

Horizontal Curve Signing Guidance

Mn/DOT District 6

References taken from:

- Mn/DOT Traffic Engineering Manual
- Minnesota Manual on Uniform Traffic Control Devices

(All attached references are subject to change.
The most current version of the manuals can be found at:
<http://www.dot.state.mn.us/trafficeng/otepubl/index.html>

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District 6 Rochester

March 2008



DISTRICT 6

Summary of Contents

Warning Signs & Chevrons

Curve warning sign application by speed (TEM).....	1
Horizontal alignment sign guidance (MUTCD)	2
Advance placement distance for warning signs (MUTCD).....	7
Roadside placement of sign detail sheet	8
Chevron spacing layout (TEM)	9
Chevron & warning sign guidance (TEM)	10

Delineators

Delineator fabrication details (TEM).....	13
Typical delineator installation (MUTCD)	14
Degree of curve determination process (TEM)	15
Delineator spacing guidelines (TEM).....	16
Roadside placement of delineators detail sheet	17
Delineator usage guidance (MUTCD)	18

Ball Bank Indicator Limiting Values in Degrees	Recommended Speed of Curve in MPH	Sign Drawing
14 Degrees	Below 20 MPH	 <p data-bbox="1143 590 1253 625">W1-1(R)</p>
12 Degrees	20 - 30 MPH	
<p>Use this sign when two turns are connected by a tangent of less than 180 meters (600 feet). The lesser of the recommended speeds for the two turns will prevail.</p>		 <p data-bbox="1143 1094 1253 1129">W1-3(R)</p>
10 Degrees	35 MPH and above	 <p data-bbox="1143 1367 1253 1402">W1-2(R)</p>
<p>Use this sign when two curves are connected by a tangent of less than 180 meters (600 feet). The lesser of the recommended speeds for the two curves will prevail.</p>		 <p data-bbox="1143 1619 1253 1654">W1-4(R)</p>
Text Ref.: 6-6.05		
January 1,1996	<p>BALL BANK ANGLES FOR SAFE CURVE SPEEDS</p>	<p>CHART 6-7</p>

Number of Alignment Changes	Advisory Speed	
	≤ 30 MPH	> 30 MPH
1	Turn (W1-1) ¹	Curve (W1-2) ¹
2 ²	Reverse Turn ³ (W1-3)	Reverse Curve ³ (W1-4)
3 or more ²	Winding Road ³ (W1-5)	

Notes:

- ¹ Engineering judgment should be used to determine whether the Turn or Curve sign should be used.
- ² Alignment changes are in opposite directions and are separated by a tangent distance of 180 m (600 ft) or less.
- ³ A Right Reverse Turn (W1-3R), Right Reverse Curve (W1-4R), or Right Winding Road (W1-5R) sign is used if the first change in alignment is to the right; a Left Reverse Turn (W1-3L), Left Reverse Curve (W1-4L), or Left Winding Road (W1-5L) sign is used if the first change in alignment is to the left.

Table 2C-5. Horizontal Alignment Sign Usage

2C.6 Horizontal Alignment Signs (W1-1 through W1-5, W1-11, W1-15)



W1-1
750 x 750 mm
30" x 30"

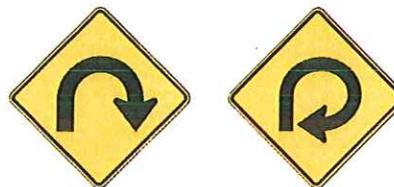
W1-2
750 x 750 mm
30" x 30"

W1-3
750 x 750 mm
30" x 30"



W1-4
750 x 750 mm
30" x 30"

W1-5
750 x 750 mm
30" x 30"



W1-11
750 x 750 mm
30" x 30"

W1-15
750 x 750 mm
30" x 30"

OPTION:

The horizontal alignment Turn (W1-1), Curve (W1-2), Reverse Turn (W1-3), Reverse Curve (W1-4), or Winding Road (W1-5) signs may be used in advance of situations where the horizontal roadway alignment changes. A One-Direction Large Arrow (W1-6) sign (see Section 2C.9) may be used on the outside of the turn or curve.

If the change in horizontal alignment is 135 degrees or more, the Hairpin Curve (W1-11) sign may be used.

If the change in horizontal alignment is approximately 270 degrees, the 270-degree Loop (W1-15) sign may be used.

GUIDANCE:

If used, these signs should be placed in advance of the horizontal alignment changes. The application of these signs should conform to Table 2C-5.

When the Hairpin Curve sign or the 270-degree Loop sign is installed, either a One-Direction Large Arrow (W1-6) sign or Chevron Alignment (W1-8) signs should be installed on the outside of the turn or curve.

OPTION:

An Advisory Speed (W13-1) plaque (see Section 2C.46) may be used to indicate the speed for the change in horizontal alignment. The supplemental distance plaque NEXT XX MILES (W7-3a) may be installed below the Winding Road sign where continuous roadway curves exist (see Section 2C.45). The combination Horizontal Alignment/Advisory Speed sign (see Section 2C.7) or the combination Horizontal Alignment/Intersection sign (see Section 2C.8) may also be used.

STANDARD:

When engineering judgment determines the need for a horizontal alignment sign, one of the W1-1 through W1-5, W1-10, W1-11, or W1-15 signs shall be used.

OPTION:

If the reduction in speed is 15 mph or greater, a supplemental combination Horizontal Alignment/Advisory Speed sign may be installed as near as practical to the point of curvature.

2C.7 Horizontal Alignment/Advisory Speed Sign Assembly



W1-2
750 x 750 mm
30" x 30"

W13-1
450 x 450 mm
18" x 18"

OPTION:

The Turn (W1-1) sign or the Curve (W1-2) sign may be combined with the Advisory Speed (W13-1) plaque (see Section 2C.46) to create a combination Horizontal Alignment/Advisory Speed Sign assembly.

STANDARD:

When used, the combination Horizontal Alignment/Advisory Speed sign assembly shall supplement other advance warning signs and shall be installed at the beginning of the turn or curve.

The minimum size of the W13-1 sign shall be 450 x 450 mm (18 x 18 in) when used in combination with a 750 x 750 mm (30 x 30 in) Horizontal Alignment sign. On high-speed expressway facilities, the minimum size of the W13-1 sign shall be 600 x 600 mm (24 x 24 in) when used in combination with a 900 x 900 mm (36 x 36 in) Horizontal Alignment sign.

2C.8 Combination Horizontal Alignment/Intersection Sign (W1-10)



W1-10
750 x 750 mm
30" x 30"

OPTION:

The Turn (W1-1) sign or the Curve (W1-2) sign may be combined with the Cross Road (W2-1) sign or the Side Road (W2-2 or W2-3) sign to create a combination Horizontal Alignment/Intersection (W1-10) sign that depicts the condition where an intersection occurs within a turn or curve.

GUIDANCE:

Elements of the combination Horizontal Alignment/Intersection sign related to horizontal alignment should conform to Section 2C.6, and elements related to intersection configuration should conform to Section 2C.37. No more than one Cross Road or two Side Road symbols should be shown on any one combination Horizontal Alignment/Intersection sign.

2C.9 One-Direction Large Arrow Sign (W1-6)



W1-6
1200 x 600 mm
48" x 24"

OPTION:

A One-Direction Large Arrow (W1-6) sign may be used to delineate a change in horizontal alignment.

STANDARD:

The One-Direction Large Arrow sign shall be a horizontal rectangle with an arrow pointing to the left or right.

If used, the One-Direction Large Arrow sign shall be installed on the outside of a turn or curve in line with and at approximately a right angle to approaching traffic.

