Basic Horizontal Curve Safety Treatments

Course Number: CE-03-902

PDH: 3

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INTRODUCTION

The roadway horizontal alignment is a series of horizontal tangents (straight roadway sections), circular curves, and spiral transitions. It shows the proposed roadway location in relation to the existing terrain and adjacent land conditions. Together with the *vertical alignment* (grades and vertical curves) and *roadway cross-sections* (lanes, shoulders, curbs, medians, roadside slopes, ditches, sidewalks), the **horizontal alignment** (tangents and curves) helps to provide a three-dimensional roadway layout. The main objective of geometric roadway design is to integrate these elements to produce a compatible speed with the road's function and location.

Safety, operational quality, and project costs can be significantly influenced by coordinating the horizontal and vertical alignments. In today's environment, designers must do more than apply design standards and criteria to 'solve' a problem. They must understand how various roadway elements contribute to safety and facility operation, including the horizontal alignment. The fundamental objective of good geometric design will remain as it has always been **– to produce a roadway that is safe, efficient, reasonably economic and sensitive to conflicting concerns.**

AASHTO's **Strategic Highway Safety Plan** set a goal of reducing annual highway fatalities by 5000 to 7000. Various guides are available to identify methods for reducing injuries and fatalities in targeted areas – one such area is the issue of vehicle crashes at horizontal curves.

The average crash rate for horizontal curves in the U.S. is roughly three times that for other highway sections. **A Guide for Reducing Collisions on Horizontal Curves** reports that nearly 25% of U.S. traffic fatalities are killed in vehicle crashes at curves annually with:

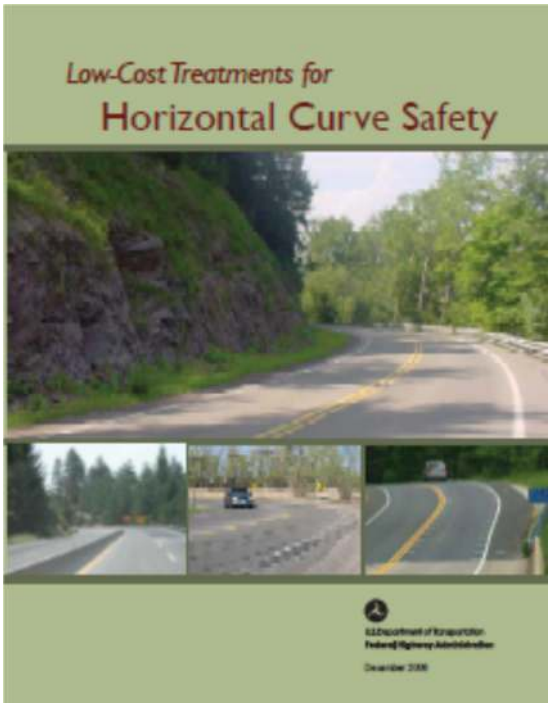
76% - *single vehicles leaving the roadway*

75% - *rural roads*

70% - *two-lane secondary (local) road crashes*

11% - *head-on crashes.*

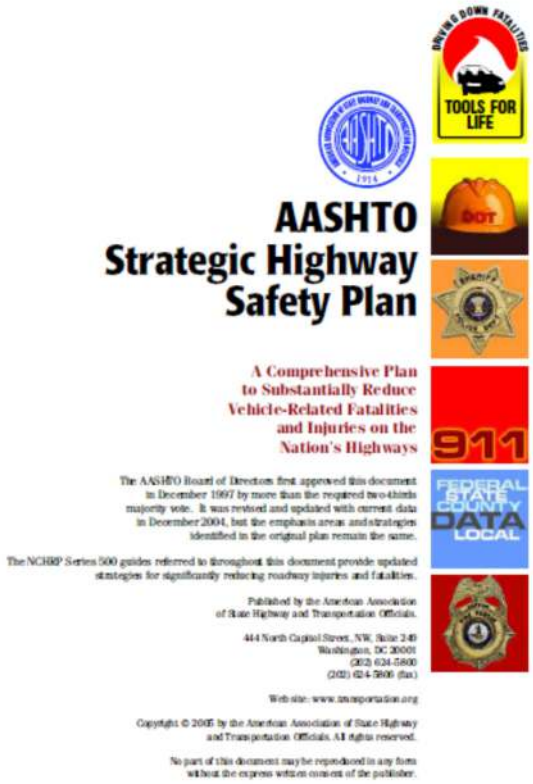
Due to these statistics, the Federal Highway Administration (FHWA) identified Roadway Departure as one of its program emphasis areas and developed practical information publications for local agencies. The main reference for this course, **Low-Cost Treatments for Horizontal Curve Safety*** is a result of these Roadway Departure program goals.



http://safety.fhwa.dot.gov/roadway_dept/horicurves/fhwasa07002/fhwasa07002.pdf

* This reference may also be referred to as "LCTHCS" throughout this document and includes only those engineering treatments that are low cost strategies.

The Strategic Highway Safety Plan identified a set of strategies for reducing highway crash fatalities at horizontal curves. These included: **Goal 15 - *Keeping Vehicles on the Roadway*;** and **Goal 16 - *Minimizing the Consequences of Leaving the Road*.**



These strategies share one of the following for improving horizontal curve safety

1. **Reduce the likelihood of a vehicle leaving its lane and either crossing the roadway centerline or leaving the roadway at a horizontal curve**

and

2. **Minimize the adverse consequences of leaving the roadway at a horizontal curve.**

Several crash emphasis areas evolved: *head-on crashes, curve-related crashes, crashes with trees in hazardous locations, and run-off-road (ROR) crashes.*

COURSE CONTENTS

This course summarizes practical information on where, when, or how to apply safety treatments for horizontal curves or winding sections. These treatments are relatively low cost versus geometric design improvements (degree of curve, shoulders, superelevation, curve length, cross-section, etc.). Information for each treatment will generally include:

Description

Application guidelines – installation practices

Design elements and materials

Effectiveness – safety improvements

Cost

Estimates for treatment effectiveness in reducing crashes are included if available. Actual observed effectiveness values of a treatment may vary depending on its location.

