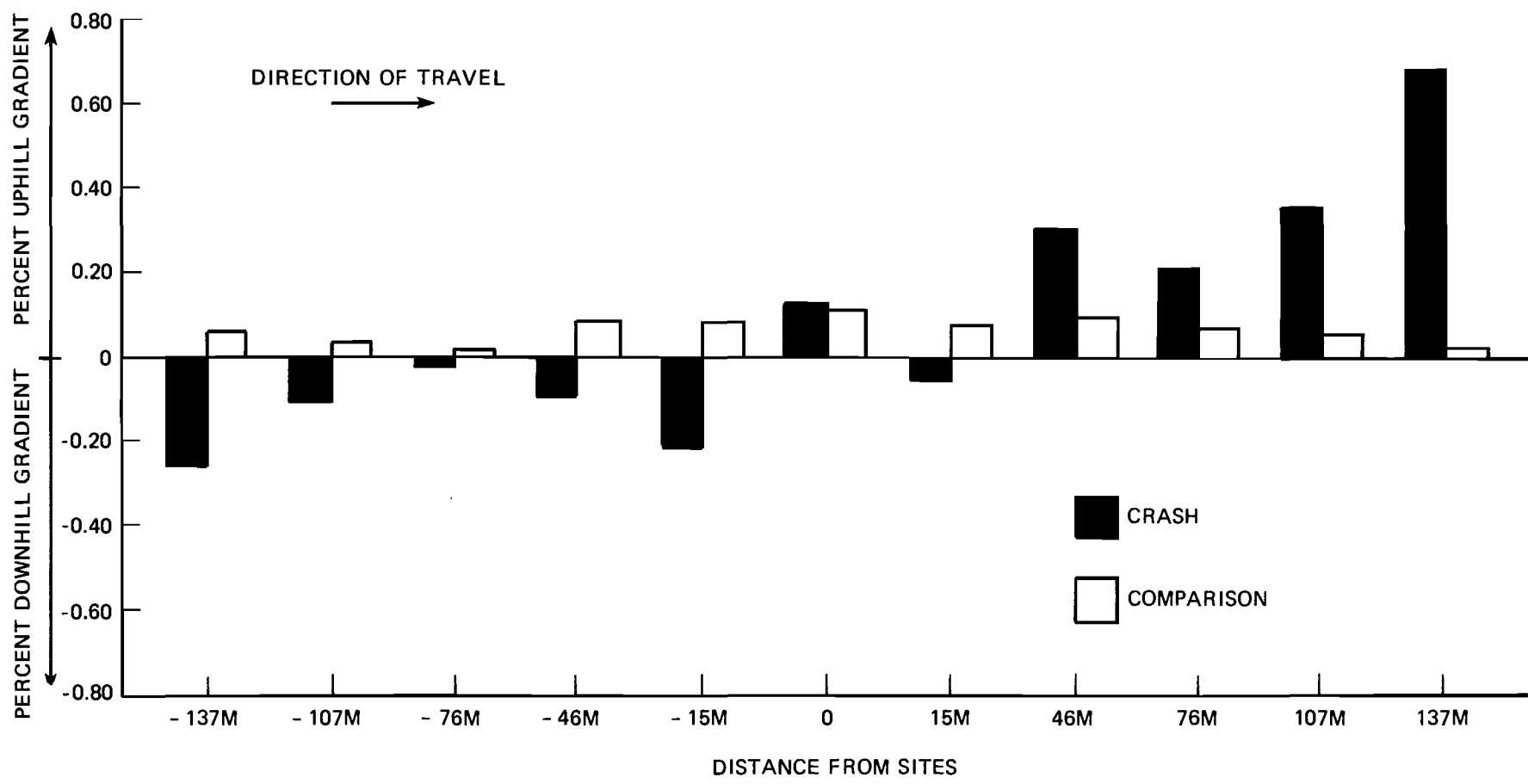


FIGURE 7.
MINIMUM GRADE 152 METERS UPSTREAM FROM FATAL
FIXED OBJECT CRASH AND COMPARISON SITES

