MONTANA DEPARTMENT OF TRANSPORTATION

ROAD DESIGN MANUAL

Chapter 9

Roadside Safety

January 2026

Contents

Chapter 9

Roadside Safety

The ideal roadway would be free of obstructions or other hazardous conditions within the entire highway right-of-way. However, this may not be practical because of economic, environmental or drainage factors. Chapter 9 presents the design principles and guidance for roadside safety. This includes information on clear zone distances, which are designed to adequately provide a clear recovery space for the majority of drivers who run off the road. This chapter also provides criteria for the use of roadside barriers, median barriers, breakaway devices and impact attenuators where providing the clear zone is not practical.

9.1 DESIGN PRINCIPLES AND APPROACH

Each project should be evaluated for opportunities to enhance the roadside environment from a safety perspective. New construction or major reconstruction projects, where changes in horizontal and vertical alignment are possible, offer the most opportunities to provide an obstacle free clear zone or implement roadside treatments. The available funds for roadside safety treatments for existing roadways are often limited. Therefore, the objective of roadside safety is to focus on the features that may provide the most safety enhancement to the overall project while balancing the other design considerations and cost tradeoffs.

Roadside safety is a design process involving the application of a clear zone and exercising good judgment in the evaluation of potential roadside safety treatments.

The steps within this process are described below:

1. Determine clear zone based on design speed, geometric features, side slopes, and traffic volumes;
2. Identify obstacles within the clear zone;

3. Determine the best roadside treatment by eliminating, relocating, making breakaway, shielding the obstacle, or delineating (in that order); and
4. If it is decided that the obstacle should be shielded, determine type and length of barrier.

This chapter will outline the concept of roadside clear zone and provide a variety of roadside treatments and alternatives available. Roadside safety elements should be closely coordinated with other geometric design elements of the roadway. Chapters 3, 4, and 5 should be referenced to understand how the roadway horizontal and vertical alignments, as well as the cross section, may impact roadside safety elements and may help the design team understand the tradeoffs for various design decisions. The design team should continue to refer to the *MDT Baseline Criteria Practitioner's Guide* for specific criteria, particularly related to roadside slopes *(1)*. Design decisions should be documented in the Scope of Work or Plan-in-Hand Report, and documented in a design exception if MDT criteria for clear zone are not met.

In addition, many of the design details for roadside safety can be found in the *MDT Detailed Drawings*, which are provided at the following link on the MDT website:

MDT Detailed Drawings

Additional information regarding roadside safety is provided in the *American Association of State and Highway Transportation Officials (AASHTO) Roadside Design Guide (2).*

9.1.1 Range of Treatments

If a roadside obstacle is within the clear zone, the design team should select the treatment that is most practical and cost-effective for the site conditions. The range of treatments, listed in order of preference, include the following:

1. Eliminate obstacles or design proposed features free of obstacles (such as slope flattening to avoid barrier warrants, removing rock outcroppings, and removing point obstacles);
2. Relocate the obstacle;
3. Where applicable, make the obstacle breakaway (such as sign posts and luminaire supports);
4. Shield the obstacle with a roadside barrier, which is also considered an obstacle and should only be used when other alternatives cannot be achieved; or
5. Delineate the obstacle.

The selected treatment will be based upon the traffic volumes, roadway geometry, proximity of the obstacle to the traveled way, project context (rural versus urban), nature of the hazard, costs for remedial action, and crash experience. The design team should evaluate roadside barrier installations early in the project design if they are a possible consideration for inclusion. A decision to do nothing may require a documented design exception.

9.1.2 Rumble Strips

Longitudinal shoulder and centerline rumble strips may be added to a roadway cross section to alert tired or inattentive drivers. Rumble strips should be installed in accordance with the *MDT Rumble Strip Policy* and in conjunction with the *MDT Detailed Drawings* and project plan details. The *MDT Rumble Strip Policy* can be found on the MDT website at the following link.

MDT Rumble Strip Guidance

9.2 ROADSIDE CLEAR ZONES

9.2.1 General Application

The clear zone widths presented in the *RDM* provide guidelines for creating a clear recovery space for the majority of drivers who run off the road. Each application of the clear zone distance should be evaluated individually, and the design team should apply and document appropriate engineering judgment.

Engineering judgment is the evaluation of available pertinent information and the application of appropriate principles for the purpose of making design decisions.

Exhibit 9-1 presents clear zone distances for design. When using the recommended distances, the design team should consider the following:

1. **Context**. If a formidable obstacle (see Section 9.3.1) lies just beyond the clear zone, it may be appropriate to remove or shield the obstacle if costs are reasonable. Conversely, the clear zone should not be achieved at all costs. Limited right-of-way or unacceptable construction costs may result in unshielded obstacles within the clear zone or may lead to the installation of a barrier. Unshielded obstacles within the clear zone, including the adjusted clear zone for horizontal curves (*CZc*), should be approved through the design exception process described further in Chapter 2, Section 2.9.
2. **Boundaries.** The design team should not use the clear zone distances as boundaries for introducing roadside obstacles such as bridge piers, non-breakaway sign supports, utility poles or landscaping features. Place these items as far from the traveled way as practical.
3. **Roadside Cross Section.** The recommended clear zone distance will be based on the type of roadside cross section. Section 9.2.2 presents several schematics for the various possibilities.
4. **Measurement.** All clear zone distances are measured from the edge of the traveled way. For auxiliary lanes that function similar to through lanes (e.g., climbing lanes and weaving lanes), the clear zone is measured from the edge of the auxiliary lane based on the mainline design speed and mainline design Annual Average Daily Traffic (AADT).
5. **Utility Occupancy Area.** It should be noted that the utility occupancy area is independent of the clear zone. It is possible for the utility occupancy area to be located inside of the clear zone. The final placement of utilities is negotiated between MDT and the utility companies. For paved roads, utilities should be located outside the clear zone, but no less than 30 feet from the edge of the outermost lane. When the final placement location of the utility has been determined, the design team should evaluate the

proposed location and determine whether a design exception should be pursued, or the utility feature should be shielded.