Topics covered in this course include:

Basic Treatments – Devices found in the MUTCD

Centerline markings

Edge lines

Horizontal alignment signs

Advisory Speed Plaque

One-Direction Large Arrow Sign

Combination Horizontal Alignment/Advisory Speed Sign

Curve Speed Sign

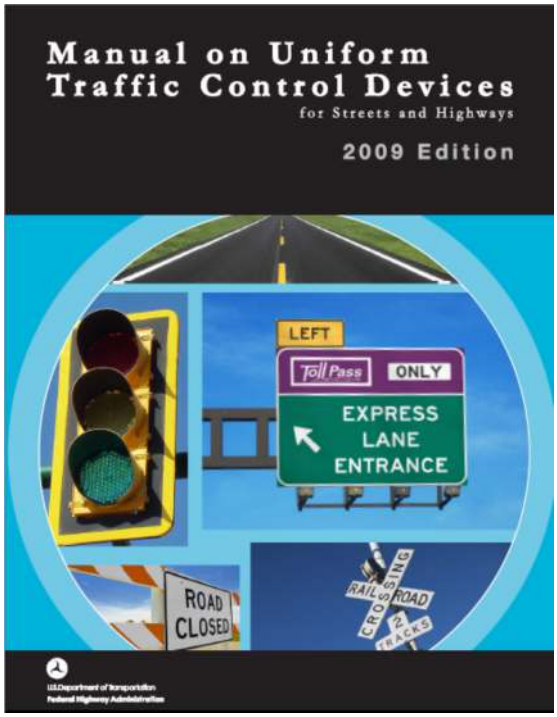
Chevrons

Delineators

The purpose of this course is to encourage readers to use this information to evaluate problems and implement appropriate treatments for problem curve locations. These treatments should help reduce roadway departure crashes, injuries, and fatalities.

MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES (MUTCD)

By law (23 CFR 655, Subpart F), the **Manual on Uniform Traffic Control Devices (MUTCD)** defines the standards for all traffic control devices in order to regulate, warn, and guide drivers safely on U.S. roadways and streets. **It is the definitive authority for traffic signs and pavement markings.** The MUTCD defines conditions about what, where, and how a device is to be placed or installed. Nationwide consistency is the goal of the MUTCD.



The MUTCD is published by the Federal Highway Administration (FHWA) to promote safety and efficiency on our public roads by establishing uniform standards for traffic control devices. It defines the nationwide standards for the installation and maintenance of the devices on all streets and highways.

The MUTCD allows us to drive anywhere in the U.S. using the same basic traffic control devices. Drivers who see a particular pavement marking or traffic sign should expect it to mean the same thing and be prepared to take the same action regardless of location.

All States are required to adopt either the MUTCD or a State MUTCD that conforms to the Federal version of the MUTCD. In some cases, States have adopted the national MUTCD with an added State Supplement.

BASIC TREATMENTS FOR HORIZONTAL CURVES

The MUTCD contains several basic traffic control devices that should be considered for horizontal curves, especially where safety problems have been identified. These treatments include:

Centerline pavement markings

Edge line pavement markings

Delineators

Horizontal Alignment signs:

Turn (W1-1), Curve (W1-2), Reverse Turn (W1- 3), Reverse Curve (W1-4), Winding Road (W1-5), Hairpin Curve (W1-11), or Loop (W1-15)

Advisory Speed Plaque (W13-1) (with any of the Horizontal Alignment signs)

One-Direction Large Arrow (W1-6) sign

Combination Horizontal Alignment/Advisory Speed (W1-1a or W1-2a) sign

Curve Speed (W13-5) sign

Chevron Alignment (W1-8) sign

Many curves may require something as simple as standard centerline and edge line markings or a basic horizontal alignment warning signs. Adding one or more of the listed devices should be determined by engineering judgment or study that considers:

- Difference in the posted speed limit and the 85th percentile speed
- Geometric features (length, radius, shoulders and roadside)
- Curve sight distance
- Unexpected geometric features (intersection or change in curve radius)
- Traffic volume

This course provides guidelines for each device. All example signs, markings, figures, and tables are from the MUTCD, except where noted otherwise.

CENTERLINE MARKINGS

Pavement marking is more than just roadway striping. It relays regulatory and vehicle-path information to the user without requiring them to divert their attention from the road. Their purpose is to encourage safe, orderly traffic flow while optimizing roadway capacity. Pavement markings need to be easily recognized and understood in order to be effective. A standardized system of marking color, shape, and application has been developed to convey the same message each time they are encountered.

All pavement markings should be maintained to ensure adequate daytime and nighttime visibility. Upon installation, it is the municipality's responsibility to maintain the marking. If the municipality decides that the marking is no longer needed, their decision process should be documented. Any markings deemed non-applicable or confusing should be removed as soon as possible.

White and yellow longitudinal markings (long lines) guide traffic along the roadway by providing visual clues to the travel path. Dashed lines (broken lines) allow vehicles to pass or change lanes. These white or yellow markers are *four to six inches wide* and applied with ten foot painted dashes and thirty foot spacing. The distance from the beginning of one dash to the beginning of the next is 40 feet. These lines provide an excellent way to estimate roadway distances (example: three dashes between two side roads; the estimated distance is 3 x 40 = **120 feet** separating the roadways).

The centerline pavement marking is the **minimal treatment** for paved curves with sufficient width and volume. Centerline markings help keep vehicles on the correct side of the road and delineate the roadway alignment. The MUTCD allows using a centerline at specific locations, such as around a curve rather than the entire roadway.

MUTCD Requirements for Centerline Markings on Paved Two-Way Streets.

	Area type	Road Class		Lanes	ADT	Travel Width (ft)
REQUIRED	Urban	Collectors	Arterials	2	6000 +	20+
	All	All		3+		
RECOMMENDED	Urban	Collectors	Arterials	2	4000+	20+
	Rural	Collectors	Arterials	2	3000+	18+
MAY CONSIDER	Any	Any		2	Any	16+

Short roadway sections may be marked with centerline pavement markings to control traffic at specific locations (curves, over hills, grade crossings, bridges, etc.) for roadways without continuous centerline pavement markings.