The One-Direction Large Arrow sign shall not be used where there is no alignment change in the direction of travel, such as at the beginnings and ends of medians or at center piers.

GUIDANCE:

The One-Direction Large Arrow sign should be visible for a sufficient distance to provide the road user with adequate time to react to the change in alignment.

2C.10 Chevron Alignment Sign (W1-8)



W1-8
450 x 600 mm
18" x 24"

OPTION:

The Chevron Alignment (W1-8) sign may be used to provide additional emphasis and guidance for a change in horizontal alignment. A Chevron Alignment sign may be used as an alternate or supplement to standard delineators on curves or to the One-Direction Large Arrow (W1-6) sign.

STANDARD:

The Chevron Alignment sign shall be a vertical rectangle. No border shall be used on the Chevron Alignment sign.

If used, Chevron Alignment signs shall be installed on the outside of a turn or curve, in line with and at approximately a right angle to approaching traffic.

OPTION:

A Chevron Alignment sign may be used on the far side of an intersection to inform drivers of a change of horizontal alignment for through traffic.

GUIDANCE:

Spacing of Chevron Alignment signs should be such that the road user always has at least two in view, until the change in alignment eliminates the need for the signs.

Chevron Alignment signs should be visible for a sufficient distance to provide the road user with adequate time to react to the change in alignment.

2C.45 Distance Plaques
(W16-2 series, W16-3 series,
W16-4, W7-3a)



W16-2
600 x 300 mm
24" x 12"



W16-2a
600 x 450 mm
24" x 18"



W16-4
600 x 450 mm
24" x 18"



W16-3
600 x 450 mm
24" x 18"



W16-3a
600 x 300 mm
24" x 12"



W7-3a
600 x 450 mm
24" x 18"

OPTION:

The Distance Ahead (W16-2 series and W16-3 series) plaques may be used to inform the road user of the distance to the condition indicated by the warning sign.

The Next Distance (W7-3a and W16-4) plaques may be used to inform road users of the length of roadway over which the condition indicated by the warning sign exists.

2C.46 Advisory Speed Plaque (W13-1)



W13-1
450 x 450 mm
18" x 18"

OPTION:

The Advisory Speed (W13-1) plaque may be used to supplement any warning sign to indicate the advisory speed for a condition.

STANDARD:

The Advisory Speed plaque shall be used where an engineering study indicates a need to advise road users of the advisory speed for a condition.

If used, the Advisory Speed plaque shall carry the message XX MPH. The speed shown shall be a multiple of 5 mph.

Except in emergencies or when the condition is temporary, an Advisory Speed plaque shall not be installed until the advisory speed has been determined by an engineering study.

GUIDANCE:

Because changes in conditions, such as roadway geometrics, surface characteristics, or sight distance, might affect the advisory speed, each location should be periodically evaluated and the Advisory Speed plaque changed if necessary.

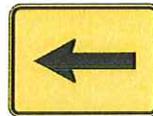
OPTION:

The advisory speed may be the 85th-percentile speed of free-flowing traffic, the speed corresponding to a 10-degree ball bank indicator reading, or the speed otherwise determined by an engineering study because of unusual circumstances.

SUPPORT:

A 10-degree ball-bank indicator reading, used in determining advisory speeds, is based on research from the 1930s. In modern passenger vehicles, the 85th-percentile speed on curves approximates a 16-degree reading.

2C.47 Supplemental Arrow Plaques
(W16-5p, W16-6p, W16-7p)



W16-5p
600 x 450 mm
24" x 18"



W16-6p
600 x 450 mm
24" x 18"



W16-7p
600 x 450 mm
24" x 18"

GUIDANCE:

If the condition indicated by a warning sign is located on an intersecting road and the distance between the intersection and condition is not sufficient to provide adequate advance placement of the warning sign, a Supplemental Arrow (W16-5p, W16-6p, or W16-7p) plaque should be used below the warning sign.

STANDARD:

Supplemental Arrow plaques shall have the same legend design as the Advance Turn and Directional Arrow auxiliary signs (see Sections 2D.25 and 2D.26) except that they shall have a black legend and border on a yellow or fluorescent yellow-green background, as appropriate.

Size of Warning Sign		Size of Supplemental Plaque							
		Rectangular						Square	
		1 Line		2 Lines		Arrow			
		mm	in	mm	in	mm	in	mm	in
600 x 600 750 x 750	24 x 24 30 x 30	600 x 300	24 x 12	600 x 450	24 x 18	600 x 450	24 x 12	450 x 450	18 x 18
900 x 900 1200 x 1200	36 x 36 48 x 48	750 x 450	30 x 18	750 x 600	30 x 24	750 x 450	30 x 18	600 x 600	24 x 24

- Notes: 1. Larger supplemental plaques may be used when appropriate.
2. Dimensions are shown as width x height.

Table 2C-3. Minimum Size of Supplemental Warning Plaques

2C.5 Placement of Warning Signs

SUPPORT:

For information on placement of warning signs, see Sections 2A.16 to 2A.21.

The total time needed to perceive and complete a reaction to a sign is the sum of the times necessary for Perception, Identification (understanding), Emotion (decision making), and Volition (execution of decision), and is called the PIEV time. The PIEV time can vary from several seconds for general warning signs to 6 seconds or more for warning signs requiring high road user judgment.

Table 2C-4 lists suggested sign placement distances for two conditions. This table is provided as an aid for determining warning sign location.

GUIDANCE:

Warning signs should be placed so that they provide adequate PIEV time. The distances contained in Table 2C-4 are for guidance purposes and should be applied with engineering judgment. Warning signs should not be placed too far in advance of the condition, such that drivers might tend to forget the warning because of other driving distractions, especially in urban areas.

Minimum spacing between warning signs with different messages should be based on the estimated PIEV time for driver comprehension of and reaction to the second sign.

The effectiveness of the placement of warning signs should be periodically evaluated under both day and night conditions.

OPTION:

Warning signs that advise road users about conditions that are not related to a specific location, such as Deer Crossing or SOFT SHOULDER, may be installed in an appropriate location, based on engineering judgment, since they are not covered in Table 2C-4.

Posted or 85th percentile speed mph (mph)	Minimum Advance Placement Distance ¹								
	Condition A: Speed Reduction and Lane Changing in Heavy Traffic ² feet	Condition B: Deceleration to the listed advisory speed (mph) for the condition							
		0 ³ feet	10 ⁴ feet	20 ⁴ feet	30 ⁴ feet	40 ⁴ feet	50 ⁴ feet	60 ⁴ feet	70 ⁴ feet
20	225	see Note ⁵	see Note ⁵	---	---	---	---	---	---
25	325	see Note ⁵	see Note ⁵	see Note ⁵	---	---	---	---	---
30	450	75	see Note ⁵	see Note ⁵	---	---	---	---	---
35	550	125	125	see Note ⁵	see Note ⁵	---	---	---	---
40	650	200	175	150	see Note ⁵	---	---	---	---
45	775	275	250	225	150	see Note ⁵	---	---	---
50	875	350	350	300	225	150	---	---	---
55	975	450	425	375	325	225	see Note ⁵	---	---
60	1125	525	525	475	425	325	200	---	---
65	1200	625	625	575	525	425	300	see Note ⁵	---
70	1275	750	725	700	625	525	400	275	---
75	1375	850	850	800	750	650	525	375	200

NOTES:

¹ The distances are adjusted for a sign legibility distance of 175 ft, which is the appropriate legibility distance for a 5 inch Series D word legend. The distances may be adjusted by deducting another 100 feet if alignment symbol signs are used. Adjustments may also be made for grades, limited sight distance, or pavement condition.

