Traffic Control for Low-Volume Rural Roads in Kansas

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Low-volume rural (LVR) roads—those that carry 400 vehicles/day or less—carry only about 8 percent of the total U.S. travel, yet they make up about two-thirds of the mileage of public highways. Because they are the largest single class of highway, it is very important that guidelines be adopted for traffic control and operational safety in order to achieve a rational balance between maximum safety and minimum cost for LVR roads. The national traffic-control guide, the Manual on Uniform Traffic Control Devices (MUTCD), contains basic guidelines on traffic-control devices (i.e., signs, signals, and markings). The MUTCD is directed mainly at the traffic-control needs of primary (higher-volume) highways rather than the traffic-control needs on LVR roads. In order to better meet the safety and guidance needs of drivers on LVR roads in Kansas, the Kansas Department of Transportation, in cooperation with Kansas State University, has developed a Handbook of Traffic Control Practices for Low-Volume Rural Roads. The suggested traffic-control practices should aid local government units in providing a roadway system in which a reasonably prudent driver, even a stranger to the area, will be able to travel safely on the roads. The consistent use of the suggested practices should result in more consistent traffic signing (and thus safer roads) with reduced liability for local governments, a reduced amount of signing, and lower traffic signing costs.

County and township roads that carry less than 400 vehicles/day are classified as low-volume rural (LVR) roads and make up a high percentage of the total rural road mileage. It has been estimated that LVR roads make up about two-thirds of the rural road mileage, but they carry only about 8 percent of the travel (1). The many miles of these LVR roads present counties and townships with very serious problems, most of which are financial (i.e., how to provide construction and maintenance dollars to improve existing roads or simply maintain them at their current condition, replace or upgrade substandard bridges, and install or maintain necessary traffic signs or pavement markings). The problem is to provide, at a reasonable cost, a roadway system on which a reasonably prudent driver, even a stranger to the area, will be able to travel safely.

In order to operate safely on LVR roads, local government officials need assistance in providing traffic control and guidance for persons who drive on LVR roads. The nationally recognized Manual on Uniform Traffic Control Devices (MUTCD) (2) serves as a general guide for traffic control on all types of roads and streets. The MUTCD is directed mainly at the traffic-control needs of higher-volume highways and does not specifically address many of the operational and guidance problems associated with LVR roads.

In recognition of the needs of county engineers, road supervisors, and other local government officials charged with safe operation of LVR roads in Kansas, the Kansas Department of Transportation (KDOT), in cooperation with the Civil Engineering Department of Kansas State University, recently developed the Handbook of Traffic Control Practices for Low-Volume Rural Roads (3) (hereafter referred to as the LVR handbook). The LVR handbook is intended to serve as a supplement to or interpretation of the MUTCD as applied to LVR roads in Kansas. It should be noted that material in the LVR handbook does not violate or run contrary to the MUTCD. For example, the shape, color, design, and requirements of traffic-control devices discussed in the LVR handbook are strictly in accordance with the MUTCD. The meanings of the terms "shall", "should", and "may" are the same for the MUTCD and the LVR handbook:

1. Shall: This is a mandatory condition. Where certain requirements in the design or application of the device are described with the "shall" stipulation, it is mandatory when an installation is made that these requirements be met.
2. Should: This is an advisory condition. Where the word "should" is used, it is considered to be advisable use, recommended but not mandatory. Documentation of the reasons for nonuse might be wise.
3. May: This is a permissive condition. No requirement for design or application is intended.

The LVR handbook, for the most part, provides guidelines for use of regulatory and warning signs with a few applications of pavement markings. It also contains material regarding a suggested traffic sign maintenance check and inventory, setting up a citizens' traffic safety complaint system, tort liability in Kansas, and other selected state statutes.

The remainder of this paper relates to selected topics from the LVR handbook.

PRINCIPLES

There are some basic principles closely related to good operating practices. Three such principles are driver expectancy, positive guidance, and consistency.

Driver Expectancy

Drivers, and people in general, expect things to operate in certain ways. When entering a dark room, a person will expect to find an on-off toggle switch for the lights. One also expects the switch to operate up for on and down for off. When it works the other way around, or when there is a rheostat knob, it takes a bit longer to respond to what is actually there. The same situation occurs with drivers. When a driver's expectancy is incorrect, either it takes longer to respond properly or, even worse, the driver may respond poorly or wrongly (4). If, for example, a curve sign shows a curve to the right but the road actually curves left, one can imagine the difficulty the driver has in properly negotiating the curve, especially a stranger to the area at night. This may seem to be an extreme example; however, this has been observed rather frequently with the "winding road sign", in which the bottom or beginning curve points in the wrong direction.

What the driver expects on a road is greatly influenced by what was experienced on the previous section of road. Studies have shown that what a driver saw--presence or absence of traffic-control devices, road surface type, condition and width, narrow bridges or culverts, etc. (this might be called the roadway environment)--is what the driver expects for the next 0.5-1 mile.