9.2.2 Clear Zone Design

The recommended clear zone distance from Exhibit 9-1 should be selected based on the highway design speed, geometric features, slope condition, and traffic volumes. Generally, the design team should select the clear zone distance for the steepest slope encountered when more than one slope falls within the clear zone. For clear zone traffic volumes, the Design AADT will be the total AADT of the roadway including both directions of travel, for both divided and undivided facilities. Refer to Sections 9.2.2.1 and 9.2.2.3 for clear zone adjustments on horizontal curves and in cut sections.

Exhibit 9-1 presents the criteria for clear zones on fill slopes which run parallel to the highway. Appendix K provides example calculations for clear zones.

Exhibit 9-1
Clear Zone Distances

Design Speed	Design AADT	Fill Slopes/Fore slopes		
		6:1 or Flatter	5:1	4:1
40 mph or less	< 750	8	8	10
	750-1499	10	12	14
	1500-6000	12	14	16
	> 6000	14	16	18
45 mph	< 750	10	12	14
	750-1499	14	16	18
	1500-6000	16	20	24
	> 6000	20	24	26
50 mph	< 750	12	12	14
	750-1499	16	18	20
	1500-6000	18	22	26
	> 6000	22	26	28
55 mph	< 750	12	14	18
	750-1499	16	20	24
	1500-6000	20	24	30
	> 6000	22	26	32
60 mph	< 750	16	20	24
	750-1499	20	26	32
	1500-6000	26	32	40
	> 6000	30	36	44
70 mph	< 750	20	22	26
	750-1499	24	30	36
	1500-6000	30	36	42
	> 6000	32	38	46
80 mph	< 750	24	26	30
	750-1499	28	32	38
	1500-6000	34	40	46
	> 6000	38	44	50

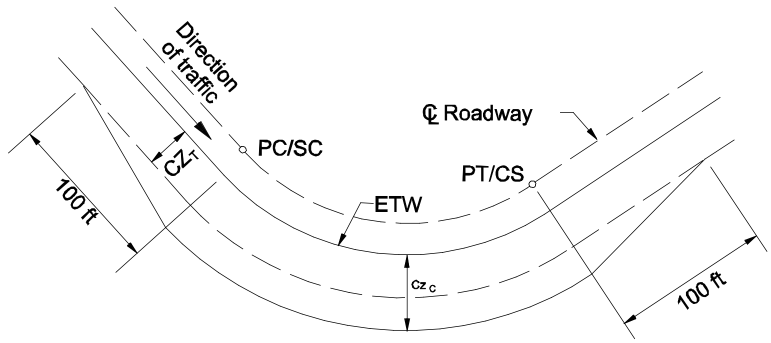
Notes:
- For 3:1 slopes, see the procedure in Section 9.2.2.2.
- All distances are measured from the edge of the traveled way (ETW).

9.2.2.1 Clear Zone Adjustment for Horizontal Curves

On the outside of horizontal curves, run-off-the-road vehicles may travel a farther distance from the traveled way before regaining control of the vehicle. The design team should modify the clear zone distance obtained from Exhibit 9-1 for horizontal curvature. The modified clear zone value for horizontal curves will be used to determine if a design exception to the clear zone criteria is necessary; see Section 9.2.2.5. This adjusted clear zone will also be the initial clear zone used if further adjustment is needed for non-recoverable slopes within recovery areas.

Exhibit 9-2 illustrates the application of the clear zone adjustment on a curve. Exhibit 9-3 provides recommended adjustments for horizontal curves.

Exhibit 9-2
Horizontal Curve Adjustments



Notes:
On the inside of horizontal curves, use the clear zone distance for a tangent roadway.
CZ_t = clear zone on tangent section
CZ_c = clear zone on horizontal curve
ETW = edge of traveled way.

Exhibit 9-3
Clear Zone Adjustment Factors for Horizontal Curves

Radius (ft)	Design Speed (mph)					
	40	45	50	55	60	70
2950	1.1	1.1	1.1	1.2	1.2	1.2
2300	1.1	1.1	1.2	1.2	1.2	1.3
1970	1.1	1.2	1.2	1.2	1.3	1.4
1640	1.1	1.2	1.2	1.3	1.3	1.4
1475	1.2	1.2	1.3	1.3	1.4	1.5
1315	1.2	1.2	1.3	1.3	1.4	
1150	1.2	1.2	1.3	1.4	1.5	
985	1.2	1.3	1.4	1.5	1.5	
820	1.3	1.3	1.4	1.5		
660	1.3	1.4	1.5			
495	1.4	1.5				
330	1.5					

Notes:
This table matches the *2011 Roadside Design Guide.*

1. Adjustments apply to the outside of a horizontal curve only.
2. Corrections are typically made only to curves less than 2950-foot radius.
3. The applicable clear zone distance on a horizontal curve is calculated by:

   $$CZ_C = (K_{CZ})(CZ_T)$$

   where: CZ_C = clear zone on outside of curve

   K_{CZ} = curve adjustment factor

   CZ_T = clear zone on a tangent section from Exhibit 9-1
4. For curves intermediate in the table, use a straight-line interpolation.
5. See Exhibit 9-2 for the application of CZ_C to the roadside around a curve.
6. Round the computed clear zone distance up to the next higher 1-foot increment.

9.2.2.2 Parallel Slopes

There are four types of fill slopes: recoverable, non-recoverable, barn-roof, and critical. The following sections discuss each type of fill slope and discuss the application of Exhibit 9-1.