² Typical conditions are locations where the road user might use extra time to adjust speed and change lanes in heavy traffic because of a complex driving situation. A typical sign is Right Lane Ends. The distances are based on the 2001 AASHTO Policy, Exhibit 3-3, Decision Sight Distance, Avoidance Maneuver E, providing the driver a PIEV/Maneuver time of 14.0 to 14.5 seconds minus the sign legibility distance of 175 feet.

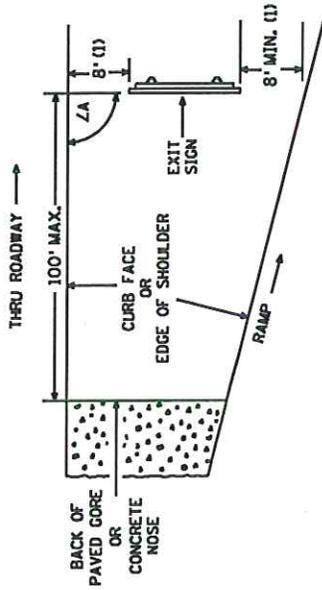
³ Typical condition is the warning of a potential Stop situation. Typical signs are Stop Ahead, Yield Ahead, Signal Ahead, and Intersection Warning signs. The distances are based on the 2001 AASHTO Policy, Equation 3-2, providing the driver a PIEV time of 2.5 seconds, a deceleration rate of 8.1 ft/second², minus the sign legibility distance of 175 ft.

⁴ Typical conditions are where the road user must decelerate to the advised speed to maneuver through the warned condition. Typical signs are Turn, Curve, Reverse Turn, or Reverse Curve, combined with an Advisory Speed sign. The distances are based on the 2001 AASHTO Policy, Equation 3-2, providing the driver a PIEV time of 2.5 seconds, a deceleration rate of 8.1 ft/second², minus the sign legibility distance of 175 ft.

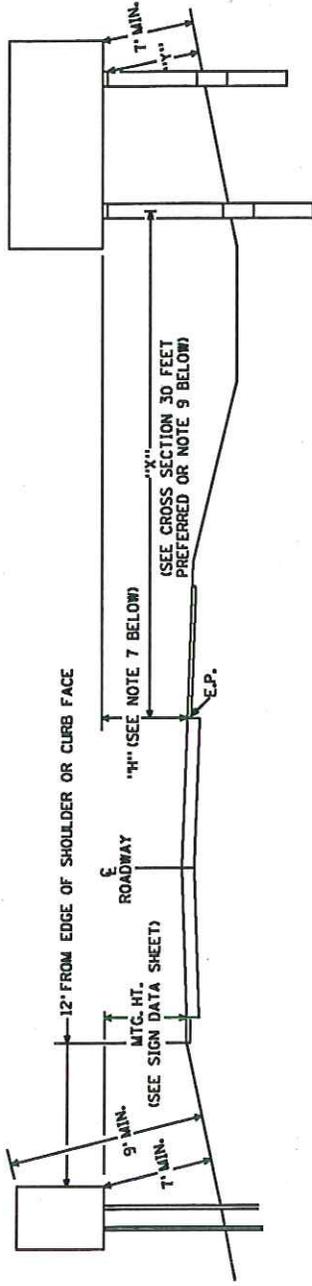
⁵ No suggested minimum distances are provided for these speeds, as placement location is dependent on site conditions and other signing to provide an adequate advance warning for the driver.

**Table 2C-4. Guidelines for Advance Placement of Warning Signs
(English units of measure)**

GORE PLACEMENT



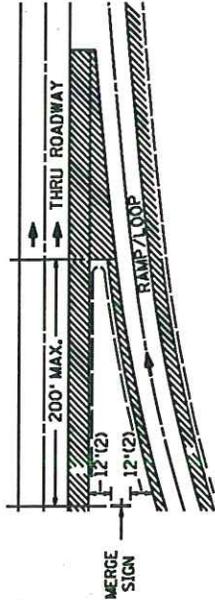
ROADSIDE PLACEMENT



ROUTE MARKER, REGULATORY & WARNING SIGNS - TYPE C

MINOR GUIDE SIGNS - TYPE D

MAJOR GUIDE SIGN - TYPE A



SPECIFIC NOTES:

(1) EXIT SIGNS

IF THESE OFFSETS CANNOT BE ATTAINED WITHIN 100 FEET OF THE PAVED GORE, A 4 FOOT OFFSET IS ACCEPTABLE. IF THE 4 FOOT OFFSETS CANNOT BE ATTAINED WITHIN 100 FEET OF THE PAVED GORE, CONTACT THE OTSO SIGNING UNIT.