Driver expectancy is affected not only by the very recent experiences but also by those things drivers have learned through past experiences (e.g., advance railroad-crossing signs are at all railroad grade crossings, stop signs are red, curve warning signs are yellow and diamond shaped, etc.). It follows that consistent use and placement of traffic-control devices can do a great deal toward assuring that the driver's expectancy is correct.

Driver expectancies are also affected by the type of road, such as an Interstate highway, a state

Figure 1. After tapering road.

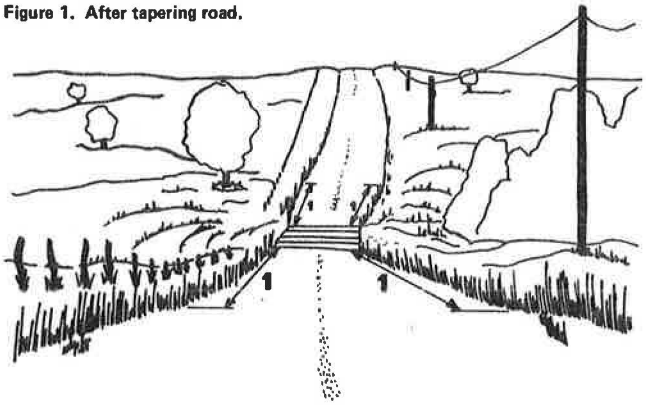


Figure 2. Before tapering road.

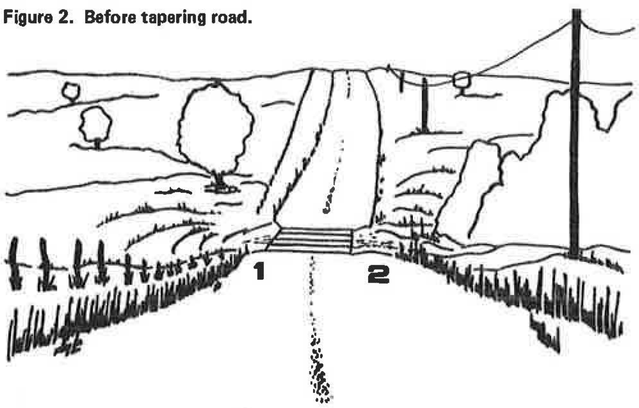
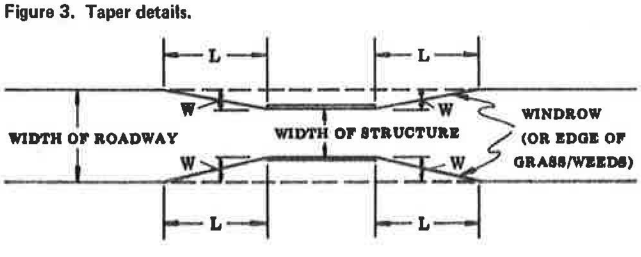


Figure 3. Taper details.



highway, or a county or township road. The driver expects to drive each of these with different levels of caution.

Positive Guidance

Positive guidance (5) is the concept that a driver can be given sufficient information where he or she needs it and in a form that can best be used to avoid a hazard safely. Positive guidance can be given the driver through conbinations of signs, hazard markers, safe speed advisory signs, and, probably most important of all, the view of the road ahead. If drivers could see the curves far enough ahead to judge their sharpness and adjust to a safe speed, or see the approaching cars on crossroads because the intersections were clear of sight obstructions, or if there were no intersections hidden by the crest of a hill, or if all narrow bridges and culverts were visible to drivers from both directions, there would be little need for anything more than an occasional stop or yield sign to assign the right-of-way at the intersection of LVR roads with higher-volume roads. The condition just described might be called roadway positive guidance. Studies have shown that the edge of the roadway ahead is among the most important pieces of guidance information the driver uses. The use of the edge of roadway in this manner provides an easy and effective way of providing positive guidance at narrow bridges and culverts or other roadside hazards or obstacles.

The following condition is an example of positive guidance. Tapering is a simple technique in which the traveled way (maintained part of the road) is gradually narrowed (tapered) some distance ahead of, say, a narrow culvert. The driver simply follows, as usual, the edge of roadway and thus is guided away from the roadside obstacle (see Figure 1). (Note, 1 shows the tapered sections; i.e., the roadway edge leads to culvert ends.) If tapering is not used, the driver may not see the end of the short culvert, and if the driver continues to follow the edge of roadway (faulty guidance), he or she may drop a wheel off the end of the culvert. This is illustrated in Figure 2. (Note, 1 depicts where the roadway is wider than the culvert, and 2 shows how the roadway edge leads the driver into the culvert ditch instead of onto the culvert.) Details of the tapering technique are shown in Figure 3 and in the table below (2, Figures 3-10) (note, Figure 3 shows explanation of W):