1. **Recoverable Fill Slopes**. For parallel fill slopes 4:1 and flatter as shown in Exhibit 9-4a, the recommended clear zone distance can be determined directly from Exhibit 9-1.
2. **Non-Recoverable Fill Slopes.** Non-recoverable slopes are composed of traversable slopes (as defined here) and critical slopes (steeper than 3:1). For parallel fill slopes between 3:1 (inclusive) and 4:1 (exclusive) as shown in Exhibit 9-4b, adjust the clear zone to include a minimum 10-foot recovery area beyond the toe of the fill slope. It is recommended that sufficient right-of-way be acquired to ensure that the recovery area can be maintained and cleared of obstacles. The following procedure is used to determine the adjusted clear zone:

a. Ensure that the slope in the recovery area beyond the toe is 4:1 or flatter. Determine the clear zone from Exhibit 9-1 using the slope rate beyond the toe, the applicable design speed and traffic volume.

b. To determine the recovery area distance beyond the fill slope toe, subtract the width of the recoverable slope(s) between the edge of travel way and the top of non-recoverable fill slope from the distance in Step 2a.

c. If the distance in Step 2b is greater than or equal to 10 feet, this distance will be the width of the recovery area. If the distance in Step 2b is less than 10 feet, the minimum recovery area will be 10 feet beyond the toe.

d. The adjusted clear zone is the distance from the edge of the traveled way to the outside limit of the recovery area; see Exhibit 9-4b.

A barn-roof slope is a two-step sloping technique in which a less steep slope (within the clear zone) is followed by a steeper slope to minimize the right-of-way needed.

3. **Barn-Roof Fill Slope** This design requires less right-of-way and embankment material than a continuous, flatter slope, see Exhibit 9-4c. A barn-roof slope should not be used just to eliminate guardrail.

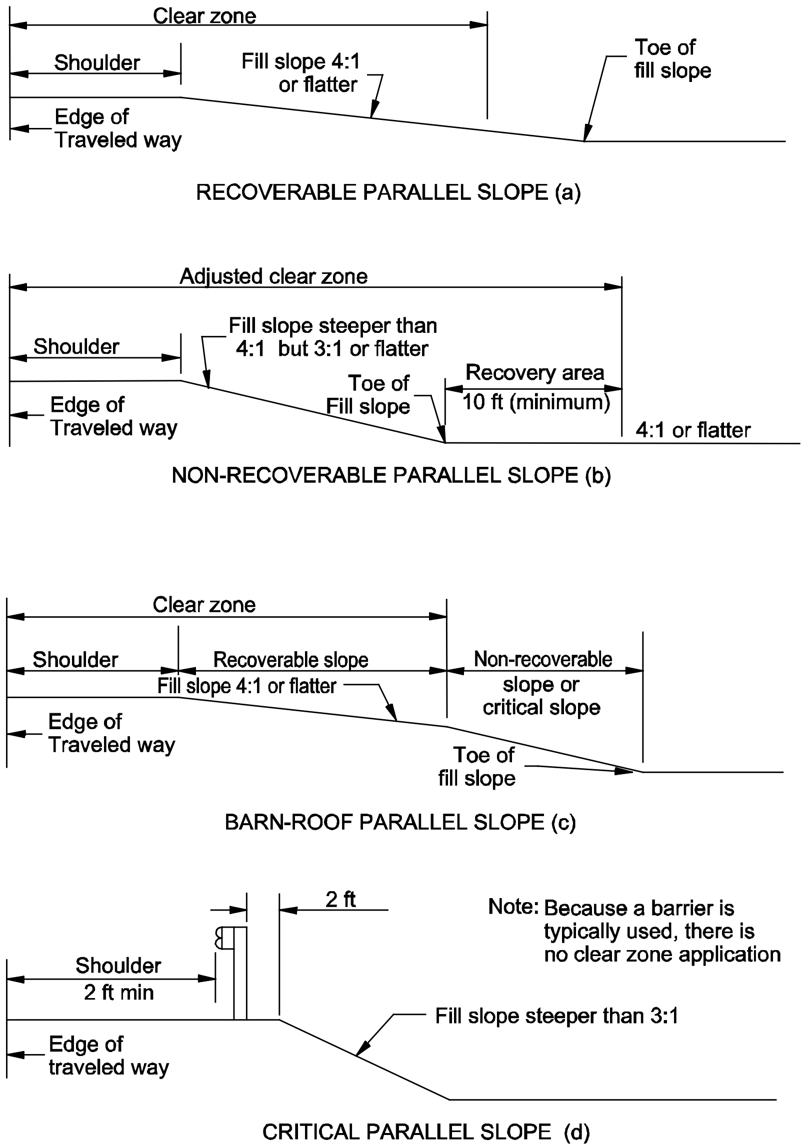
   a. Recoverable/recoverable barn-roof fill slopes may be designed with two recoverable slope rates; the second slope is steeper than the slope adjacent to the shoulder. If the clear zone for the flatter slope extends beyond the hinge point between the two slopes, determine the clear zone using the steeper slope.

   b. Recoverable/non-recoverable barn-roof fill slopes may be designed with a recoverable slope leading to a non-recoverable slope (Exhibit 9-4c). The clear zone should be provided entirely on the recoverable slope (i.e., the shoulder and recoverable slope should equal the clear zone distance). If the clear zone based on the recoverable slope extends beyond the slope break between the recoverable and non-recoverable slope, use the procedure in Step #2 (Non-Recoverable Fill Slopes) to determine the lateral extent of the clear zone.

   c. Recoverable/critical barn-roof fill slopes may be designed with a recoverable slope leading to a critical slope (i.e., fill slopes steeper than 3:1). See Exhibit 9-4c. This barn-roof design may only be used if there are no other practical alternatives. The clear zone based on the recoverable slope rate should be provided entirely on the recoverable slope (i.e., the clear zone should equal or be less than the sum of the shoulder width and recoverable slope width). Otherwise, a barrier may be warranted. See Section 9.3.2.

4. **Critical Fill Slope.** A 3:1 slope is a practical maximum when considering maintenance operations (e.g., mowing), erosion control and roadside safety. Fill slopes steeper than 3:1 are critical slopes and may require a barrier if located within the clear zone. Critical slopes should be reviewed for stability by the Geotechnical Section. See Exhibit 9-4d and Section 9.3.2.