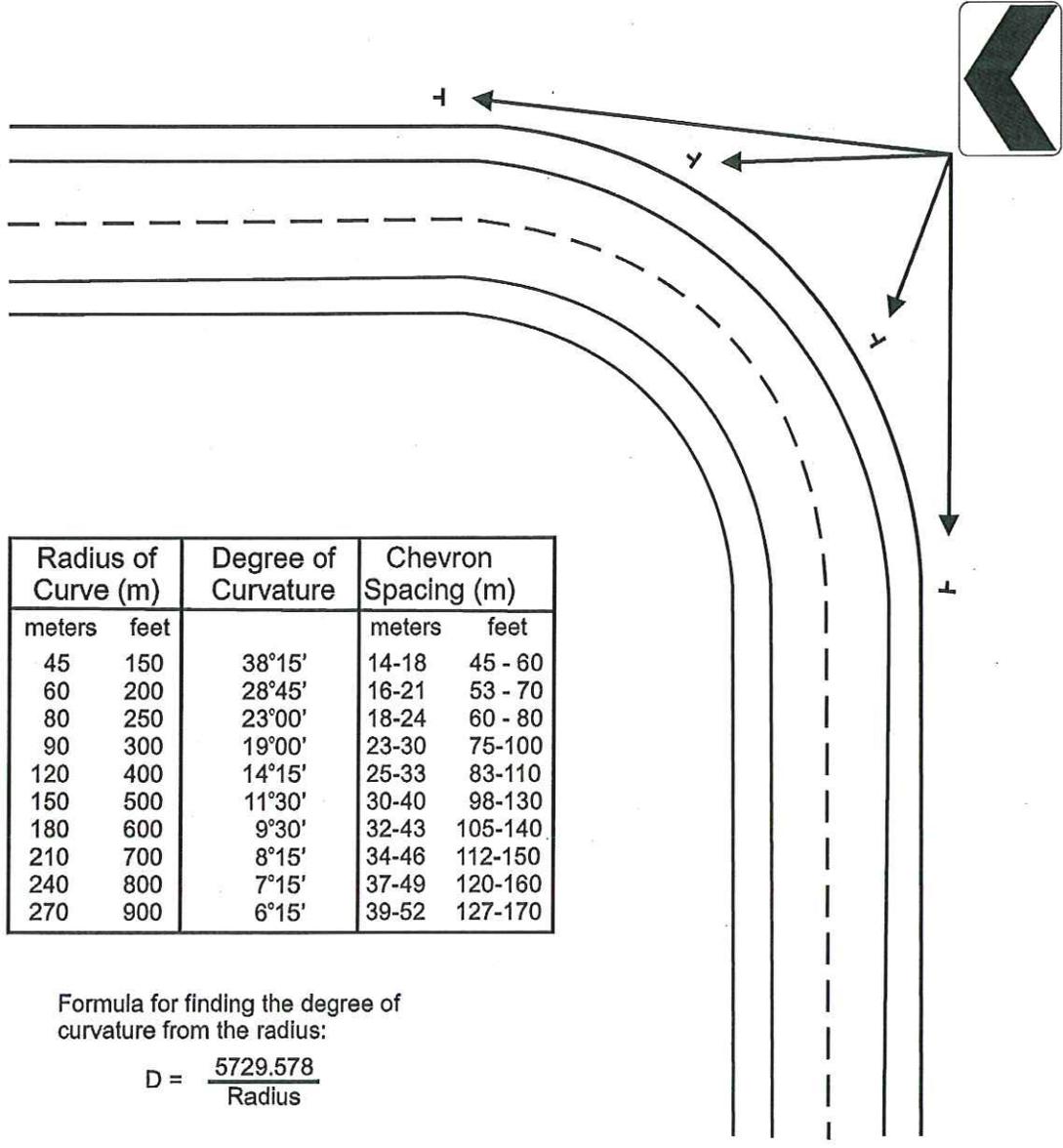
(2) MERGE SIGNS

IF THESE OFFSETS CANNOT BE ATTAINED WITHIN 200 FEET OF THE PAVED GORE, A 4 FOOT OFFSET IS ACCEPTABLE. IF THE 4 FOOT OFFSETS CANNOT BE ATTAINED WITHIN 200 FEET OF THE PAVED GORE, CONTACT THE OTSO SIGNING UNIT.

NOTES:

1. IF A SECONDARY SIGN IS MOUNTED BELOW A MAJOR SIGN, THE MAJOR SIGN SHALL BE AT LEAST 8' ABOVE THE PAVEMENT EDGE AND THE SECONDARY SIGN AT LEAST 5'.
2. ALL ROUTE MARKERS, WARNING AND REGULATORY SIGNS SHALL BE AT LEAST 7' ABOVE PAVEMENT EDGE.
3. SIGN FACES SHALL BE VERTICAL.
4. OVERHEAD SIGNS SHALL BE POSITIONED AT RIGHT ANGLES TO THE THRU ROADWAY UNLESS OTHERWISE NOTED.
5. TO AVOID SPECULAR GLARE, ZA SHALL BE APPROXIMATELY 93° FOR SIGNS LOCATED LESS THAN 30' FROM THE EDGE OF PAVEMENT AND APPROXIMATELY 92° FOR SIGNS LOCATED 30' OR MORE FROM EDGE OF PAVEMENT. THIS APPLIES TO SIGNS TYPE A, C, & D AND INCLUDES SIGNS IN THE GORE.
6. "Y" IS THE PERPENDICULAR DISTANCE FROM THE GROUND LINE TO THE FRICTION FUSE ON THE POST. THIS DISTANCE SHALL BE AT LEAST 7'.
7. WHERE "X" IS LESS THAN 30', "H" SHALL BE 7' ± 6", WHERE "X" IS 30' OR GREATER, MINIMUM AND PREFERRED "H" IS 5'.
8. LATERAL CLEARANCES GIVEN APPLY TO RIGHT AND OR LEFT SIDE INSTALLATION.
9. WHEN A TYPE A SIGN IS INSTALLED DIRECTLY BEHIND TRAFFIC BARRIER, THE LEFT EDGE OF THE SIGN PANEL SHALL BE LOCATED A MINIMUM OF 4 FEET BEHIND THE FACE OF THE TRAFFIC BARRIER.

SIGN PLACEMENT



Radius of Curve (m)		Degree of Curvature	Chevron Spacing (m)	
meters	feet		meters	feet
45	150	38°15'	14-18	45 - 60
60	200	28°45'	16-21	53 - 70
80	250	23°00'	18-24	60 - 80
90	300	19°00'	23-30	75-100
120	400	14°15'	25-33	83-110
150	500	11°30'	30-40	98-130
180	600	9°30'	32-43	105-140
210	700	8°15'	34-46	112-150
240	800	7°15'	37-49	120-160
270	900	6°15'	39-52	127-170

Formula for finding the degree of curvature from the radius:

$$D = \frac{5729.578}{\text{Radius}}$$

Text Ref.: 6-6.02

WARNING SIGNS

6.01 Purpose

The warning sign applications that are discussed in this section are those which:

1. are not specifically addressed in the MN MUTCD, or
2. provide additional guidance to that given in the MN MUTCD on application, location, and usage of certain types of warning signs, or
3. establish practices relating to engineering and traffic investigation requirements for certain warning signs.

The chart in Chart 6-5 and the following paragraph are reprinted from the MN MUTCD, Section 2C-3, and are duplicated here to stress the importance of maintaining proper minimum distances for warning sign placement.

Since warning signs are primarily for the benefit of the driver who is unacquainted with the road, it is very important that care be given to the placement of such signs. Warning signs should provide adequate time for the driver to perceive, identify, decide, and perform any necessary maneuver. This total time to perceive and complete a reaction to a sign is the sum of the times necessary for Perception, Identification/ understanding, Emotion/decision making, and Volition/execution of decision, and is here referred to as the PIEV time. The PIEV time can vary from about 3 seconds for general warning signs to 10 seconds for high driver judgment condition warning signs.



6-6.02 Advisory Exit Speed Signs

The Advisory Exit Speed sign (W13-2) advises motorists of the maximum recommended speed on a ramp.

This sign shall be installed in accordance with the following guidelines:

1. If the maximum recommended speed on a ramp, as it exits the mainline roadway, is less than, or equal to, 70 percent of the design speed of the mainline roadway, the exit ramp shall be signed with an Advisory Exit Speed sign. Locate the sign along the mainline in accordance with the MN MUTCD, Section 2C-33.
2. The removal or replacement of existing signs not

meeting the above guidelines should be through normal attrition as follows:

- a. Replace existing Advisory Exit Speed signs with new signs if ramp speeds meet the above recommendation.
- b. Remove existing Advisory Exit Speed signs if ramp speeds do not meet the above recommendation.
- c. Remove existing Advisory Ramp Speed signs located along the mainline. If a ramp speed meets the above recommendation, install an Advisory Exit Speed sign when the Ramp Speed sign is removed.

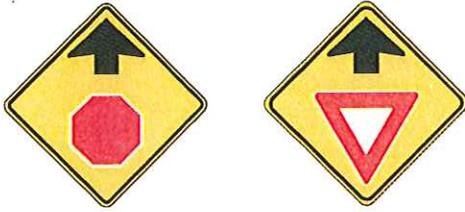


6-6.03 Chevron Alignment Signs

The Chevron Alignment sign (W1-8) is a warning sign and, as with all warning signs, should be used sparingly, as excessive use will reduce its effectiveness. Generally, this sign should be used only on 6 degree curves or greater. Curves of less than 6 degrees would be marked by standard delineation as covered in Chapter 7.

Although this sign aids in delineating the roadway, it is a warning sign and shall be installed as specified in the MN MUTCD, Sections 2A-23, 2A-24 and 2C-10. Height and lateral clearance for all signs on a curve should be uniform, to accurately delineate the roadway.

The first sign should be placed near the beginning of the curve. Spacing of the signs should be such that the motorist always has two in view, until the change in alignment eliminates the need for the signs. Variables such as approach speed, grade, super elevation, visibility and vertical alignment all affect the spacing of the signs. Chart 6-6 shows spacing of signs on various curves. Generally, the sign size is governed by the road classification (refer to Appendix C of the MN MUTCD or the Standard Signs Summary). Although the standard size for conventional roads is 450 x 600 mm (18" x 24"), the 600 x 750 mm (24" x 30") sign may be used based on engineering judgment.