CENTERLINE MARKINGS - TWO-LANE, TWO-WAY ROADWAY OPTIONS

Two-direction passing zone markings - a normal broken yellow line

- passing with care is permitted for traffic traveling in either direction;

One-direction no-passing zone markings - a double yellow line, one of which is a normal broken yellow line and the other is a normal solid yellow line

- passing with care is permitted for traffic traveling adjacent to the broken line, but is prohibited for traffic traveling adjacent to the solid line

Two-direction no-passing zone markings - two normal solid yellow lines

- passing is prohibited for traffic traveling in either direction.

Please note that a single solid yellow line shall never be used for center line marking on two-way roadways.

For undivided two-way roadways with four or more lanes for moving motor vehicle traffic, the centerline markings shall be the two-direction no-passing zone markings (solid double yellow line).

Yellow centerline pavement markings are used to separate traffic lanes with opposite directions of travel on a roadway. These markings can also be installed at locations that are not the geometric center of the roadway.

<u>Centerline pavement markings are required on:</u>

Paved urban arterials & collectors	Traveled way 20 feet or wider ADT = 6000 vehicles/day or more**
Paved two-way streets or highways	Three or more lanes
Rural arterials & collectors	Traveled way 18 feet or wider ADT = 3000 vehicles/day or more
Where engineering judgment indicates a need	

**May be used for a minimum ADT of 4000 vehicles/day

Centerline markings may be placed on paved two-way roads with minimum widths of 16 feet - engineering judgment should determine any potential for traffic encroachment on the pavement edges, effects of parked vehicles, and traffic drifting into opposing lanes. For curves (without centerlines) identified as potential safety problems, centerline markings should be the first minimal treatment applied. For low traffic volume areas (less than 200 vehicles per day) and/or a pavement width less than 16 feet, post delineators, chevrons, or curve warning signs may be used.

WIDTHS & PATTERNS OF LONGITUDINAL PAVEMENT MARKINGS

Normal Line - 4 to 6 inches wide.

Wide Line - at least twice the width of a normal line. The width of the line indicates the degree of emphasis.

Double Line - two parallel lines separated by a discernible space.

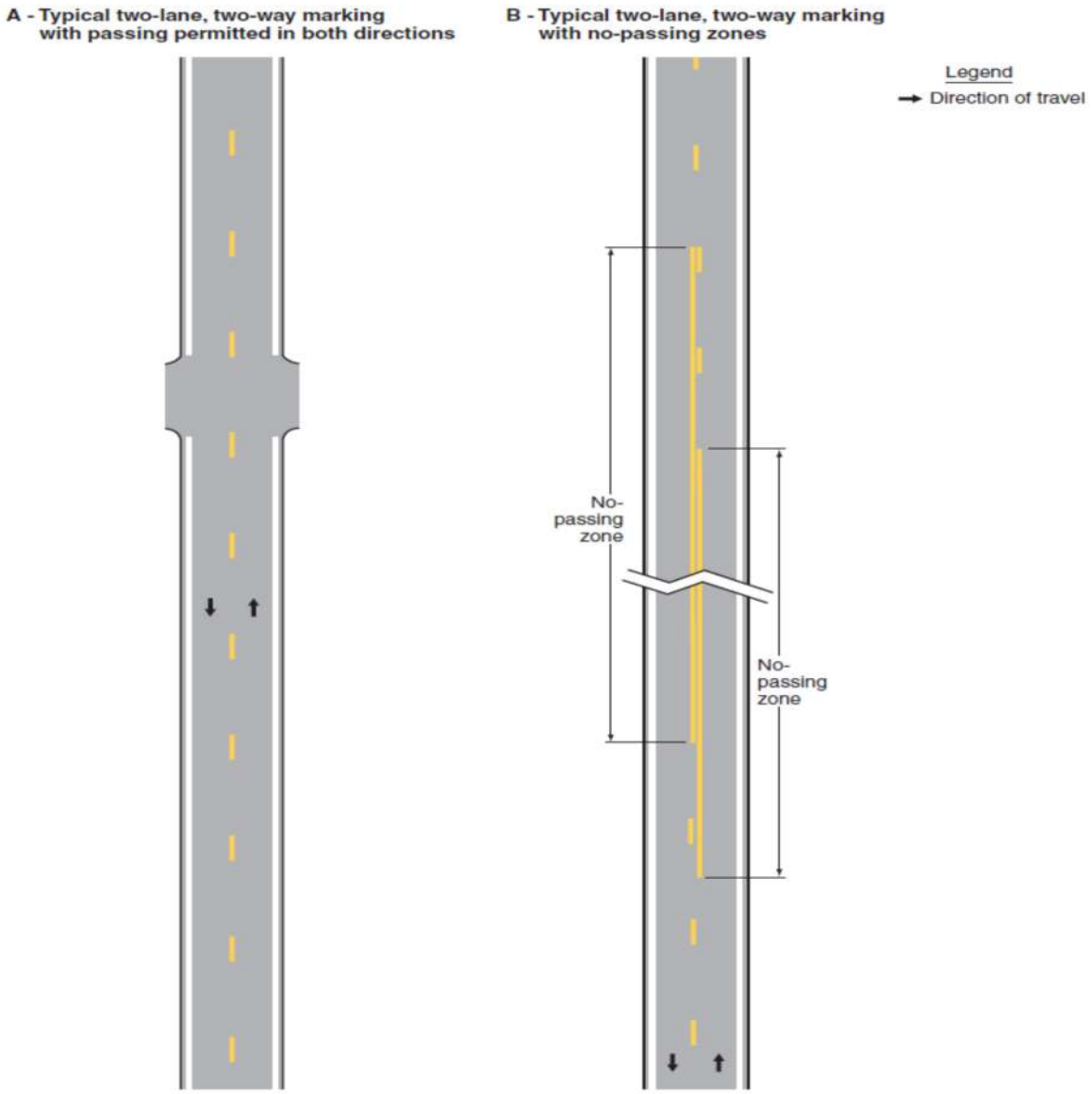
Broken Line - normal line segments (10 feet) separated by (30 feet) gaps.

Dotted Line for Extensions - noticeably shorter line segments (typically 2 feet) separated by shorter gaps (typically 2 to 6 feet). The width of a dotted line shall be at least the same as the width of the line it extends.

Dotted Line for Lane Lines - 3 feet line segments with 9 feet gaps.