Exhibit 9-4
Clear Zone Application for Fill Slopes



9.2.2.3 Cut Slopes

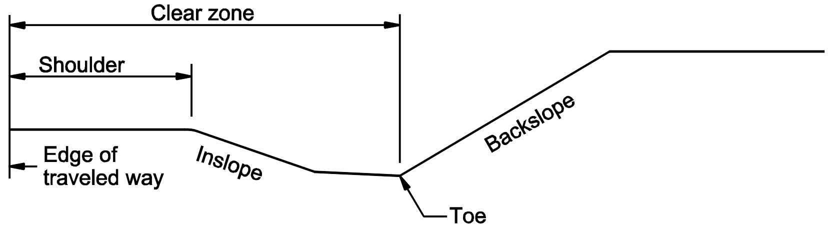
Exhibit 9-5 presents the clear zone application for ditch sections typically constructed in roadside cuts without curbs. The applicable clear zone across a ditch section will depend upon the inslope, the backslope, the horizontal location of the toe of the backslope, and various highway factors (e.g., design speed and traffic volumes). Use the following procedure to determine the recommended clear zone distance:

1. **Check Inslope.** Use Exhibit 9-1 to determine the clear zone based on the ditch inslope.
2. **Check Location of the Toe of Backslope**. Based on the distance from Step #1, determine if the toe of the backslope is within the clear zone. The toe of the backslope is defined as the intersection of the ditch bottom and the

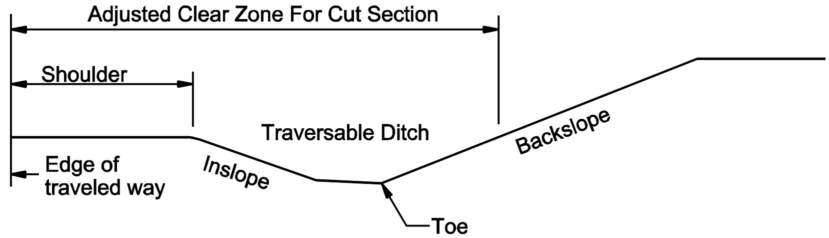
backslope. If the toe is at or beyond the clear zone, then the design team usually need only consider roadside obstacles within the clear zone on the inslope and within the ditch. If the toe is within the clear zone, the design team should determine if the ditch is traversable.

3. **Check Ditch Traversability**. The design team should evaluate the traversability of the ditch cross section. See Section 9.3.5.1. If the ditch is not traversable, the ditch should be relocated outside the clear zone or redesigned as a traversable ditch without impact to the existing flow patterns within the project area.
4. **Clear Zone Adjustment for Cut Backslope (Earth Cuts).** If the toe of the backslope is within the clear zone distance from Step #1 above and the ditch is traversable, determine an adjusted clear zone that will extend onto the backslope. Exhibit 9-5 provides an illustration. This clear zone will be a distance beyond the toe of backslope as follows:
    a. Calculate the percentage of the clear zone available to the toe of the backslope.
    b. Subtract this percentage from 100 percent and multiply the results by the clear zone for the backslope in Exhibit 9-6, which presents the application for backslope clear zone factors.
    c. Add the available clear zone to the toe of the backslope to the value determined in Step 4b. Round the total up to the next higher 1 foot increment. This yields the required clear zone from the edge of traveled way to a point on the backslope.
5. **Clear Zones (Rock Cuts).** For rock cuts with a steep smooth backslope, the clear zone should be adjusted to the toe of the backslope and no shielding of the slope is required. The rock cut should be relatively smooth to minimize the hazards of vehicular impact. If the face of the rock is rough or rock debris occurs in the ditch section, a barrier may be warranted.

Exhibit 9-5
Clear Zone Application for Cut Slopes



TOE OF BACKSLOPE NOT WITHIN CLEAR ZONE (a)



TOE OF BACKSLOPE WITHIN CLEAR ZONE (b)

Exhibit 9-6
Adjusted Backslope Clear Zone Factors

Design Speed	Design AADT	Backslope/Earth cuts 6:1 or Flatter	5:1	4:1	3:1
40 mph or less	< 750	7	7	7	7
	750-1499	12	12	12	12
	1500-6000	14	14	14	14
	> 6000	16	16	16	16
45 mph	< 750	10	10	8	8
	750-1499	14	14	12	12
	1500-6000	16	16	14	14
	> 6000	20	20	18	16
50 mph	< 750	12	10	10	10
	750-1499	16	14	12	12
	1500-6000	18	16	14	14
	> 6000	22	20	18	16
55 mph	< 750	12	12	10	10
	750-1499	16	16	14	12
	1500-6000	20	18	16	14
	> 6000	22	22	20	18
60 mph	< 750	14	14	12	10
	750-1499	20	18	16	12
	1500-6000	24	22	18	14
	> 6000	26	26	24	20
70 mph	< 750	16	16	14	12
	750-1499	22	20	18	16
	1500-6000	28	24	22	20
	> 6000	30	30	26	24
80 mph	< 750	18	18	16	14
	750-1499	24	22	20	18
	1500-6000	30	26	24	22
	> 6000	32	32	28	26

Notes
1. To use this table, follow procedure in Section 9.2.2.3 Step 4.
2. All distances are measured from the edge of the traveled way (ETW).

9.2.2.4 Curbed Sections

The clear zone width is not reduced due to the presence of curb. However, because substantial development typically occurs in urban areas, it is usually impractical to remove or shield all obstacles within the clear zone. The following guidelines are acceptable criteria when curbs are encountered and it is impractical to maintain design clear zone:

1. **Horizontal Clearance**. For roadways within the boundaries of an urban area where the design speed is less than or equal to 50 miles per hour, the recommended minimum horizontal clearance to a frangible object is 1.5 feet from the face of curb. The minimum lateral offset for non-frangible objects is 6 feet from face of curb on outside of curves and 4 feet elsewhere.
2. **Sidewalks.** Where sidewalks are adjacent to the curb, locate all appurtenances behind the sidewalk, if practical. In addition, the design team should ensure that sufficient sidewalk width is available between appurtenances and the curb to meet the Pubic Right-of-Way Accessibility Guidelines (PROWAG) clearance criteria; see Chapter 7 for additional information on multimodal design considerations and the MDT criteria in the *MDT Baseline Criteria Practitioner's Guide (1)*.