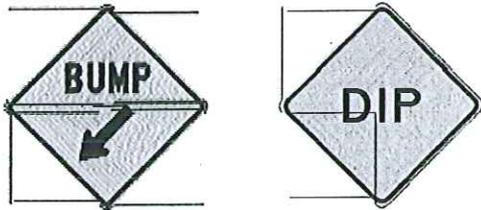


6-6.04 Advance Warning Signs on Local Road Approaches

This section details the installation and maintenance of advance warning signs on local road approaches to conventional highway intersections.

The advance warning signs are: STOP AHEAD, YIELD AHEAD, and SIGNAL AHEAD.

1. Maintenance of these advance warning signs currently in place on all local road approaches to conventional highway intersections is the responsibility of the local road authority.
2. At new intersections, or at intersections where traffic control is revised by Mn/DOT, Mn/DOT will investigate the need for advance warning signs on the local road approaches and furnish and install the appropriate sign. The road authority(s) should be notified in writing of the sign installations. Maintenance of the advance warning signs will then become the complete responsibility of the local road authority.



6-6.05 BUMP and DIP Signs

This section presents guidelines on the placement of BUMP (W8-1a) and DIP (W8-2) warning signs. The BUMP and DIP signs shall be installed in advance, and at the site of, sharp rises or depressions in the profile of the roadway, respectively, which are sufficiently abrupt to create a hazardous condition, to cause considerable discomfort to passengers, to cause a shifting of the cargo, or to deflect a vehicle from its true course at the normal driving speeds for the road.

It may be desirable to supplement these signs with an Advisory Speed plaque (MN MUTCD, Section 2C-42) especially if the condition exists on a high speed roadway and of such a severe nature as to damage a vehicle if a motorist fails to make the necessary reduction in speed prior to the hazardous condition.

At less severe or multiple bumps, a BUMP AHEAD (W8-1a) or BUMPS (W8-1b) sign, should be placed an adequate distance in advance of the site(s) to ensure that a motorist has sufficient warning before arriving at the location (s). An appropriate distance plaque, W20-100P or NEXT ___ MILES (W7-3a), shall be placed below the warning sign. At the site of each severe bump, a "down arrow" shall be added to the sign face instead of "AHEAD" to identify the exact location of the bump. Figure 6.14 shows the typical placement of these signs.

When locations have multiple bumps of lesser severity or pavement breaks, for a distance in excess of 1.6 km (one mile), then the "ROUGH ROAD" (W8-8) warning sign should be used. The supplemental distance plaque W7-3a should be used below it.

Note:

The use of a flashing beacon or orange flag is discretionary, depending on the severity of the bump or dip. When used, they should be mounted on the advance sign assembly.



6-6.06 Advisory Curve Surveys

Curve and turn signs should be used to inform the driver of a change in geometrics that is not readily apparent or occurs in an unexpected location compared to the typical character of the roadway. These warning signs require caution on the part of the vehicle operator and may call for reduction of speed or a maneuver in the interest of comfort and safety. The need for curve and turn signs may be determined in the field by making several trial runs through the curves in a test vehicle equipped with a slope meter or an electronic meter, such as Model E45 manufactured by Rieker Instrument Company. The ball-bank reading is a measure of the amount of centrifugal force on the vehicle.

1. Slope Meter

The slope meter is an instrument used to determine the comfortable speed that a passenger vehicle can travel around a curved roadway section. This instrument consists of a steel ball in a sealed, curved glass tube filled with an alcohol solution. The tube, bent on the arc of a circle, is graduated from 0 to 20 degrees, both to the left and right of

the zero point. The tube is enclosed in a metal case. When mounting the ball-bank indicator, the vehicle should be in a stationary level position. The speedometer of the test vehicle must be accurately calibrated and the tires uniformly inflated. The indicator should be mounted vertically, with the steel ball at the zero point. All occupants who are to be in the vehicle when the observations are made should be in the same position when mounting or checking the instrument as when making the test drive. This is necessary because changing the position of a passenger or the load in the test vehicle may cause the vehicle body to tilt to the right or left. This tilting action or body roll will cause a change in the slope meter readings.

2. Procedures for Testing A Curve

The use of the slope meter or electronic meter to measure the comfortable speed on curves involves the efforts of two people--one to drive and the other to observe the meter. The following procedures should be followed in each test:

- a. The curve under observation should first be appraised by the driver to determine the approximate safe speed which can be maintained.
- b. The driver should then conduct the first test at a speed 10 mph below the appraised speed.
- c. Each succeeding test should be made at a speed 5 mph greater than the preceding test, until the meter has reached 10 degrees, except as indicated on Chart 6-7.
- d. On each test, the driver should attain the trial run speed at a distance of at least 400 m (1/4 mile) from the beginning of the curve.
- e. The course throughout the curve should be maintained precisely in the center of the lane and at uniform speed. Using a vehicle with cruise control aids in this process.
- f. The observer shall note carefully the position of the ball on the slope meter or the display on an electronic meter at the approximate center of the curve and shall record the reading.
- g. The reading shall be recorded as right or left of zero. The turn sign showing an arrow bent at a right angle (W1-1 left or right) should be used to mark curves on which a meter indicates 10 degrees or more at a speed of 30 mph or less. Additional protection may be provided by use of the Advisory Speed plate.
- h. The curve sign showing a curved arrow (W1-2 left or right) should be used to mark a curve where a test with a meter gives readings of 10 degrees or more at speeds equal to or greater than 35 mph and equal to or less than the legal speed limit established on that section of highway. Additional protection may be provided by the use of the Advisory Speed plate.

- i. The reverse curve sign (W1-4 Left or Right) and reverse turn sign (W1-3 Left or Right) shall be installed to mark two curves or two turns as defined above and connected by a tangent of less than 180 m (600 feet). When an advisory speed plate is used, the lower of the two recommended speeds will prevail.

3. Curve Study Sheet

It is important that all information be recorded as indicated on a curve study sheet. As provided on the curve study sheet, trial runs should be made in each direction. The ball bank angles in Chart 6-7 shall be used to establish the safe speed on curves. As an example, for the speed range 35 mph and above, the comfortable speed for the curve is the exact speed which swings the ball 10 degrees off center on a slope meter or displays 10 degrees on an electronic meter. Any speed which causes the ball to move more than 10 degrees away from the zero position is considered uncomfortable to the driver and possibly unsafe at higher speeds.



6-6.07 Crossing Signs

6-6.07.01 Pedestrian Crossing Signs (warning and regulatory)

1. Typical Pedestrian Crossings

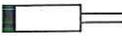
This section covers usage of pedestrian warning signs at locations where emphasis is needed to alert motorists to pedestrians crossing the highway. Specifics for installation of the STOP FOR PEDESTRIAN IN CROSSWALK (R1-X1) sign are found in the MN MUTCD.

Typical examples where special treatment should be considered include isolated intersections where there are heavy pedestrian volumes, pedestrian crossings where approach visibility is poor, and at mid-block crosswalks.

Special treatment is not usually required at normal intersections within municipalities, or at rural intersections.