A variety of paint and thermoplastic materials are used for centerline markings – depending on agency preferences regarding pavement marking applications. Thermoplastic is more cost-effective due to their durability. But their higher initial costs may not be economic for low-volume rural roads. Other centerline materials may include rumble strips, raised pavement markers, and profile thermoplastics.

Figure 3B-1. Examples of Two-Lane, Two-Way Marking Applications



A 1996 Kentucky study based on analysis of entire roadway sections estimated that centerline markings reduced crashes by 35 percent. Other studies suggest that municipalities can expect safety benefits from centerline markings with varied results based on roadway and traffic factors.

Pavement marking costs depend on several factors: *material* (paint or thermoplastic); *installers* (agency or contractor); *geometric design* (curve or tangent section); *location* (single or multiple sites); etc.

EDGE LINE MARKINGS

Edge line markings define and delineate roadway edges. These pavement markings help guide road users during adverse weather and visibility conditions plus they also prevent vehicles from drifting onto the shoulder and roadside area.

Edge lines are a solid white line at the travel lane's right edge for horizontal curves. Along with the centerline or lane lines, edge lines define the boundary of the travel lane for the user. These markings are typically applied to an entire roadway section but can be installed before or within curves.

WARRANTS FOR USE OF EDGE LINES

Edge line markings should be placed on the following paved streets or highways:

- Freeways,
- Expressways, and
- Rural arterials with a traveled way of 20 feet or more in width and an ADT of 6,000 vehicles per day*.

* May be used for rural arterials and collectors with an ADT of 3,000 vehicles per day or greater.

While it is not necessary to have centerlines in order to install edge lines, white lines applied to both edges of narrow two-way roads may mistakenly signal one-way operation to road users.

The standard edge line width is 4 to 6 inches, with the 4-in line being the most common. Freeways and some lower class roads have used six-inch edge lines. Wide 8 to 12 inch edge lines (while not typical) can be used to emphasize curves and provide better visibility. This wide edge line should not be used on roadways narrower than 20 feet in order to prevent head-on collisions.

Results from a New York study showed that installing edge lines on two-lane roads with curves reduced fixed object crashes by 17 percent and total crashes by 5 percent. The **Low Cost Local Road Safety Solutions** produced the results from several studies citing safety benefits of wider edge lines.

HORIZONTAL ALIGNMENT SIGNS

Roadway horizontal curves are the second most likely locations for serious vehicle crashes (intersections are number one) that result in injuries and fatalities (lane departures, with head-on incidents for curves to the right, and run-off-road crashes for curves to the left). Proper signage can guide motorists through curves without leaving their lane.

Curve warning signs depend on the roadway geometry of the first curve, the advisory speed of the sharpest corner, and whether it is a single curve or multiple curves.

An alignment warning sign may be placed a maximum distance of **100 feet** in advance of the curve, and a minimum distance of **100 feet** from any other signs.

The MUTCD recommends the following four Horizontal Alignment signs to warn drivers of a horizontal curve:

Turn (W1-1)

Curve (W1-2)

Hairpin Curve (W1-11)

270-degree Loop (W1-15)

The advance warning signs shown below are recommended for roadways sections with multiple curves in close proximity:

Reverse Turn (W1-3) **Reverse Curve (W1-4)** **Winding Road (W1-5)**

Table 2C-5. Horizontal Alignment Sign Selection

Type of Horizontal Alignment Sign	Difference Between Speed Limit and Advisory Speed				
	5 mph	10 mph	15 mph	20 mph	25 mph or more
Turn (W1-1), Curve (W1-2), Reverse Turn (W1-3), Reverse Curve (W1-4), Winding Road (W1-5), and Combination Horizontal Alignment/Intersection (W10-1) (see Section 2C.07 to determine which sign to use)	Recommended	Required	Required	Required	Required
Advisory Speed Plaque (W13-1P)	Recommended	Required	Required	Required	Required
Chevrons (W1-8) and/or One Direction Large Arrow (W1-6)	Optional	Recommended	Required	Required	Required
Exit Speed (W13-2) and Ramp Speed (W13-3) on exit ramp	Optional	Optional	Recommended	Required	Required

For curves with the advisory speeds of 30 mph or less, W1-1 Turn signs should be used. If the advisory speed is greater than 30 mph, W1-2 Curve signs should be used. The appropriate type of sign to use should be determined by engineering judgment that considers roadway geometry, traffic volume, road type, and other factors.