Refer to Chapter 2, Section 2.2.1 for detailed functional classification descriptions of rural and urban roadways.

9.2.2.5 Design Deviations

The design team must seek design approval when the proposed design does not provide the clear zone criteria presented in this section and as required in the *MDT Baseline Criteria Practitioner's Guide (1).* (Note: If the clear zone violation is appropriately shielded i.e. barrier installed, no documentation is necessary). Additional information on design exceptions for clear zone criteria is presented in Chapter 2, Section 2.9.

9.3 ROADSIDE BARRIER WARRANTS

9.3.1 Roadside Obstacles

Section 9.2 presents the recommended clear zone distances for various highway conditions. These distances should be free of any fixed or non-traversable obstacles. In general, barrier warrants are based on the relative severity between impacting the barrier and impacting the obstacle. Examples of roadside obstacles may include:

- Non-breakaway: sign supports, luminaire supports, traffic signals poles, railroad signal poles, and fire hydrants;
- Concrete footings extending more than 4 inches above the ground;
- Bridge piers and abutments at underpasses, bridge parapet ends, and pedestrian rail ends (see Exhibit 9-7);
- Retaining walls;
- Trees with diameter greater than 4 inches (at present or at maturity);
- Rough rock cuts;
- Large boulders;

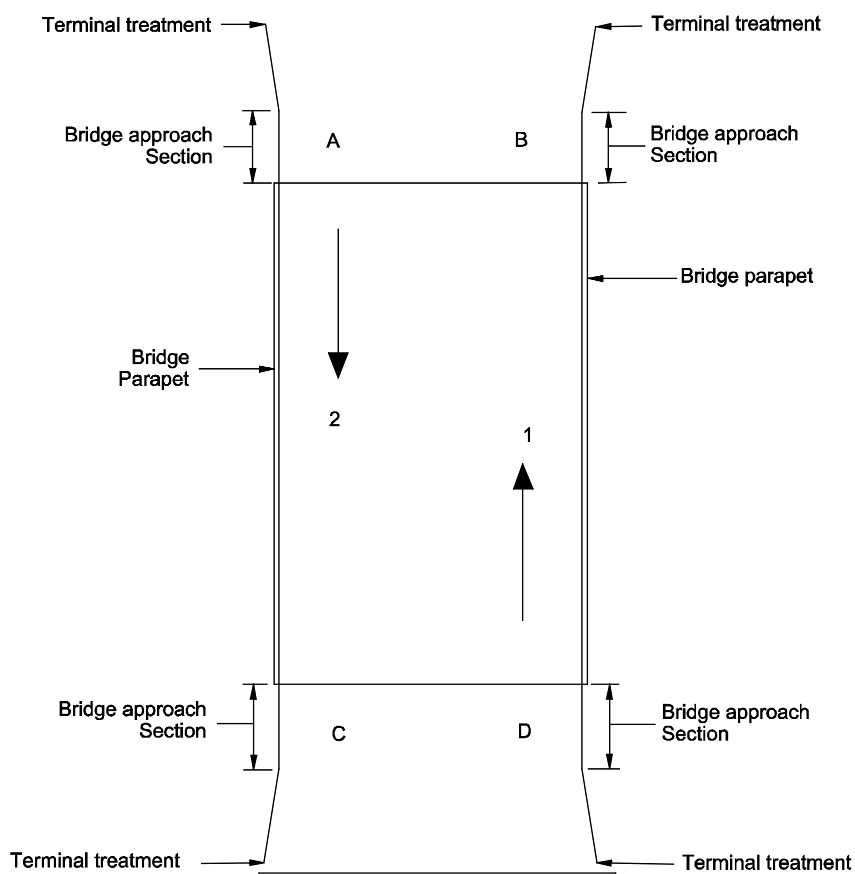
Once the design team has concluded that an obstacle is located within the clear zone, the first attempt should be to remove or relocate the obstacle or to make the object breakaway.

- Critical parallel slopes;
- Streams or permanent bodies of water (where the depth of water is at least 12 inches);
- Non-traversable ditches;
- Utility poles or towers; and
- Culvert headwalls and ends.

If it is not practical to remove or relocate the obstacle, a barrier should be installed only if engineering judgment indicates it is a reasonable solution. For example, it would probably not be practical to install a barrier to shield an isolated point obstacle, such as a tree, located near the edge of the clear zone.

Shielding obstacles located just outside the clear zone may be appropriate particularly for features or sites that have a crash history, or if there is a potential for harm if encountered by an errant vehicle. For example, shielding a bridge end location just outside the clear zone may be justified, due to the potential severity of the crash and running speeds higher than the design speeds. These situations should be reviewed and addressed during the development of the project.