Figures 6.15A and 15B set forth guidelines for the placement of Pedestrian Warning signs (W11-2), STOP FOR PEDESTRIAN IN CROSSWALK signs (R1-X1), and pedestrian crosswalk markings. In urban areas, the distance for the advance crossing sign may be less where mounting

Wide Angle VIP Retroreflective Sheeting (TYPE IX)

NAME	DELINEATOR	SIZE	COLOR	INFORMATION SEE MN MUTCD
One Tenth Mile Delineator (X4-8)		100 x 100 mm (4" x 4")	White	Section 2D-46
Guide Delineator (X4-6)		200 x 600 mm (8" x 24")	Black top on White or Yellow	None
Chevron Alignment Sign (W1-8)		450 x 600 mm (18" x 24")	Black on Yellow	Section 2C-10
Alignment Delineator (X4-7)		100 x 200 mm (4" x 8")	White or Yellow	None

Type VII MD Retroreflective Sheeting

Cylinder Style		150 mm (6") Diameter 225 mm (9") Height	White or Yellow	Section 3D-4.5
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Text Ref.: 7-5.04

July 1, 1998	DELINEATOR FABRICATION DETAILS	CHART 7-6
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NOTE:
 Delineators should be placed at a constant distance from the roadway edge except when an obstruction exists near the pavement edge, the line of delineators should make a smooth transition to the inside of the obstruction.

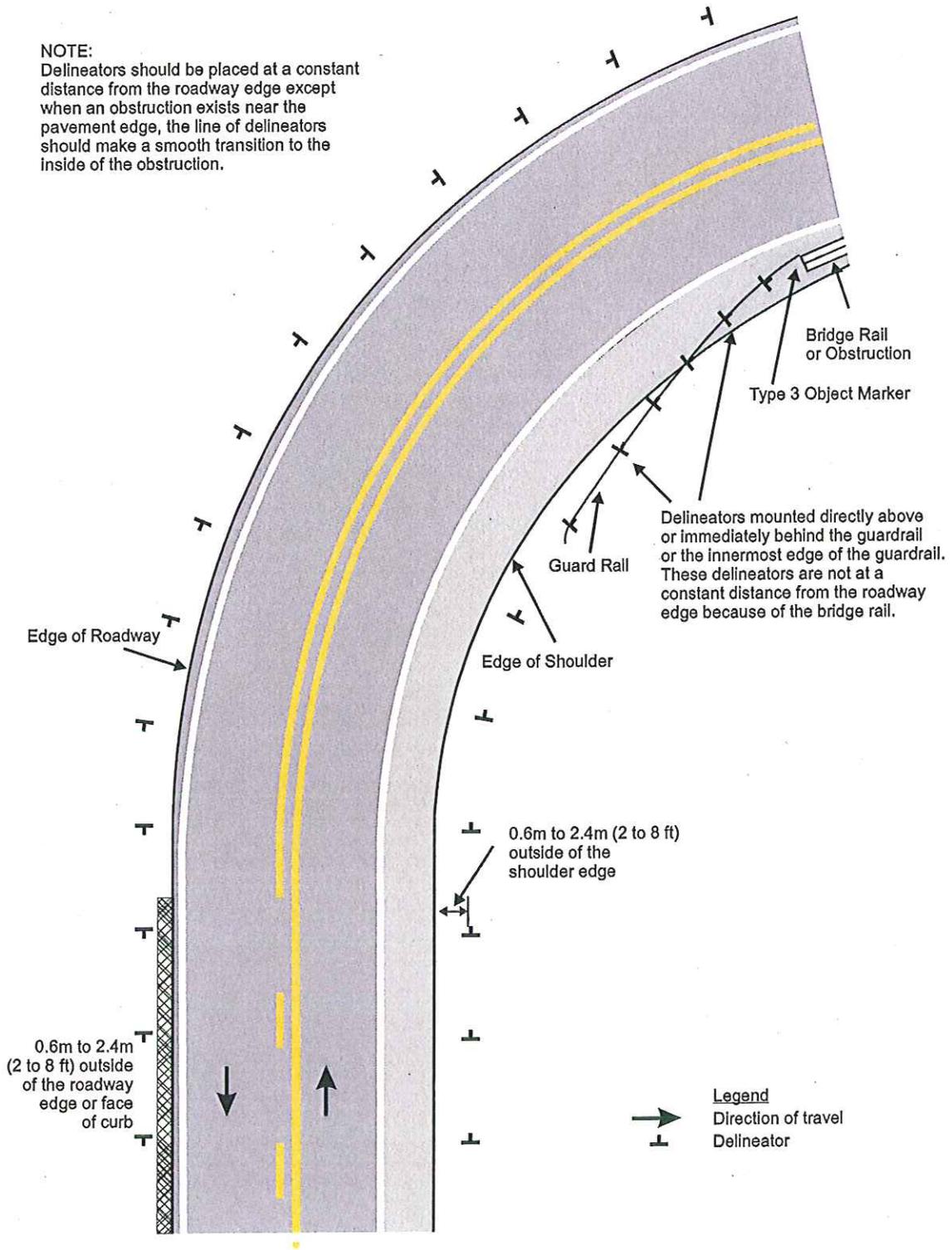
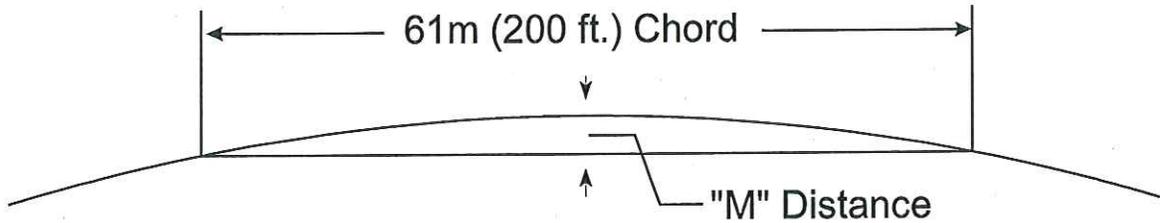


Figure 3D-1 Typical Delineator Installation



Take 61m (200 ft.) tape, chain, or rope and stretch it between two points on a curve. At the center (30.5m or 100 ft. mark), measure the distance in meters and millimeters (feet and inches) between the chord and the arc.

DEGREE OF CURVE RELATED TO "M" FOR A 61m (200 ft.) CHORD

Degree of Curve	Distance "M"		Distance "M"		Radius	
	meters	feet	millimeters	inches	meters	feet
0°30'	0.134	.44	14	5-1/2		
1°00'	0.265	.87	27	10-1/2	1745	5,730
1°30'	0.399	1.31	40	15-3/4	1165	3,820
2°00'	0.533	1.75	53	21	875	2,865
2°30'	0.664	2.18	66	26	700	2,292
3°00'	0.798	2.62	80	31-1/2	580	1,910
3°30'	0.933	3.06	93	36-3/4	500	1,637
4°00'	1.064	3.49	107	42	435	1,432
4°30'	1.198	3.93	119	47-1/4	390	1,273
5°00'	1.332	4.37	133	52-1/2	350	1,146
5°30'	1.466	4.81	147	57-3/4	320	1,042
6°00'	1.600	5.25	160	63	290	955
6°30'	1.734	5.69	174	68-3/8	270	881
7°00'	1.868	6.13	187	73-5/8	250	819
7°30'	2.002	6.57	200	78-7/8	235	764
8°00'	2.140	7.02	214	84-1/4	220	716
8°30'	2.274	7.46	227	89-1/2	205	674
9°00'	2.408	7.90	241	94-3/4	195	637
9°30'	2.545	8.35	255	100-1/4	185	603
10°00'	2.679	8.79	268	105-1/2	175	573