	Minimum Taper Lengths (ft) at Following Prevailing Speeds		
W (ft)	<30 mph	30-40 mph	>40 mph
<2	30	50	100
3	45	75	150
4	60	100	200
5	75	125	250
6	90	150	300

Consistency

Consistency relates to the sameness of the nature of the road from one section to another. Inconsistencies are sudden changes in the nature of the road. Inconsistencies violate a driver's expectancy; thus, either the road should be made consistent, which is usually impractical, or something should be done to make the driver's expectancy correct, i.e., restructure the driver's expectancy. In the case of a hidden curve in a nearly straight roadway, the use of a curve warning sign with, perhaps, an advisory speed plate will correctly restructure the driver's expectancy. After seeing the curve sign, the driver expects the curve, knows whether the road curves left or right, and knows the speed at which the curve can be comfortably and safely driven.

Other examples of inconsistencies are as follows:

1. A two-lane road suddenly narrowing to a one-lane road,
2. A blacktop road changing to a gravel road,
3. A bridge narrower than the approaching roadway, and
4. A blind intersection in an area where most intersections have clear sight distances.

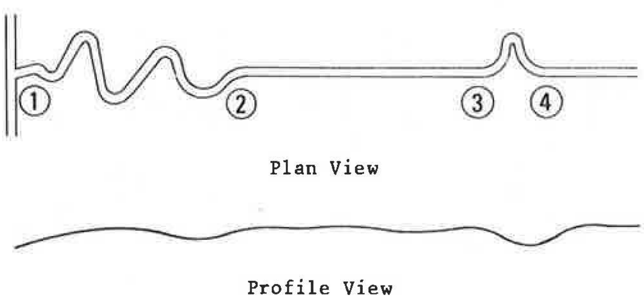
Whether or not a situation is an inconsistency may depend on the direction in which the driver is traveling. The driver, traveling from 1 to 4 in Figure 4, finds the first part of the road, 1 to 2, very consistent, i.e., there is hardly time to pick up speed before seeing or being on another curve. After passing 2, the road is straight for as much as a mile, and the driver now expects the road to continue straight, and what is seen confirms this expectancy as the road appears to continue straight from 3 to 4. The driver may think that it is "just a little dip", but then what a surprise to have to suddenly handle three 30-mph curves. Obviously, some expectancy restructuring is in order, and signing is likely the best way to do it. For the driver traveling from 1 to 4, no signs are needed at 1 or from 1 to 2, since the alignment is consistent. A curve warning sign prior to 3 (probably with a speed advisory plate) will be sufficient to give the driver enough information to handle the situation, i.e., we have satisfactorily changed the driver's expectancy so "what he expects is what he gets." Now, consider the driver traveling from 4 to 1. Likely, the driver will need an advance curve warning sign and a speed plate placed prior to 4. From 3 to 2, an advance winding road sign is likely needed for the driver to know what to expect. One must drive the roads to identify the inconsistencies.

A, B, and C Roads

As noted earlier, the driver's expectancy is influenced by the type of road being traveled and how the driver perceives the road. Traditionally, highways have been classified by administrative jurisdiction (such as state, county, or township) by volume and, most frequently, according to function such as arterials, collectors, or local service. It is impossible for a driver to perceive the administrative classification of roads without state, county, or township route markers. It is difficult, if not impossible, for the driver to judge the function of the road or its volume without special training. What the driver does observe are the physical roadway characteristics such as width and kind of surface, riding quality, road surface drainage, presence or absence of traffic-control devices, hills, and sharp curves. The road classifications--type A, B, and C--that are used in the LVR handbook are based on roadway characteristics that drivers readily perceive, and these characteristics in turn influence the driver's expectancies.

The physical characteristics of each type of road are summarized in Table 1. On entering a road, all the physical characteristics, except operating speed and drainage, are almost immediately seen by the driver. After driving a short distance, width of road, type of surface, and riding quality will suggest an appropriate safe speed to a reasonably prudent driver. All it takes is a little rain for the effects of the well-drained versus a poorly drained road to become apparent to the driver. Figures 5 through 8 show examples of the types of roads.

Figure 4. Plan and profile views of road.



Once the driver has decided what kind of road it is, he or she will choose how to drive the road. Table 2 gives some of the expectancies related to the classification of rural roads just presented. By knowing what a driver expects, inconsistencies can be identified and appropriate actions can be taken to lessen or remedy the problem.

Table 3 gives the recommended handling of some selected inconsistencies for the three types of roads. Note that just as driver expectancies are different for each type of road (drivers expect a lower level of signing and maintenance on a type C than on a B or A road), inconsistencies are also different. For example, what may be an inconsistent situation on a type A road often is a consistent situation on a type C road and, consequently, may require no positive guidance or signing.

Classifying the roads as type A, B, or C provides guidance for local government agencies to treat all roads in a consistent fashion relative to meeting the driver's expectancy. This is very important in meeting the objective of providing a reasonably safe roadway system at a reasonable cost.