Exhibit 9-7
Barrier Warrants at Bridges



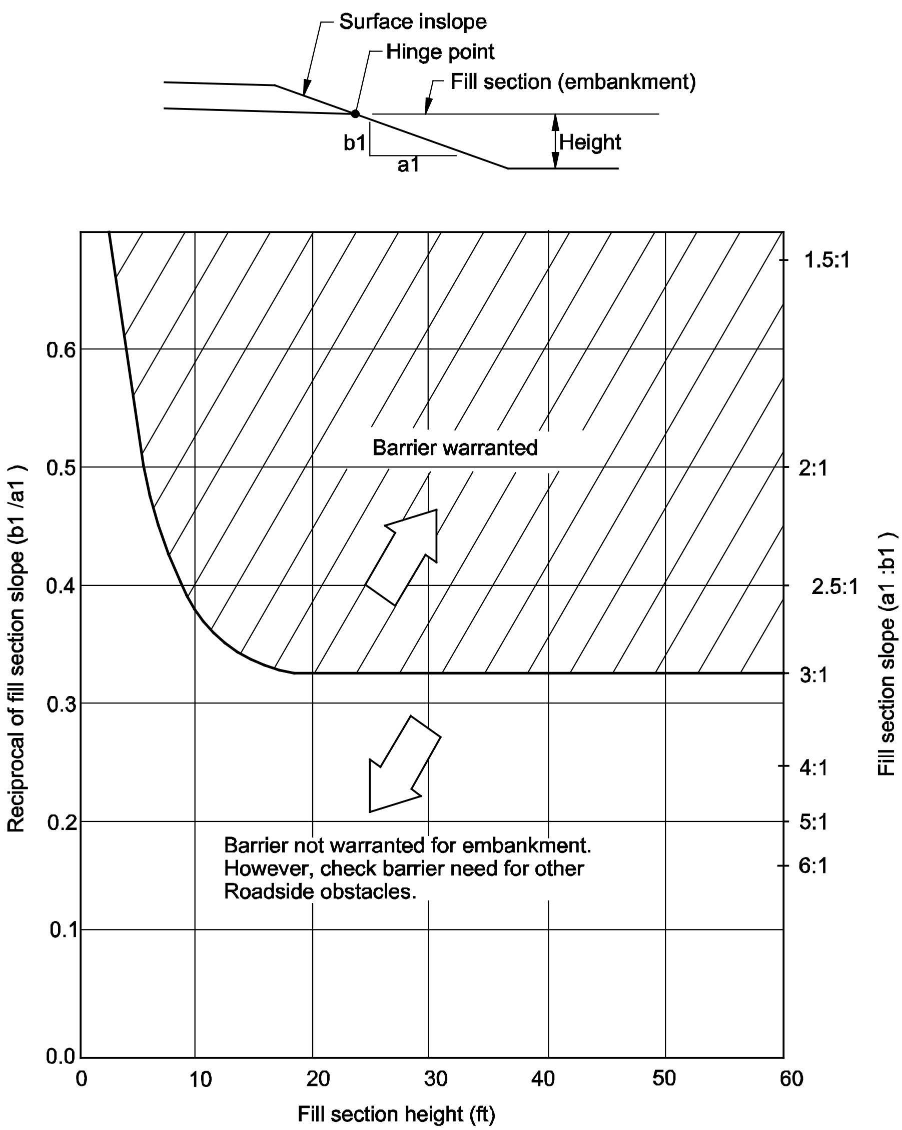
Traffic Direction	Bridge approach section Required at *
1 and 2	A B C D
2 only	A B
1 only	C D

* Approach rail locations C and B may not be appropriate for two-way facilities, if beyond the clear zone of the approaching traffic. Location, design speed, and crash history should be considered to determine if it is warranted.

9.3.2 Embankments

The severity of the roadside embankment depends upon the rate of fill slope and the height of fill. For all highways, use Exhibit 9-8 to determine if a barrier is warranted. For low embankment heights, the criteria allow fill slopes steeper than 3:1 to remain unshielded. A barrier is not required for areas outside of the shaded region, unless there are roadside obstacles within the clear zone as determined from Section 9.2.

Exhibit 9-8
Barrier Warrants for Embankments

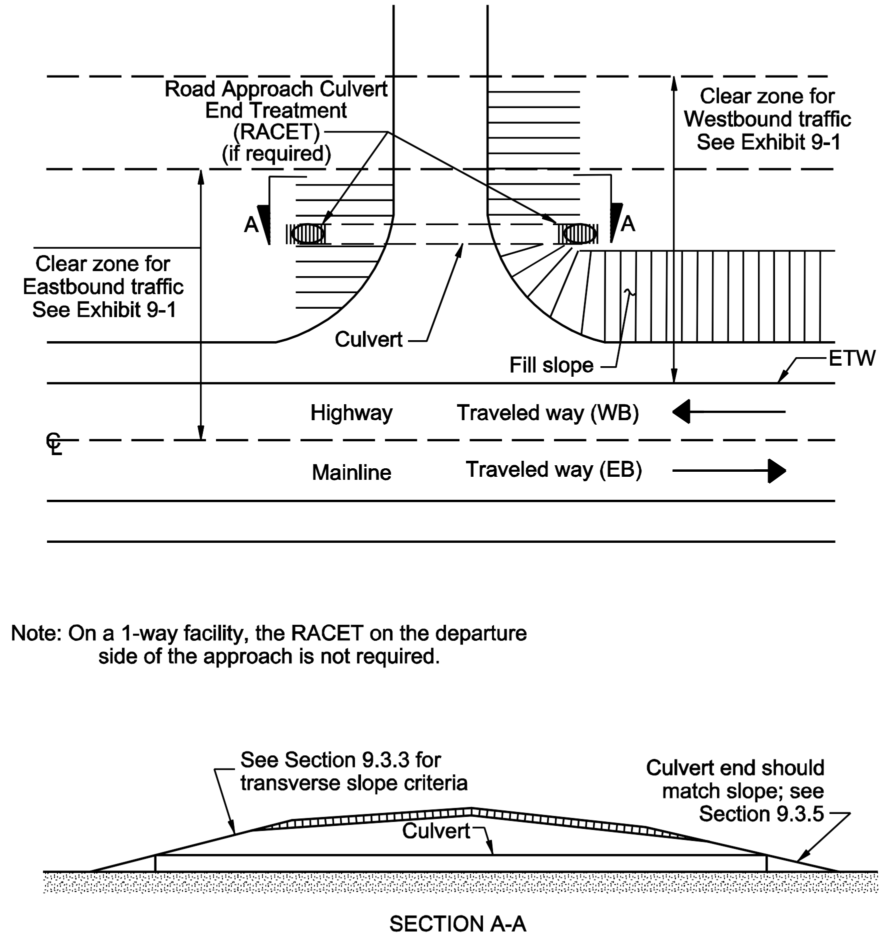


Note: Points which fall on the solid line do <u>Not</u> warrant a barrier.

9.3.3 Transverse Slopes

Where the highway mainline intersects an approach, side road, or median crossing, a slope transverse to the mainline will be present. Exhibit 9-9 provides an illustration. In general, transverse slopes should be as flat as practical.