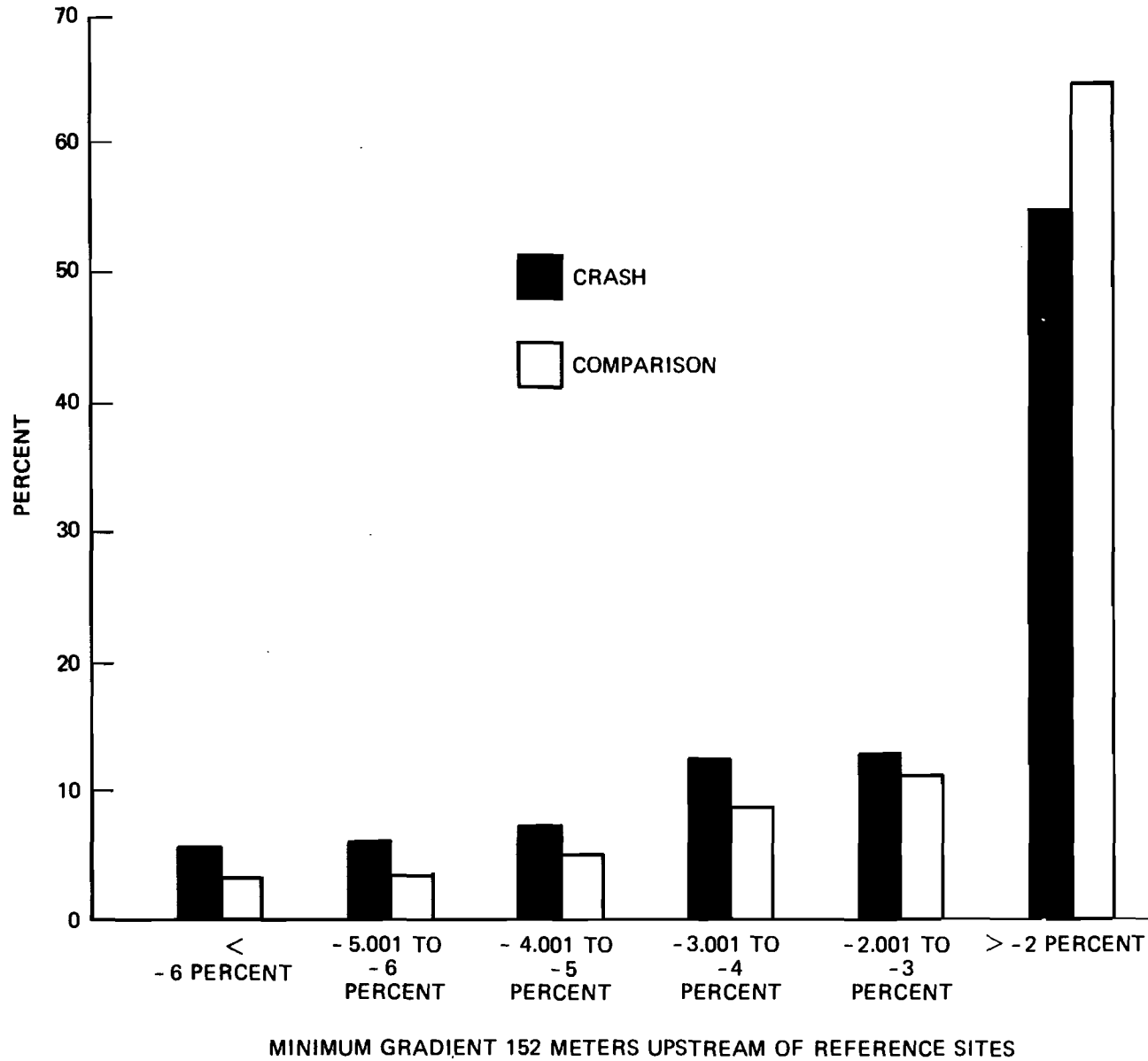


FIGURE 8.
PERCENT OF FATAL CRASH AND COMPARISON SITES WITH COMBINATIONS
OF MAXIMUM CURVATURE AND MINIMUM GRADIENT