Text Ref.: 7-6.04.02

July 1, 1998	FINDING THE DEGREE OF CURVE FOR A HORIZONTAL CURVE	CHART 7-7
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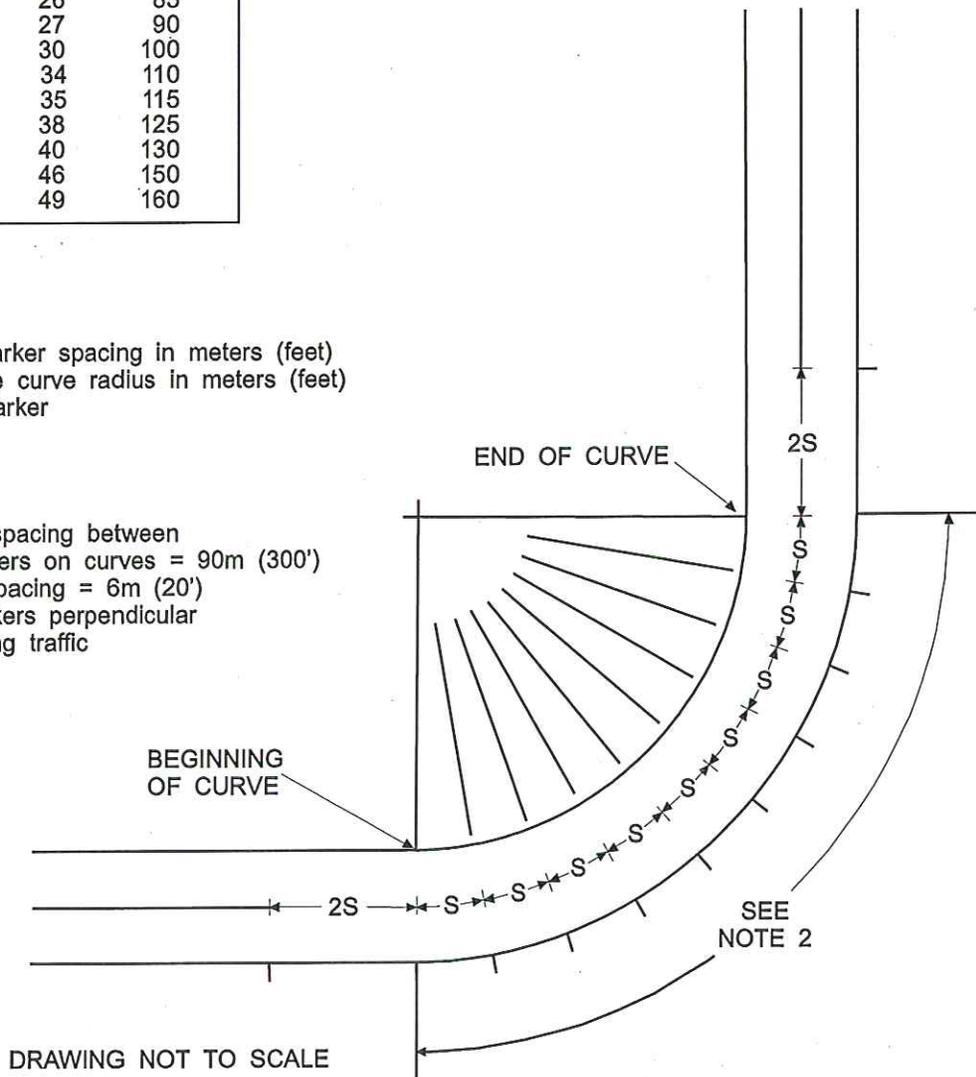
Curve Radius (meters feet)		Guide Marker Spacing (meters feet)	
15	50	6	20
23	75	6	20
30	100	8	25
45	150	9	30
61	200	11	35
91	300	15	50
122	400	17	55
152	500	20	65
183	600	21	70
213	700	23	75
241	800	24	80
274	900	26	85
305	1000	27	90
366	1200	30	100
427	1400	34	110
488	1600	35	115
549	1800	38	125
610	2000	40	130
762	2500	46	150
914	3000	49	160

LEGEND:

- S = Guide marker spacing in meters (feet)
- R = Centerline curve radius in meters (feet)
- I = Guide marker

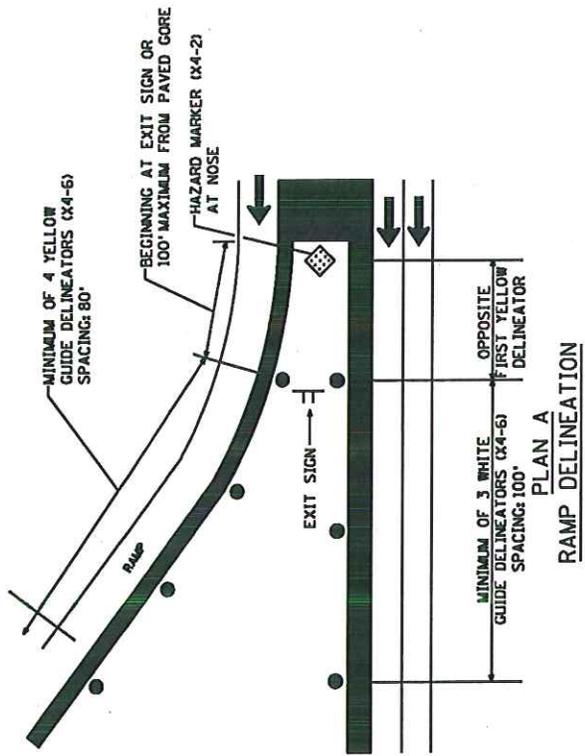
NOTES:

- 1) Maximum spacing between guide markers on curves = 90m (300')
- Minimum spacing = 6m (20')
- 2) Install markers perpendicular to oncoming traffic

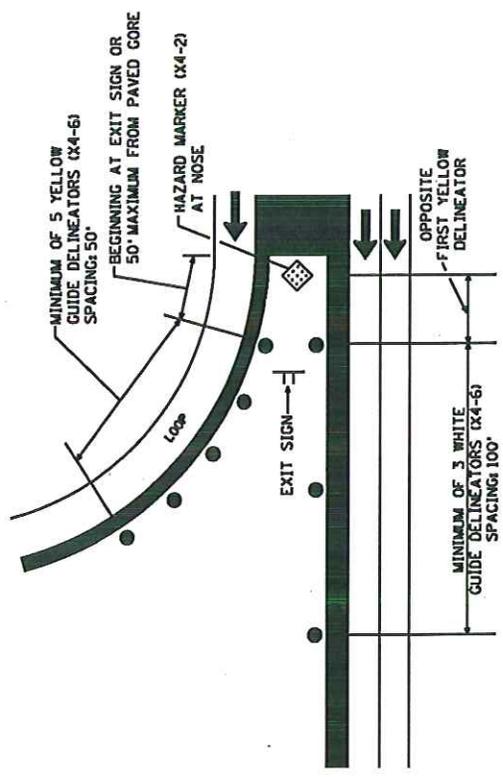


Text Ref.: 7-6.04.02

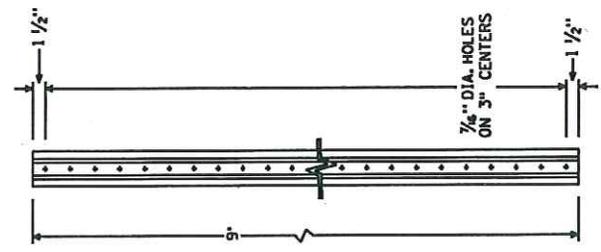
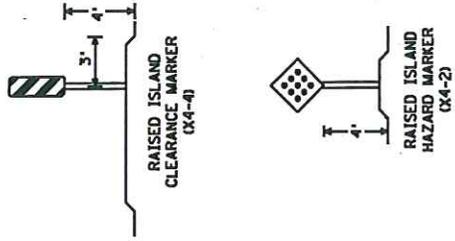
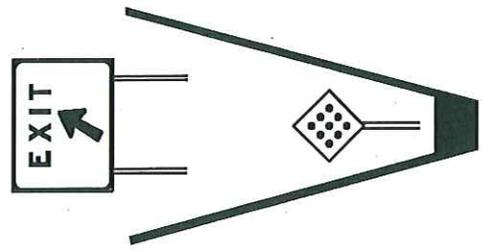
July 1, 1998	DELINEATOR SPACING ON HORIZONTAL CURVES	CHART 7-8
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PLAN A
RAMP DELINEATION