Exhibit 9-9
Transverse Slopes



For slopes within the clear zone, the following will apply:

1. **Rural Conditions**. For rural (outside the boundaries of urban areas) roadways and urban roadways where the design speed is greater than 45 miles per hour, provide a transverse slope no steeper than 6:1. Transverse slopes of 10:1 are desirable where practical. Transverse slopes for median crossovers should be 10:1 or flatter, and 20:1 is desirable.
2. **Urban Conditions**. For roadways within the boundaries of an urban area where the design speed is less than or equal to 45 miles per hour, transverse slopes of 6:1 or flatter are desirable, where practical. Where necessary, steeper transverse slopes may be used to provide practical designs (e.g., urban facilities with closely spaced driveways).

Slopes may be transitioned to a steeper slope beyond the clear zone. Where these criteria cannot be practically met in rural areas, consider providing a roadside barrier. The decision to use a barrier will be made on a case-by-case basis considering costs, traffic volumes, severity of the proposed transverse slope, and other relevant factors (e.g., height of slope, crash history).

9.3.4 Rock Cuts

Rough rock cuts located within the clear zone may be considered a roadside obstacle. The backslope through rock cut sections is determined by the Geotechnical Section based on their field investigation. At the steepest, the backslope typically will not exceed 0.25:1. For large cuts, benching of the backslope may be required to remove loose overburden from the top of the formation material.

The following will apply to their treatment:

1. **Obstacle Identification**. There is no precise method to determine whether or not a rock cut is sufficiently "rough" to be considered a roadside obstacle. This will be evaluated on a case-by-case basis applying engineering judgment and documented accordingly.
2. **Debris.** A roadside obstacle may be identified based on known or potential occurrences of rock debris encroaching onto the roadway. If rock debris is expected within the clear zone, a barrier for capturing the debris may be required. Contact the Geotechnical and Maintenance Sections to determine the length, need, and type of barrier required.
3. **Barrier Warrant.** If the rock cut is determined to be an obstacle and it is within the clear zone, a barrier may be warranted.

9.3.5 Roadside Drainage Features

Effective drainage is one of the most critical elements in the design of a roadway. Drainage features should be designed and constructed considering their potential consequences on run-off-the-road vehicles. Ditches, curbs, culverts, and drop inlets are common drainage system elements that should be designed, constructed, and maintained considering both hydraulic efficiency and roadside safety.

In general, the following options, listed in order of preference, are applicable to all drainage features:

1. Construct or relocate outside the clear zone. For skewed culverts with end treatments that are not skewed, the design team should make sure all of the end treatment is outside the clear zone.
2. Design or modify drainage structures so that they are traversable or present a minimal hazard to an errant vehicle. For large culverts, it may not be cost effective to lengthen the pipe; therefore, building a pipe grate is an alternative. See Chapter 11 for drainage and end treatment designs. If the culvert has a Flared End Terminal Section (FETS), the opening is greater than the diameter of the pipe.
3. If a drainage feature, with an opening greater than 36 inches or including some other obstacle (e.g., a headwall), cannot effectively be redesigned or relocated, consider shielding it by a traffic barrier. In addition, consider a traffic barrier, if the feature is in a vulnerable location and if a barrier installation is judged to be cost effective.
4. Evaluate the condition, provide no corrective measure, and seek a design exception to document the obstacle located within the clear zone.

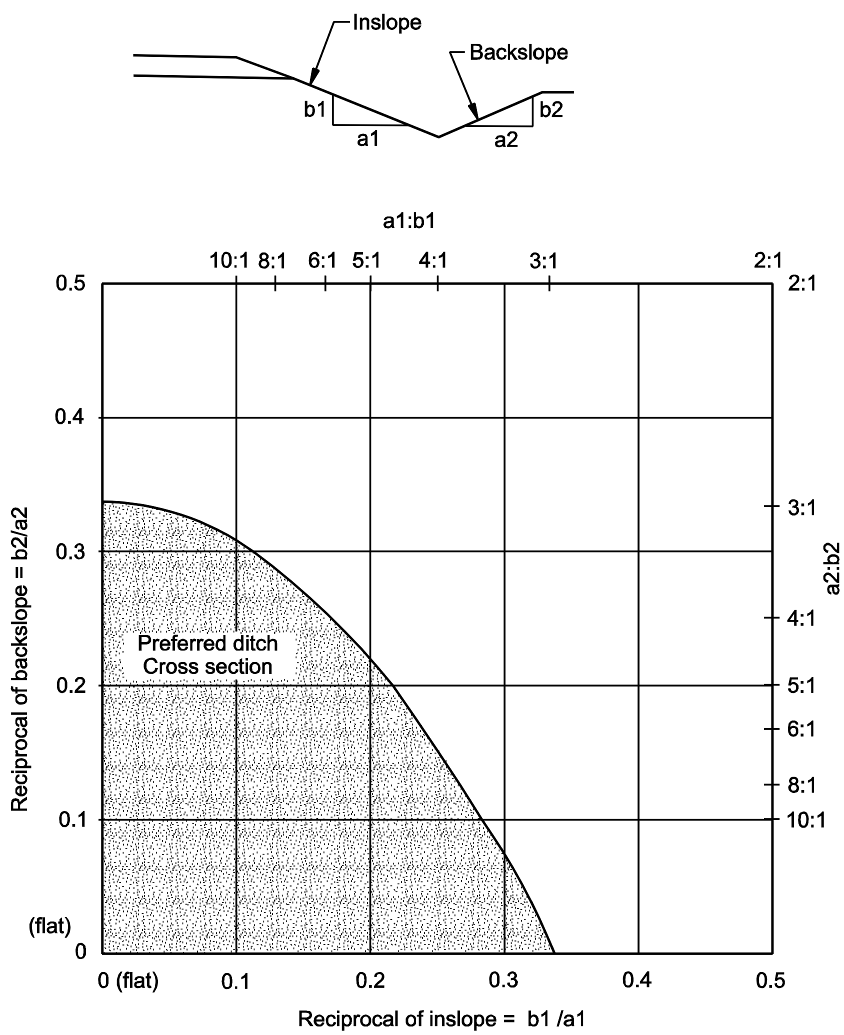
When shielding a point obstacle such as a culvert opening, the further from the roadway the obstacle is, the longer the length of guardrail needed to shield it. This results in a long crashworthy obstacle nearer the roadway to shield a point obstacle further from traffic. For this reason, FETS for smaller diameter pipes located in the clear zone are often left unshielded, and are instead documented in a design exception.