INTERSECTIONS

It is desirable for a driver to have an unobstructed view of the intersection and a length of the intersecting road sufficient to permit stopping or slowing the vehicle to avoid collisions. When traffic at the intersection is controlled by signs, there is less need for an unobstructed view. The minimum sight distance considered safe under various conditions is related directly to vehicle speeds and to the distances traveled while the driver sees the situation, reacts, and brakes.

It is important to take great care to place signs only where they are needed in order to prevent breeding disrespect for the signs. If it is economically feasible, sight obstructions should be removed so that signs become unnecessary. At all times, signs shall be visible and kept clear of obstructions such as trees, bushes, and weeds.

The two basic criteria for placement of advance signs are the approach speed and the reduced speed required to comply with the sign message [see Table 4 (6)]. In rural areas, two signs should not be located closer together than 200 ft along the highway. All signs should be located so as to be viewed by motorists without obstruction for a distance of at least 400 ft. Placing signs in dips or beyond the crest of hills and placing informational signs

Table 1. Classification of LVR roads by typical physical characteristics.

Characteristic	Road Type A	B	C
Typical width of traveled way and number of visible wheel paths	⩾22 ft, three or four visible wheel paths (if gravel)	16-24 ft, three visible wheel paths	⩽16 ft, two or no visible wheel paths
Prudent operating speed (mph)	⩾40	25-45	⩽40
Surface material	Paved or gravel	Gravel, sand, or dirt	Natural surface may have some gravel or sand
Riding quality	No adverse effect	May cause reduction in operating speed	Typically poor; may be impassable due to poor weather
Drainage	All-weather road with good surface drainage; water carried to ditches	All-weather road with some surface ponding; water carried in ditches	Fair-weather road; ditches are narrow or nonexistent; surface ponding likely to affect drivability

on curves should be avoided.

Type A Road Intersecting Type A Road

Intersection traffic-control devices should be installed on the minor legs. YIELD signs should be used when there is at least a 50-ft clear sight triangle in both quadrants. STOP signs should be used when the clear sight triangle in either quadrant is less than 50 ft. If the STOP or YIELD sign is not visible from 450 ft, then an advance warning sign should be placed (see Figure 9 and Table 4). [Note, in Figure 9 the distance "D" figures are recommended distances (7, p. 393).]

Type B or C Road Intersecting Type A Road

Intersection traffic-control devices should be installed on the minor legs. YIELD signs should be used when there is at least a 50-ft clear sight triangle in both quadrants. STOP signs should be used when the clear sight triangle in either quadrant is less than 50 ft. If, on a type B road, a STOP or YIELD sign is not visible from 300 ft or, on a type C road, a STOP or YIELD sign is not visible from 225 ft, then an advance warning sign should be placed (see Figure 9 and Table 4).

Type B Road Intersecting Type B Road

If either the intersection or vehicles on the intersecting road cannot be seen from 300 ft away, a "crossroad" or "t symbol" sign should be used. More positive control, such as YIELD or STOP signs, may

Figure 5. Type A paved road.

Figure 6. Type A gravel road.

Figure 7. Type B road.

Figure 8. Type C road.

Table 2. Some driver expectancies by roadway type.

Condition	Road Type A	Road Type B	Road Type C
Roadside obstacles	Some	Some	Many
Vertical alignment	Consistent with previous 0.5-1 mile	Consistent with previous 0.5-1 mile	May be consistent with previous 0.5-1 mile
Horizontal alignment	Consistent with previous 0.5-1 mile	Consistent with previous 0.5-1 mile	Consistent with previous 0.5-1 mile
Vehicle right-of-way at intersection	Expects to have right-of-way	Prepared to yield right-of-way	Expects to yield right-of-way
Safe stopping sight distance	Adequate for usual operating speed	Adequate for usual operating speed	Adequate for usual operating speed
Influence of opposing traffic	None	Slow down to pass opposing vehicle	Difficult to pass opposing vehicle

Table 3. Handling of selected inconsistencies.

Inconsistency	Road Type A	Road Type B	Road Type C
T or Y intersection	Should be signed unless adequate sight distance is provided	Should be signed unless adequate sight distance is provided	Should be signed unless adequate sight distance is provided
Railroad crossing	Shall have advance sign and crossbucks	Shall have advance sign and crossbucks	Shall have advance sign and crossbucks
Narrow bridge or culvert	All shall be signed	All shall have positive guidance; some should be signed	All shall have positive guidance; few should be signed
Low water stream crossing	Should be signed	May be signed	May be signed
Dead end	NA	NA	Should be signed