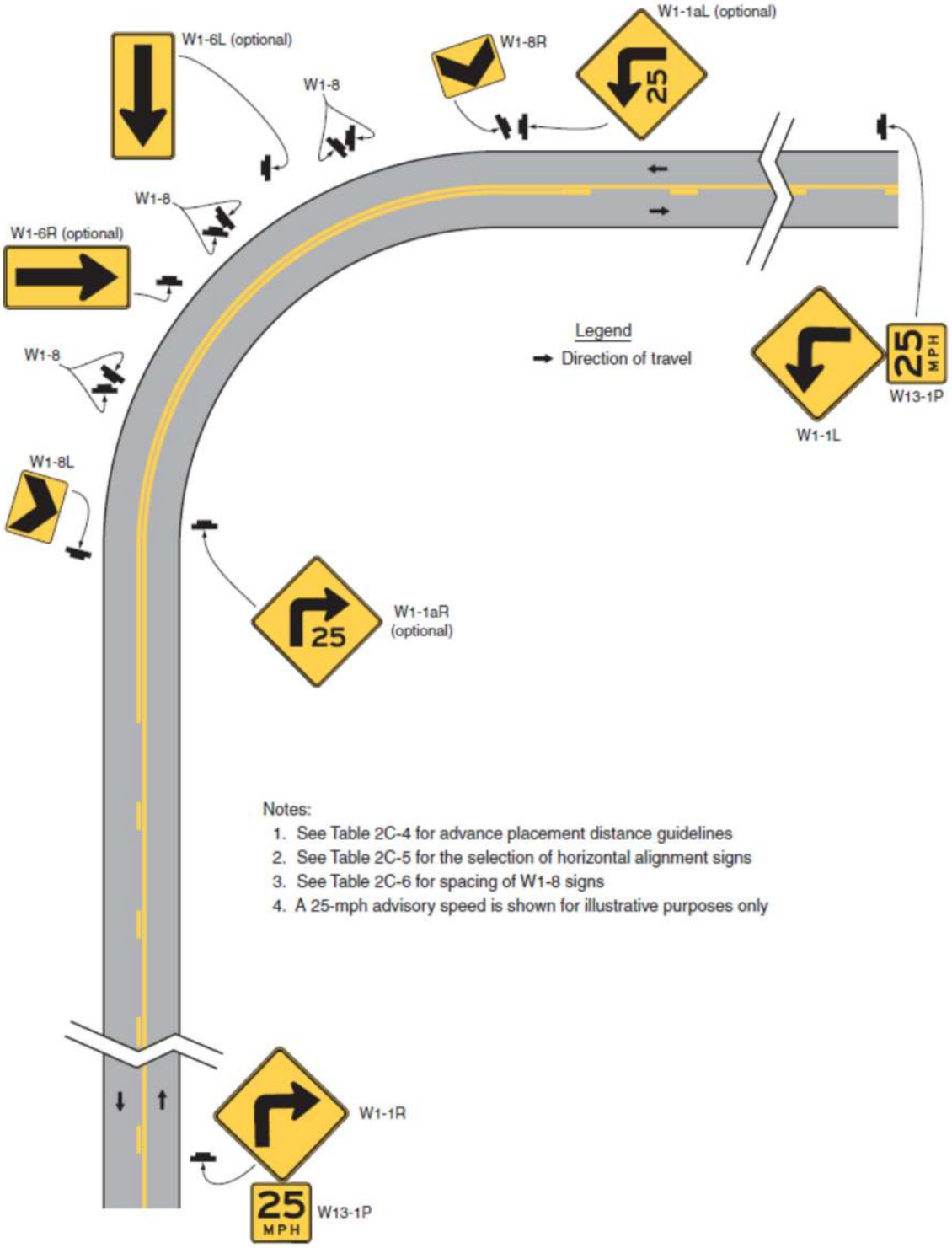
W1-1

W1-2

TURN CURVE

≤ 30 mph > 30 mph

Figure 2C-2. Example of Warning Signs for a Turn



Curves with the following conditions may not need a Horizontal Alignment sign:

- **gentle to moderate curvature where speed advisory is not required**
- **adequate curve sight distance**
- **adequate pavement markings, raised pavement markers, and delineation**

The Hairpin Curve (W1-11) sign should be used for curves of 135 degrees or more.

The Loop (W1-15) sign is generally limited to 270-degree loops (cloverleaf interchange ramps).

Two curves in opposite directions separated by a maximum tangent distance of 600 feet may be signed with a Reverse Turn (W1-3) or Reverse Curve (W1-4) sign.

At locations where the lower advisory speed of two curves is 30 mph or less, a Reverse Turn sign should be used. If the lower advisory speed is greater than 30 mph, Reverse Curve signs may be used. However, this is subject to engineering judgment that considers the traffic volume, type of road, and other factors.

Retroreflective sheeting is used on traffic signs to ensure low light and nighttime visibility. Recently, many municipalities have shifted from engineering grade (Type I) to using high-intensity grade (Type III), and microprismatic sheeting (Type V). As the grades increase (Type I to V), the signs become brighter and more durable - but with increasing unit costs.

Data from a 1968 evaluation of curve warning signs showed an 18% crash reduction may be achieved by using warning signs. More recent research is currently not available but a safety benefit seems likely from proper horizontal alignment signage

Winding Road (W1-5) signs may be used for road segments of three or more curves less than 600 feet apart. NEXT XX MILES (W7-3aP) supplemental distance plates may be installed below Winding Road signs on continuous roadway curves that occur within a specified distance.

Table 2C-4 (MUTCD) shows appropriate placement distances in advance of the point of curvature for warning signs. For example, using an 85^{th}-percentile speed of 50 mph and an advisory speed of 30 → the warning sign should be installed 125 feet before the point of curvature.

Table 2C-4. Guidelines for Advance Placement of Warning Signs

Posted or 85th-Percentile Speed	Advance Placement Distance[1]								
	Condition A: Speed reduction and lane changing in heavy traffic[2]	Condition B: Deceleration to the listed advisory speed (mph) for the condition							
		0[3]	10[4]	20[4]	30[4]	40[4]	50[4]	60[4]	70[4]
20 mph	225 ft	100 ft[6]	N/A[5]	—	—	—	—	—	—
25 mph	325 ft	100 ft[6]	N/A[5]	N/A[5]	—	—	—	—	—
30 mph	460 ft	100 ft[6]	N/A[5]	N/A[5]	—	—	—	—	—
35 mph	565 ft	100 ft[6]	N/A[5]	N/A[5]	N/A[5]	—	—	—	—
40 mph	670 ft	125 ft	100 ft[6]	100 ft[6]	N/A[5]	—	—	—	—
45 mph	775 ft	175 ft	125 ft	100 ft[6]	100 ft[6]	N/A[5]	—	—	—
50 mph	885 ft	250 ft	200 ft	175 ft	125 ft	100 ft[6]	—	—	—
55 mph	990 ft	325 ft	275 ft	225 ft	200 ft	125 ft	N/A[5]	—	—
60 mph	1,100 ft	400 ft	350 ft	325 ft	275 ft	200 ft	100 ft[6]	—	—
65 mph	1,200 ft	475 ft	450 ft	400 ft	350 ft	275 ft	200 ft	100 ft[6]	—
70 mph	1,250 ft	550 ft	525 ft	500 ft	450 ft	375 ft	275 ft	150 ft	—
75 mph	1,350 ft	650 ft	625 ft	600 ft	550 ft	475 ft	375 ft	250 ft	100 ft[6]

[1] The distances are adjusted for a sign legibility distance of 180 feet for Condition A. The distances for Condition B have been adjusted for a sign legibility distance of 250 feet, which is appropriate for an alignment warning symbol sign. For Conditions A and B, warning signs with less than 6-inch legend or more than four words, a minimum of 100 feet should be added to the advance placement distance to provide adequate legibility of the warning sign.