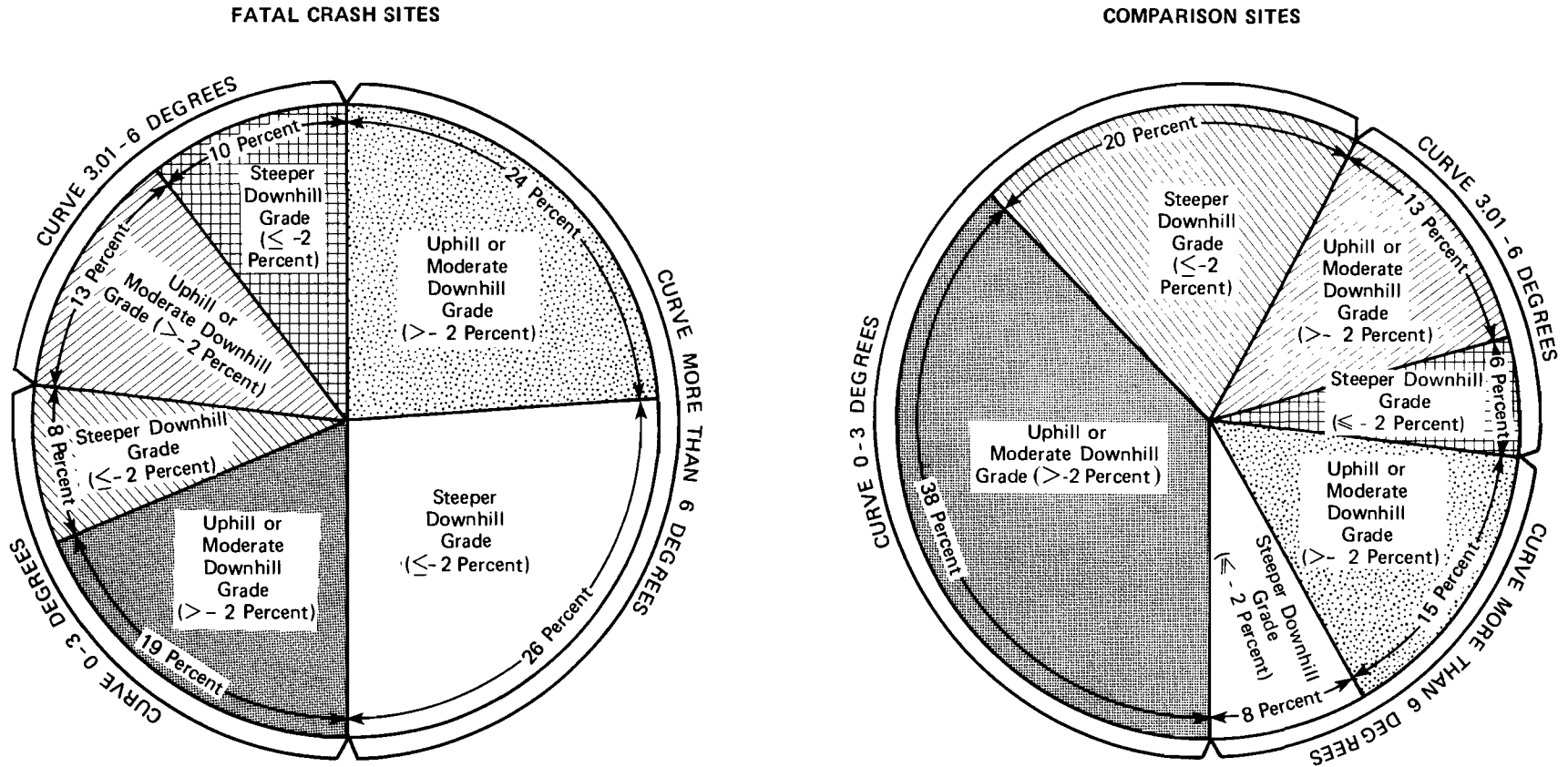


FIGURE 9.
PERCENT OF FATAL FIXED OBJECT CRASH LOCATIONS AND ENTIRE GEORGIA ROADWAY
BY FUNCTIONAL CLASSIFICATION OF ROADWAYS