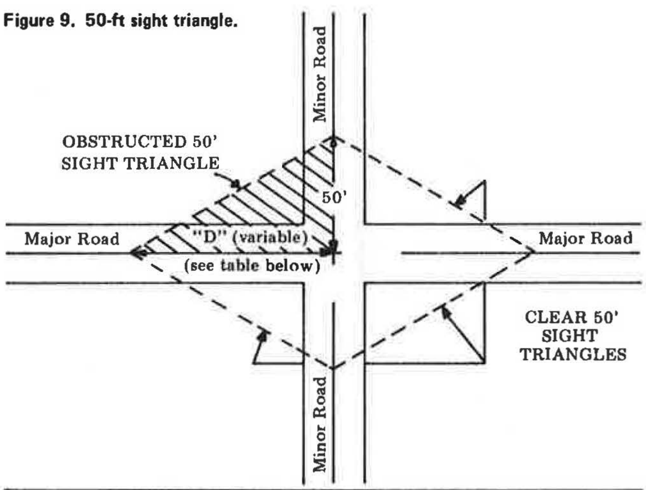
Note: NA = not applicable.

Table 4. Advance warning sign placement.

Posted or 85th[a] Percentile (perceived) Speed (mph)	Recommended Minimum General Warning Sign[b] Placement Distance (ft): Condition I[c], Stop Condition, at 0 mph	Condition II[d], Deceleration Conditions to Listed Advisory Speed (at following mph or desired speed at condition): 10	20	30	40	50
20	100	100				
25	100	100				
30	100	150	100			
35	150	200	175	100		
40	225	275	250	175		
45	300	350	300	250	150	
50	375	425	400	325	225	
55	450	500	475	400	300	225
60	550	575	550	500	400	300
65	650	650	625	575	500	375
70	750	750	700	650	575	450

[a] 85th percentile (prevailing) speed is that speed at or below which 85 percent of the vehicles travel.
[b] Distance provides for 3-s reaction perception (PIEV) time, 125-ft sign legibility distance, and comfortable breaking distance (7, Figure VII-15B). If 48-in signs are used, the legibility distance may be increased to 200 ft. This would allow a reduction of the above distances by 75 ft.
[c] Typical signs for condition I are crossroad, stop ahead, signal ahead, ped-xing, railroad advance warning, etc.
[d] Typical signs for condition II are turn, curve, divided road, hill, dip, etc.

Figure 9. 50-ft sight triangle.



Speed (MPH) (Minor Road)	10	10	10	10	10	10	10
Speed (MPH) (Major Road)	10	20	30	40	45	50	55
Distance "D" (feet)*	45	90	130	180	200	220	240

be used on the minor legs. If more positive control is needed, the YIELD sign should be used when there is at least a 50-ft clear sight triangle in both quadrants, and the STOP sign should be used when the clear sight triangle in either quadrant is less than 50 ft (see Figure 9). If the STOP or YIELD sign is not visible from 300 ft, an advance warning sign should be used.

Type C Road Intersecting Type B or C Road

If either the intersection or vehicles on the intersecting road cannot be seen from 225 ft away, a "crossroad" or "t symbol" sign may be used. More positive control such as YIELD or STOP signs may be used on the minor legs. If more positive control is needed, the YIELD sign should be used when there is at least a 50-ft clear sight triangle in both quadrants, and the STOP sign should be used when the clear sight triangle in either quadrant is less than 50 ft (see Figure 9). If the STOP or YIELD sign is not visible from 225 ft, an advance warning sign should be used. The intersection of two type C roads seldom requires intersection signing.

Sight Triangle

The decision to use a specific traffic-control device at an intersection is based on the driver's ability to see the other legs of the triangle. The sight triangle is used to describe the area that must be clear of obstacles more than 3 ft in height. A 50-ft sight triangle is shown in Figure 9.

Usually, when there is a sight problem at an intersection, STOP or YIELD signs are used in pairs; however, there may be some locations where this does not apply. When a minor road (types A, B, or C) intersects a major road (type A), the location may indicate that only one quadrant does not have a clear 50-ft sight triangle. Due care is recommended in the installation of nonpaired STOP signs or YIELD

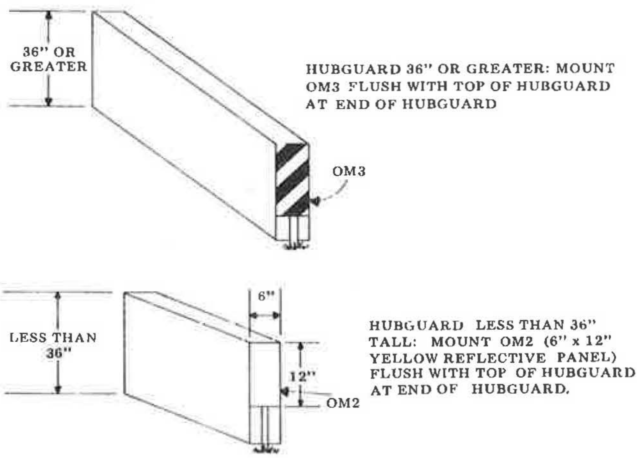
Table 5. Signing for curves and turns.