[2] Typical conditions are locations where the road user must use extra time to adjust speed and change lanes in heavy traffic because of a complex driving situation. Typical signs are Merge and Right Lane Ends. The distances are determined by providing the driver a PRT of 14.0 to 14.5 seconds for vehicle maneuvers (2005 AASHTO Policy, Exhibit 3-3, Decision Sight Distance, Avoidance Maneuver E) minus the legibility distance of 180 feet for the appropriate sign.

[3] Typical condition is the warning of a potential stop situation. Typical signs are Stop Ahead, Yield Ahead, Signal Ahead, and Intersection Warning signs. The distances are based on the 2005 AASHTO Policy, Exhibit 3-1, Stopping Sight Distance, providing a PRT of 2.5 seconds, a deceleration rate of 11.2 feet/second^2, minus the sign legibility distance of 180 feet.

[4] Typical conditions are locations where the road user must decrease speed to maneuver through the warned condition. Typical signs are Turn, Curve, Reverse Turn, or Reverse Curve. The distance is determined by providing a 2.5 second PRT, a vehicle deceleration rate of 10 feet/second^2, minus the sign legibility distance of 250 feet.

[5] No suggested distances are provided for these speeds, as the placement location is dependent on site conditions and other signing. An alignment warning sign may be placed anywhere from the point of curvature up to 100 feet in advance of the curve. However, the alignment warning sign should be installed in advance of the curve and at least 100 feet from any other signs.

[6] The minimum advance placement distance is listed as 100 feet to provide adequate spacing between signs.

ADVISORY SPEED PLAQUE

An Advisory Speed plaque (W13-1) is used to supplement warning signs and state advisory speeds for specific conditions. It should be installed below a Horizontal Alignment sign to advise drivers of the safe operating speed through the curve. These safe speeds (displayed in multiples of 5 mph) are advisory and not the legal speed limit.

The MUTCD requires an engineering study to determine the need of an advisory speed plaque. The advisory speed may be any of the following:

- 85th-percentile speed
- 16-degree ball bank indicator reading
- the speed otherwise determined due to unusual circumstances

The **Traffic Control Devices Handbook** suggests using the Advisory Speed plaque whenever the difference between the advisory speed and the posted speed is 6 mph or more.

ONE-DIRECTION LARGE ARROW SIGN

One-Direction Large Arrow (W1-6) signs have proven to be beneficial for curve locations with warning signs that are still experiencing crashes. This sign defines changes in horizontal alignment. Arrow signs provide vital information about curve location and sharpness plus it helps guide the driver.

One-Direction Large Arrow signs are typically installed on the outside of a turn or curve in line with the approaching tangent section, and at approximately a right angle to traffic. Usually, only one of these arrows is used per horizontal curve. One-Direction Large Arrow signs should not be used for locations with no alignment change in direction of travel – beginning/end of medians or at center piers.

One-Direction Large Arrow signs may be used as a supplement or alternative to Chevrons for delineating horizontal alignment changes. These signs may also supplement Turn or Reverse Turn signs for abrupt curves. Typically, either the One-Direction Large Arrow sign or a Chevron Alignment sign is installed with the Hairpin Curve sign or the Loop sign. The Arrow sign should be is limited to sharper curves and be used with an advisory speed plaque.

COMBINATION HORIZONTAL ALIGNMENT/ADVISORY SPEED SIGN

The Turn (W1-1) sign or the Curve (W1-2) sign can be combined with the Advisory Speed (W13-1) plaque to form a combination Turn/Advisory Speed (W1-1a) sign or a combination Curve/Advisory Speed (W1-2a) sign. This sign is intended to advise drivers to slow down as they negotiate any changes in the roadway's horizontal alignment. The speed displayed should be based on the advisory speed for the horizontal curve using recommended engineering practices. These signs may supplement but not replace the advance Horizontal Alignment sign and Advisory Speed plaque, and should be placed at the beginning of the turn or curve.

W1-1a W1-2a

It is left up to an agency's engineering judgment when to use combination Turn/Advisory Speed (W1-1a) sign or combination Curve/Advisory Speed (W1-2a) signs. The Curve Speed (W13-5) sign should be used instead of the combination signs when the distance between the advance horizontal alignment sign and the point of curvature is 200 feet or less. Otherwise, the signs would be too close.

CURVE SPEED SIGN

As shown above, Curve Speed (W13-5) signs perform a similar function as the Combination Horizontal Alignment/Advisory Speed signs. This sign informs motorists of the advisory speed and where the recommended speed changes along the horizontal roadway curvature (compound or spiral design). This sign should be installed either on the inside or outside of the curve to increase its visibility.

It is recommended to use only either one Curve Speed sign or Combination Horizontal Alignment/Advisory Speed sign for locations that may call for both.

CHEVRON ALIGNMENT SIGN

The Chevron Alignment (W1-8) sign conveys critical information about the location and curve sharpness plus it helps guide the driver through the curves. These signs are the best devices for defining the direction and sharpness of curves due to their pattern, size, and location. An advance curve warning sign needs to be installed along with any Chevrons.

Although Chevron Alignment signs may supplement One-Direction Large Arrow signs or delineators, the MUTCD does not provide specific guidance for their usage. The **Traffic Control Devices Handbook** advises installing Chevrons where the difference between the advisory and posted speeds is 25 mph or greater.

Chevrons need to be highly visible in order to provide adequate driver perception-reaction time. These signs should be installed on the outside of a turn or curve, in line with or at a right angle to approaching traffic. A minimum of two chevrons should always be visible by the road user. Three or more visible chevrons help drivers to visualize any changes in the alignment. For two-lane, two-way roads, two-sided Chevron signs can be positioned to guide traffic traveling both directions.

Using higher posts for Chevrons may be helpful at locations with limited sight distance or decreased visibility. The mounting height for Chevron Alignment signs is 5 feet above the surface for rural areas, and 7 feet in urban areas.

Table 2C-6. Typical Spacing of Chevron Alignment Signs on Horizontal Curves

Advisory Speed	Curve Radius	Sign Spacing
15 mph or less	Less than 200 feet	40 feet
20 to 30 mph	200 to 400 feet	80 feet
35 to 45 mph	401 to 700 feet	120 feet
50 to 60 mph	701 to 1,250 feet	160 feet
More than 60 mph	More than 1,250 feet	200 feet

Note: The relationship between the curve radius and the advisory speed shown in this table should not be used to determine the advisory speed.