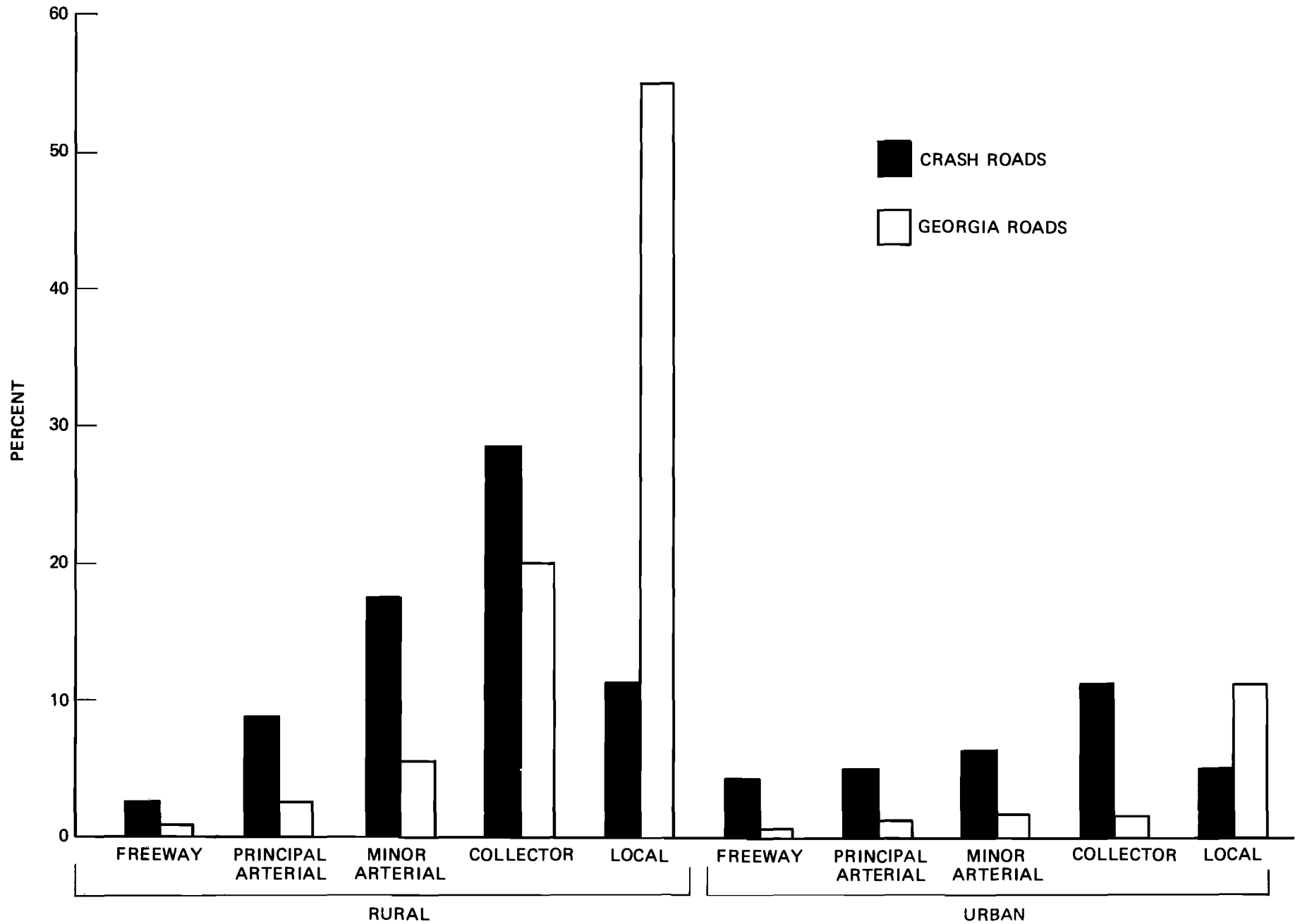


FIGURE 10
DISTANCE FROM ROADSIDE OF OBJECTS IN FATAL CRASHES