Usual Operating Speed (mph)	Safe Speed[a] (mph)								
	60	55	50	45	40	35	30	25	≤20
60			C	CA	CA	CA	TA	TA	TA
55				C	CA	CA	TA	TA	TA
50					C	CA	TA	TA	TA
45						C	TA	TA	TA
40							T	TA	TA
35								T	TA
30									T
25									
≤20									

Note: C = curve sign or reverse curve sign (or winding road sign, if applicable), T = turn sign or reverse turn sign (or winding road sign, if applicable), and A = advisory speed plate.

[a]The speed that indicates a reading of 10° on the ball bank indicator.

Figure 10. Typical mounting of object marker on narrow bridge that is used by wide farm equipment.



signs. Such installations should be considered only if justified and recommended by an engineering and traffic study. [Note that YIELD signs are recommended where sufficient sight distance for safe approach speeds greater than 10 mph exist (50-ft sight triangles).]

Recent research by Stockton and others (8) shows that STOP-controlled intersections are not, in general, safer than YIELD-controlled intersections; YIELD control requires less travel time than STOP control and also provides some savings in operational costs.

TURNS AND CURVES

The turn and curve warning signs inform a driver of a change in the horizontal direction of the roadway. Before the decision can be made to use this type of sign, and which specific sign to use, many factors must be taken into consideration. First, the higher of the operating approach speed (prevailing speed) or the established speed limit must be compared with the advisory safe speed of the curve in order to establish whether a "turn" sign or a "curve" sign is necessary as well as to determine the need for an advisory speed plate. Other considerations include determining if the curve is consistent with the previous roadway alignment, and the classification of the road type with regard to driver expectancy.

The advisory safe speed of a curve can be determined by the use of a ball bank indicator, also known as a slope meter. The indicator will give a reading of 10 (10°) when the vehicle in which it is mounted negotiates a curve at the highest speed that is considered safe and comfortable.

Table 5 is intended for use in determining signing for type A and B roads. It may also be used for signing type C roads if positive guidance is considered inadequate at specific locations. Table 4 should be used for consistent placement of "turn" and "curve" signs.

NARROW BRIDGES, CULVERTS, AND ROADSIDE OBSTACLES

Bridges and culverts that are narrower than the approach roadway and narrow roadways with obstacles adjacent to the shoulder violate the drivers's expectancy and therefore are considered to be inconsistencies. As such, it is necessary to provide positive guidance so that the driver has sufficient information to safely negotiate the narrow bridge, culvert, or adjacent obstacle. This section covers several different, but related, problems: narrow bridges and culverts, one-lane bridges and culverts, and roadside obstacles.

Because the driver's expectancy changes with the physical characteristics of the roadway, the amount of needed positive guidance also changes. The following guidelines are intended for use at or near a narrow or one-lane bridge or culvert. Note that the guidelines differ, depending on the type of road.

For type A roads, the following guidelines are suggested:

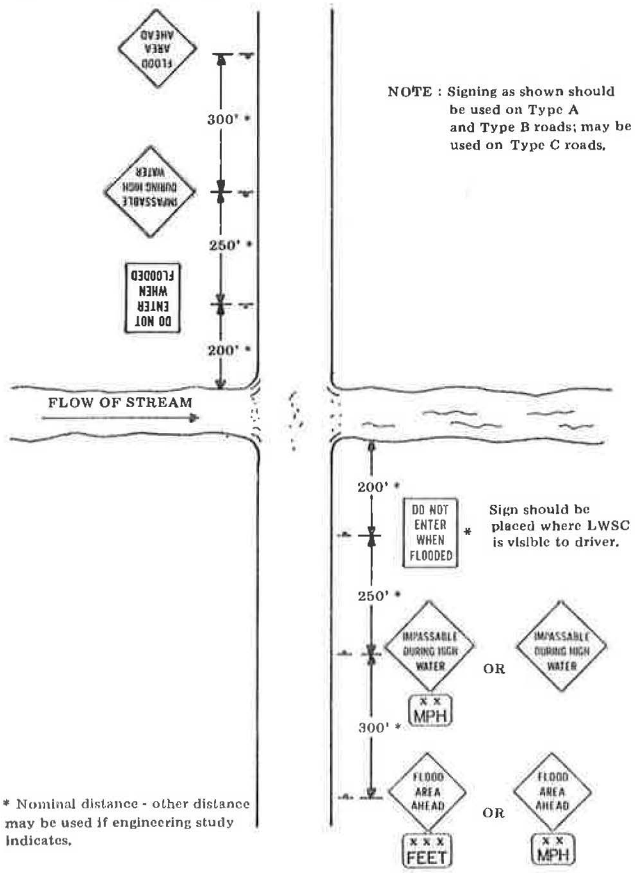
1. A NARROW BRIDGE sign or a ONE-LANE BRIDGE sign should be used on each approach,
2. Type 3 object markers shall be used on each approach,
3. The approaches to the structure should be tapered,
4. Guardrail may be used,
5. Delineators may be used, and
6. Pavement markings may be used.