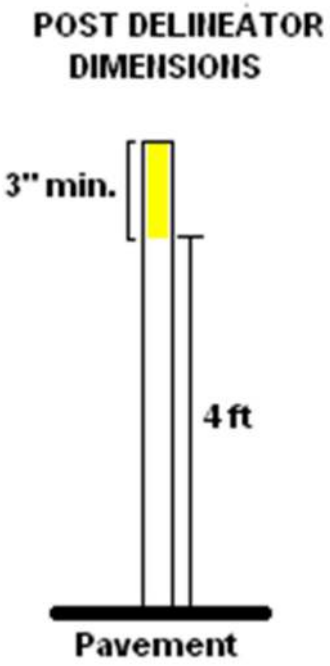
Chevrons have been shown to reduce vehicle encroachments onto the centerline for horizontal curves over 7 degrees.

The cost to install Chevrons may vary depending on the specific location - but a typical installation of about 10 of these signs costs approximately $500.

DELINEATORS

Delineators are useful for roadway locations with sections where the alignment might be confusing or unexpected (lane-reduction transitions, horizontal curves, etc.). These are effective *guidance* devices (rather than warning devices) at night and during adverse weather since they remain visible when pavement markings do not.

Delineators are typically either circular or rectangular (3-in minimum) retroreflective devices that normally retroreflect light from a distance of 1,000 feet when illuminated by standard automobile high beam headlights. They can be placed either on barriers or lightweight breakaway posts.



(Source: Gregory J. Taylor)

Single delineators: One retroreflective element for a given direction of travel at a specific location. May be installed on the left-hand side where needed

Double delineator: Two identical retroreflective elements mounted together for a direction. An appropriately sized vertically elongated delineator may be substituted for a double delineator.

A series of single delineators should be located on the right side of freeways and expressways and on one side of interchange ramps, except when either of the following conditions is met:

1) On tangent sections of freeways and expressways with both of the following conditions:

a. Continuous raised pavement markers are used to supplement pavement markings on lane lines throughout all curves and on all tangents,

and

b. Roadside delineators are used to direct traffic into all curves.

2) On sections of roadways with continuous lighting between interchanges.

Delineators may also be used on other classes of roadways and their colors should comply with the edge line color. Plus, single delineators may be installed on the left-hand side of roadways where needed.

Appropriate colors can indicate where either an outside or inside traffic lane merges into an adjacent lane. Delineators should be installed adjacent to the lane reduced for the full transition length and show the reduction.

Delineator Colors

White	Left-hand side of a two-way roadway
Red	Wrong direction of ramp or roadway
	Truck escape ramp

Red delineators may be used on the reverse side of any delineator to warn drivers traveling in the wrong direction. These delineators should also be used on both sides of truck escape ramps (spaced at 50-foot intervals) to identify the ramp entrance. Spacing beyond the entrance should be adequate for the escape ramp's length and design.

The MUTCD does not provide specific guidance when to use delineators. Due to their relatively low cost, delineators should be considered for horizontal curves (less than 7 degrees) with advance curve warning signs. The mounting height of delineators should be approximately *4 feet* (measured vertically from the bottom of the device to the elevation of the edge of the pavement). They may be mounted at a lower elevation on the face or top of guardrails or other barriers.

Delineators should be installed at a constant distance from the edge of roadway *2 to 8 feet* outside the outer edge of the shoulder; or in line with roadside barriers (maximum distance of 8 feet outside the outer edge of the shoulder). If there are any obstructions between the pavement edge and the line of the delineators, the delineators should be transitioned to the innermost edge of the obstruction. The delineators should be transitioned just behind, directly above, or on the barrier's innermost edge for guardrail or other longitudinal barriers.

Delineators for horizontal curves should be spaced so several delineators are always visible to the road user. Delineators should be spaced 200 to 530 feet apart on *mainline tangent sections* and 100 feet apart on *ramp tangent sections*. Delineators of the appropriate color may be mounted closely-spaced on barriers to form a continuous "ribbon" of delineation where needed. Double or vertically elongated delineators should be installed at 100-foot intervals along acceleration and deceleration lanes.