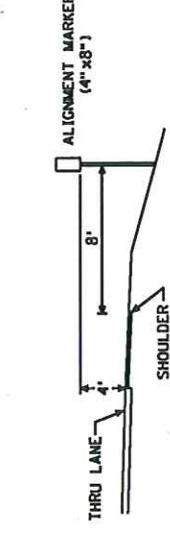
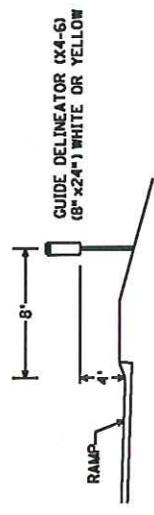
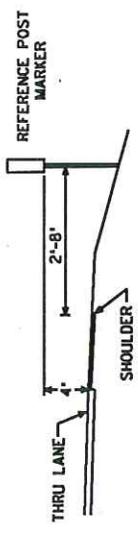
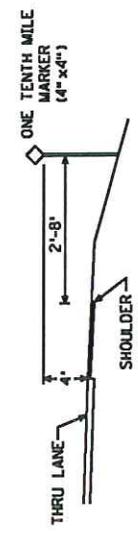


PLAN B
LOOP DELINEATION



MM/DDOT 3401
NORMAL WEIGHT = 2 LB./FT.

DELINEATOR POST



TYPICAL PLACEMENT

DELINEATORS AND MARKERS

PART 3. MARKINGS

Chapter 3D. Delineators

3D.1 Delineators

SUPPORT:

Delineators are particularly beneficial at locations where the alignment might be confusing or unexpected, such as at lane reduction transitions and curves. Delineators are effective guidance devices at night and during adverse weather. An important advantage of delineators in certain locations is that they remain visible when the roadway is wet or snow covered.

STANDARD:

Delineators are considered guidance devices rather than warning devices.

OPTION:

Delineators may be used on long continuous sections of highway or through short stretches where there are changes in horizontal alignment.

3D.2 Delineator Design

STANDARD:

Delineators shall be retroreflective devices mounted above the roadway surface and along the side of the roadway in a series to indicate the alignment of the roadway. Delineators shall consist of retroreflector units that are capable of clearly retroreflecting light under normal atmospheric conditions from a distance of 300 m (1,000 ft) when illuminated by the high beams of standard automobile lights.

Retroreflective elements for delineators shall have a minimum dimension of 75 mm (3 in).

OPTION:

Elongated retroreflective units of appropriate size may be used in place of two retroreflectors mounted as a unit.

3D.3 Delineator Application

STANDARD:

The color of delineators shall conform to the color of edge lines stipulated in Section 3B.6.

Single delineators shall be provided on the right side of expressways and freeways and on at least one side of interchange ramps, except in the following cases:

A. On tangent sections of expressways and freeways when all of the following conditions are met:

1. Raised pavement markers are used continuously on lane lines throughout all curves and on all tangents to supplement pavement markings.
2. Where whole routes or substantial portions of routes have large sections of tangent alignment.
3. Roadside delineators are used to lead into all curves.

B. On sections of roadways where continuous lighting is in operation between interchanges.

OPTION:

Delineators may be provided on other classes of roads. Single delineators may be provided on the left side of roadways.

GUIDANCE:

Single delineators should be provided on the outside of curves on interchange ramps.

Where median crossovers are provided for official or emergency use on divided highways and where these crossovers are to be marked, a double yellow delineator should be placed on the left side of the through roadway on the far side of the crossover for each roadway.

Double or vertically elongated delineators should be installed at 30 m (100 ft) intervals along acceleration and deceleration lanes.

OPTION:

Red delineators may be used on the reverse side of any delineator where it would be viewed by a road user traveling in the wrong direction on that particular ramp or roadway.

Delineators of the appropriate color may be used to indicate a lane reduction transition where either an outside or inside lane merges into an adjacent lane.

GUIDANCE:

For lane reduction transitions, the delineators should be used adjacent to the lane or lanes reduced for the full length of the transition and should be so placed and spaced to show the reduction (see Figure 3B-12).

SUPPORT:

Delineators are not necessary for traffic moving in the direction of a wider pavement or on the side of the roadway where the alignment is not affected by the lane reduction transition.

GUIDANCE:

On a highway with continuous delineation on either or both sides, delineators should be carried through transitions.

OPTION:

On a highway with continuous delineation on either or both sides, the spacing between a series of delineators may be closer.

STANDARD:

When used on a truck escape ramp, delineators shall be red.

GUIDANCE:

Red delineators should be placed on both sides of truck escape ramps. The delineators should be spaced at 15 m (50 ft) intervals for a distance sufficient to identify the ramp entrance. Delineator spacing beyond the ramp entrance should be adequate for guidance according to the length and design of the escape ramp.

3D.4 Delineator Placement and Spacing

GUIDANCE:

Delineators should be mounted on suitable supports so that the top of the highest retroreflector is 1.2 m (4 ft) above the near roadway edge. They should be placed 0.6 to 2.4 m (2 to 8 ft) outside the outer edge of the shoulder, or if appropriate, in line with the roadside barrier that is 2.4 m (8 ft) or less outside the outer edge of the shoulder.

Delineators should be placed at a constant distance from the edge of the roadway, except that where an obstruction intrudes into the space between the pavement edge and the extension of the line of the delineators, the delineators should be transitioned to be in line with or inside the innermost edge of the obstruction. If the obstruction is a guardrail, the delineators should be transitioned to be either just behind, directly above (in line with), or on the innermost edge of the guardrail.

Delineators should be spaced 60 to 160 m (200 to 530 ft) apart on mainline tangent sections. Delineators should be spaced 30 m (100 ft) apart on ramp tangent sections.

SUPPORT:

Examples of delineator installations are shown in Figure 3D-1.

OPTION:

When uniform spacing is interrupted by such features as driveways and intersections, delineators which would ordinarily be located within the features may be relocated in either direction for a distance not exceeding one quarter of the uniform spacing. Delineators still falling within such features may be eliminated.

Delineators may be transitioned in advance of a lane transition or obstruction as a guide for oncoming traffic.

GUIDANCE:

The spacing of delineators should be adjusted on approaches to and throughout horizontal curves so that several delineators are always simultaneously visible to the road user. The approximate spacing shown in Table 3D-1 should be used.

3D.4.1 Intersection Delineator

OPTION:

Delineators may be used to guide motorists through unlit or poorly lit intersections. In such instances, they shall be of the same color as the corresponding edge line.

SUPPORT:

Several methods of delineating intersections have been used. One which provides guidance to all motorists regardless of their direction of approach to an intersection is a cylindrical or near cylindrical design.

One such design is based on a single 150 or 200 mm (6 or 8 inch) diameter tube, 230 to 305 mm (9 to 12 in) tall. The tube should have a black background or be painted black and have two 75-mm (3-in) white retroreflective bands of applied 75 mm (3 in) apart. (see Figure 3D-2)

When mounted such that the post is inside of the tube, it will provide delineation equally in all directions.

OPTION:

When used, at least one delineator of this type should be used in each corner of an intersection. (see Figure 3D-2)