For type B and type C roads, the following guidelines are suggested:

1. A NARROW BRIDGE sign or a ONE-LANE BRIDGE sign may be used, and
2. Type 3 object markers shall be used on each approach, unless the approaches to the structure are tapered such that the structure is no longer narrower than the roadway [if tapering is used, type 3 object markers may be used to warn of an additional hazard (e.g., concrete bridge rails)].

In addition to the signs that designate narrow bridges or culverts, or one-lane bridges or culverts, the existence of the structures and/or adjacent obstacles can be shown through the use of object markers or other means of positive guidance.

Figure 11. Typical signing of LWSC.



Because it is generally believed that the driver gets the most information from the physical characteristics of a roadway, there is a greater potential for providing the driver with positive guidance by modifying those physical characteristics to lead the driver safely through the hazard. This is the principle involved in the practice of tapering the approach of a roadway so that it gradually narrows to the width of the structure.

The Kansas Secondary Roads Policy (SRP) 4.05-80 permits a variation in mounting height of object markers only at certain narrow bridges used by wide farm equipment. When the bridge rail is 36 in or more above the bridge deck, install a type 3 object marker (12x36 in) flush with the top of the rail at the rail end. When the bridge rail is less than 36 in above the bridge deck, use a type 2 object marker (all yellow relective panel 6x12-in minimum size), with the top of the panel flush with the top of bridge rail. Type 2 markers may be larger if conditions permit.

When object markers are installed below the normal mounting height of 4 ft, the county must keep weeds mowed in front of the sign, and periodic cleaning is necessary for the sign to function properly or maintain sign visibility and reflectivity (see Figure 10, which is taken from KS SRP 4.05-80).

LOW-WATER STREAM CROSSINGS

Low-water stream crossings (LWSCs), or fords, are rarely encountered by the driver; therefore, they can be considered inconsistencies. The recommendations for signing LWSCs are based on research by Carstens and Woo (9).

Experience reported by persons who have responsibility for road systems that include LWSCs indicates some concern with liability problems growing out of their use (9). However, a majority of officials that have this experience report that they are satisfied with LWSCs and that road users seem to accept them.

This experience suggests that a risk analysis generally will show that the potential for accidents and liability will be reduced, rather than increased, when an LWSC is substituted for a bridge that is structurally deficient or functionally obsolete. It is recommended that adequate warning of the presence of an LWSC be given if the risk of accidents and liability results from the use of an LWSC is to be kept within acceptable limits.

One of the conclusions from the research (9) is that the risk of accidents and liability would be further reduced if motorists were discouraged from crossing an LWSC while it was flooded. The findings from an evaluation of alternative signing patterns support this conclusion by suggesting the use of a regulatory sign with the message DO NOT ENTER WHEN FLOODED. The intent of this sign is to prohibit passage across the LWSC if the roadway is covered with water.

At LWSCs, debris or mud may remain on the roadway after flood waters have receded and erosion of the roadway may have occurred. Thus, it is important that road segments with LWSCs be checked following heavy rains so that required maintenance may be performed promptly or that the road can be closed if necessary.

On type A and B roads, the three signs FLOOD AREA AHEAD, IMPASSABLE DURING HIGH WATER, and DO NOT ENTER WHEN FLOODED should be used (see Figure 11).

On type C roads, the FLOOD AREA AHEAD sign should be used. The IMPASSABLE DURING HIGH WATER and/or DO NOT ENTER WHEN FLOODED signs also may be used.

For type A, B, and C roads, if only one sign is used, it shall be the FLOOD AREA AHEAD sign. If only two signs are used, the first sign shall be the FLOOD AREA AHEAD sign.

The placement of the sign or signs may vary, depending on the usual operating speed and terrain. It is important not to give the driver too much information or too many tasks to perform, such as a steep grade to negotiate with the FLOOD AREA AHEAD sign on the steep grade. In this case, it is best to warn of the steep grade and also warn of the LWSC before the grade. Distances longer or shorter than those shown in Figure 11 may be used if an engineering study so indicates.

Also note that the FLOOD AREA AHEAD and IMPASSABLE DURING HIGH WATER signs are warning signs and shall conform to MUTCD standards for warning signs. The DO NOT ENTER WHEN FLOODED sign is a regulatory sign and shall conform to MUTCD standards for regulatory signs.

CONCLUSION

The consistent use of the suggested traffic controls for LVR roads should result in the following:

1. More consistent signing and increased guidance on LVR roads,
2. Increased safety for the LVR road user,
3. Reduced liability for local government units in case of lawsuits arising from highway accidents,
4. Reduced amount of signing, and
5. Reduced costs of signing.