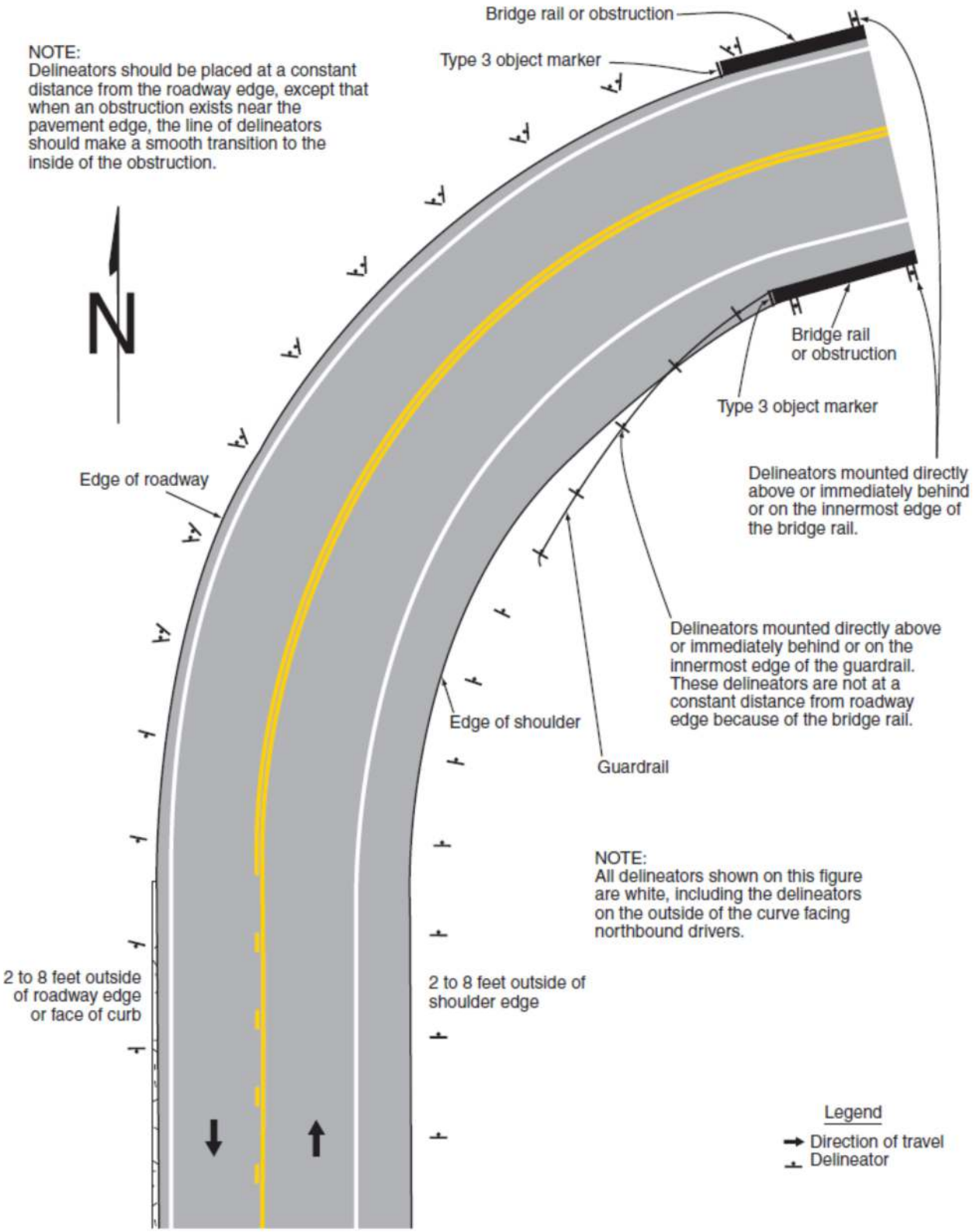
Data from a 1966 Ohio Department of Transportation Study found that delineators on rural two-lane curves reduced run-off-road crashes by 15 percent.

Table 3F-1. Approximate Spacing for Delineators on Horizontal Curves

Radius (R) of Curve	Approximate Spacing (S) on Curve
50 feet	20 feet
115 feet	25 feet
180 feet	35 feet
250 feet	40 feet
300 feet	50 feet
400 feet	55 feet
500 feet	65 feet
600 feet	70 feet
700 feet	75 feet
800 feet	80 feet
900 feet	85 feet
1,000 feet	90 feet

Notes:
1. Spacing for specific radii may be interpolated from table.
2. The minimum spacing should be 20 feet.
3. The spacing on curves should not exceed 300 feet.
4. In advance of or beyond a curve, and proceeding away from the end of the curve, the spacing of the first delineator is 2S, the second 3S, and the third 6S, but not to exceed 300 feet.
5. S refers to the delineator spacing for specific radii computed from the formula $S=3\sqrt{R-50}$.
6. The distances for S shown in the table above were rounded to the nearest 5 feet.

Figure 3F-1. Examples of Delineator Placement



MAINTENANCE TREATMENTS

Road agencies should properly maintain their roadways as well as any associated traffic control devices. It is important to plan and execute maintenance activities for continued user safety. The following maintenance treatments are highly recommended.

Restripe pavement markings as they lose their visibility.

Paint-based pavement markings have a typical service life of 1 to 2 years – which depends on material type, traffic volume, and climate. Thermoplastic markings have a much longer service life. Regular pavement marking inspection and restriping is crucial to provide adequate visibility.

Replace faded signs and those with low levels of retroreflectivity.

Retroreflective sheeting material for roadway signs is primarily responsible for night-time visibility. Although this material is being continuously improved to provide brighter and more durable signs, all signs still lose their color, retroreflectivity, and visibility over time. Responsible parties should have regularly scheduled inspections to ensure appropriate retroreflective levels for all signs. Any sign found to be ineffective should be replaced as soon as possible.

Cut back foliage to improve the sight distance through the curve and increase visibility of traffic control devices.

Safety at horizontal curve locations can be improved by providing the longest possible sight distance through curves or to traffic signs. Various types of vegetation can severely limit a motorist's view of the roadway or signs. Clearing any overgrowth can significantly improve sight distance through the curve and allow drivers to not only see the curve's length and sharpness – but also to see oncoming traffic. Annual roadway inspections can be used for identifying and correcting these issues.

Maintain the shoulders and smooth transitions between pavement and shoulder.

Roadway shoulders without any type of pavement or stabilization will usually erode over time and produce **pavement drop-offs**. Different types of delineation, markings, and warning systems can help correct this situation but periodic shoulder maintenance can *prevent* drop-offs from occurring.

Eliminate roadside obstacles, such as culvert headwalls, or provide adequate shielding.

Since run-off-road crashes occur more frequently at horizontal curves, it is important to minimize any roadside obstacles and install appropriate traffic barriers to shield them. Local authorities should be able to repair any barrier when needed.

Improve drainage around the curve.

Water flows on horizontal curves are caused by the roadway's superelevation. Improper or poor drainage on these curves may result in shoulder deterioration which in turn can cause pavement drop-off and shoulder loss. The use of curbs and improved drain maintenance may help resolve these issues.

SUMMARY

The purpose of this course was to encourage readers to use this information to evaluate problems and implement appropriate treatments for problem curve locations. These treatments should help reduce roadway departure crashes, injuries, and fatalities.

This course summarizes practical information on where, when, or how to apply safety treatments for horizontal curves or winding sections. These treatments are relatively low cost versus geometric design improvements (degree of curve, shoulders, superelevation, curve length, cross-section, etc.). Information for each treatment generally included *description, application guidelines, design elements and materials, effectiveness, and cost.*

Estimates for treatment effectiveness in reducing crashes were included if available. Actual observed effectiveness values of a treatment can vary depending on its location.

Topics covered in this course include:

Basic Treatments – Devices found in the MUTCD

Centerline markings

Edge lines

Horizontal alignment signs

Advisory Speed Plaque

One-Direction Large Arrow Sign

Combination Horizontal Alignment/Advisory Speed Sign

Curve Speed Sign

Chevrons

Delineators

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