ACKNOWLEDGMENT

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REFERENCES

1. J.C. Glennon. Design and Traffic Control Guidelines for Low-Volume Rural Roads. NCHRP, Rept. 214, 1979.
2. Manual on Uniform Traffic Control Devices for Streets and Highways. FHWA, U.S. Department of Transportation, 1978.
3. Handbook on Traffic Control Practices for Low-Volume Roads. Kansas Department of Transportation, Topeka, 1981.
4. G.J. Alexander and H. Lunenfeld. Some Factors Affecting Reception and Use of Information by Drivers. Public Roads, June 1972.
5. G.J. Alexander and H. Lunenfeld. Positive Guidance in Traffic Control. FHWA, 1973.
6. R.H. Oliver and others. Advance Placement of Warning Signs. Subcommittee on Traffic Engineering, AASHTO, Washington, DC, June 18, 1979.
7. A Policy on Geometric Design of Rural Highways. AASHO, Washington, DC, 1965.
8. W.R. Stockton, R.Q. Brackett, and J.M. Mounce. STOP, YIELD, and No Control at Intersections. FHWA, Rept. FHWA/RD-81/084, 1981.
9. R.L. Carstens and R. Yun-Hao Woo. Liability and Traffic Control Considerations for Low Water Stream Crossings. Engineering Research Institute, Iowa State Univ., Ames, April 1981.

Measuring Surface Erosion on Forest Roads and Estimating Costs of Erosion Control—Preliminary Results

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Simulated rainfall was applied to three types of roadway on six sections of forest road to measure runoff and sediment yield. The three surfaces were native granitic material, native material treated with dust oil, and bituminous surface treatment. The roads are located within the Silver Creek Experimental Watershed, Boise National Forest, Idaho. Test plots of the roadway were isolated from the adjacent roadway with barriers sealed to the surface. Discharge and suspended sediment were sampled continuously. Rainfall was simulated by a large sprinkling infiltrometer at a rate of 2 in/h for 25-40 min. The first test was conducted on a dry plot, followed by a second test 24 h later. Measurements for each plot included bulk density by depth increments, loose soil on the road surface in pounds per unit area, particle-size distribution for each sample, gravimetric soil moisture before and after each simulated rainfall, and a detailed survey of each plot. Results of runoff and sediment yield measurements are presented. Construction costs for standard and nonstandard items on forest roads were determined by recording the labor and equipment necessary to complete each activity based on local rates. Programs for estimating costs of erosion-control features were developed for the HP-41CV calculator and minicomputers with BASIC language capability. Cost estimates derived from current estimating procedures are compared with costs developed from observed labor and equipment times.

Two of the major objectives of the engineering research project in the Intermountain Forest and Range Experiment Station are to (a) develop practical and reliable methods to estimate runoff and sediment yield from forest roads with various erosion-control treatments and (b) determine incremental costs of erosion-control treatments. Easily accessed timber stands have been roaded, and many of the unaccessed timber stands are on steep sites with fragile soils where watershed and fishery values are high. Erosion control remains an important consideration in forest road construction, but the ability to analyze the cost-effectiveness of erosion control must be improved.

Cost-effective erosion control for forest roads is, as the name implies, composed of two parts: (a) estimation of sediment yield from roads with selected erosion-control treatments and (b) estimation of construction costs for these treatments. Proper consideration of these two steps will provide the most erosion control for the least cost for given site conditions. This paper describes a series of research studies on this subject conducted cooperatively by the Engineering Research Project, Intermountain Forest and Range Experiment Station, and the Civil Engineering Department, University of Idaho.

WATER AND SEDIMENT YIELDS FROM ROADWAY SURFACES

Runoff and sediment models most appropriate for general use on forest roads are Road Sediment (ROSED) (1-3), which is a detailed process model, and Simplified Road Sediment (SIRSED) (4), which is a simplified version of ROSED. Input for these models include the geometry of the proposed road, expected climatic events, and many characteristics of the soil. The current version of ROSED requires calibration for the particular locality where it is to be used. The usual calibration method consists of setting up a rainfall simulator over a section of road, applying rainfall at a known rate for a selected time period, and measuring runoff and sediment yield. Initial soil moisture prior to rainfall and final soil moisture immediately after rainfall must be measured. Then model parameters are adjusted until the model output matches measured runoff and sediment yield. These values of model parameters can presumably be used in ROSED to simulate other precipitation events, terrain, and groundcover modification for similar sites. If ROSED performs accurately, it would be an effective planning tool for forest engineers and hydrologists. A systematic effort is needed to verify the ROSED model. If this is successful, a method of obtaining soil parameters for the ROSED model from easily measured site characteristics must be developed.

Our procedure for the evaluation of ROSED and the development of a general surface-erosion-prediction method for forest roads consists of four stages:

1. Testing of the ROSED and SIRSED models on