9.3.5.1 Roadside Ditches

Exhibits 9-10 and 9-11 present inslope and backslope combinations for basic ditch configurations. Cross sections which fall in the shaded region of each of the figures are considered traversable. Ditch sections which fall outside the shaded region are considered non-traversable and should be redesigned to an acceptable cross section; otherwise, consider providing a roadside barrier. For example, V-ditches with a 4:1 inslope require a 6:1 or flatter backslope to be traversable.

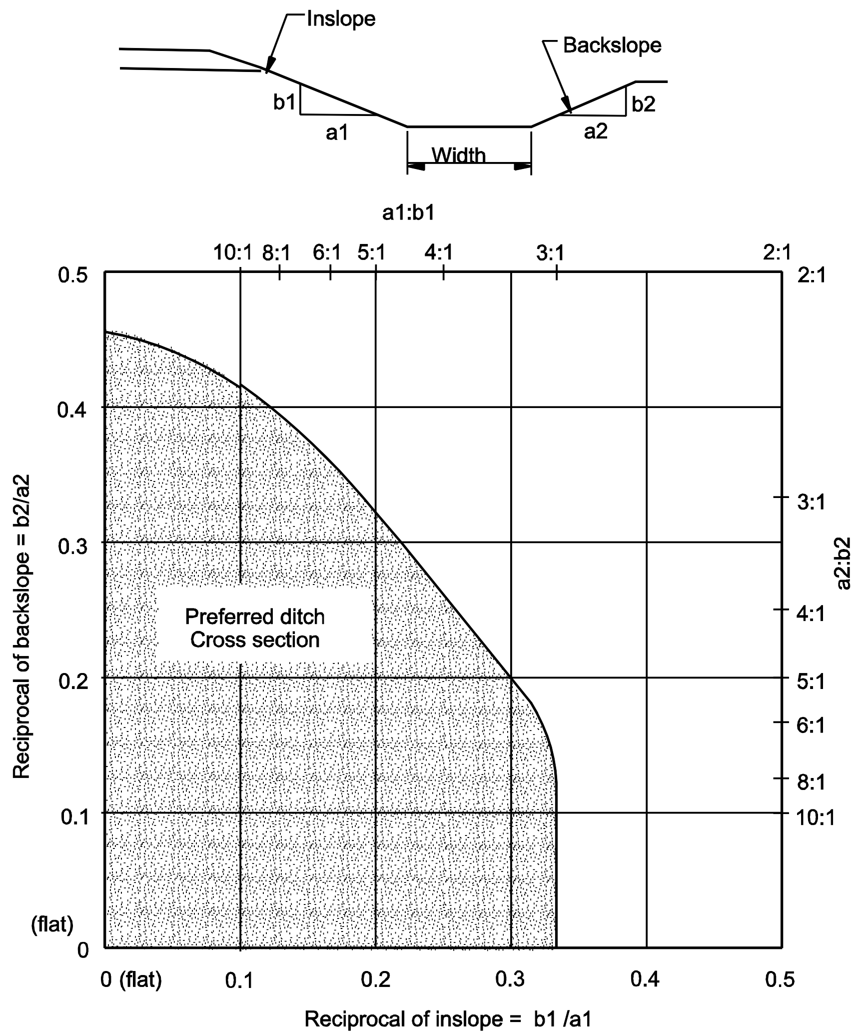
Chapter 5 presents additional information on the configuration of roadside ditches and how it relates to the overall roadway cross section. The *MDT Baseline Criteria Practitioner's Guidelines* provides MDT criteria for inslopes and backslope based on functional classification and design speed *(1)*. Chapter 11 provides more information regarding roadside and irrigation ditches. These ditch sections meet the traversability criteria in Exhibits 9-10 and 9-11.

Exhibit 9-10
Preferred Cross Section for Ditches



Note: This chart is applicable to all V-ditches, rounded ditches with a bottom width less than 8 feet, and trapezoidal ditches with bottom widths less than 4 feet.

**Exhibit 9-11
Preferred Cross
Sections for Ditches
(With Gradual Slope
Changes)**



Note: This chart is applicable to all rounded ditches with a bottom width of 8 feet or more, and to trapezoidal ditches with bottom widths equal to or greater than 4 feet.

9.3.5.2 Curbs

Curbs are typically used for drainage control. In general, curbs should not be used on new construction projects in rural areas. Section 9.4.3 discusses the relative placement of curbs and guardrail. The *MDT Detailed Drawings* provide information on the different types of curbs used for MDT projects and the criteria for their placement.

9.3.5.3 Cross Drainage Structures

Cross drainage structures should be checked to determine if their inlets or outlets are within the clear zone. If an inlet or outlet is within the clear zone on a recoverable slope, the preferred treatment is to extend the structure so the obstacle is located beyond the clear zone. Extending the pipe on a recoverable slope may result in warping the side slopes to match the opening. Abrupt changes in parallel slopes should be avoided within the clear zone. Section 9.3.3

provides guidance on transverse slopes that should be considered. For larger skewed culverts, the edge protection may not be parallel with the roadway, and the culvert should be extended so that the 2:1 edge protection is entirely outside the clear zone.

Typically, it is not practical to extend a cross drainage structure so that the end is outside the clear zone when it is located on a non-recoverable slope. A recoverable barn-roof slope can be constructed having a slope that provides adequate clear zone width on top of the pipe.

Where extending the culvert is impractical due to site conditions, other treatments should be evaluated, such as shielding with a roadside barrier, flattening the slope to provide a recoverable slope, use of a modified end treatment, or requesting an exception to leave the obstacle.

For major drainage structures which are costly to extend, shielding with a roadside barrier may often be the most practical alternative.

9.3.5.4 Parallel Drainage Structures

Parallel drainage culverts are those which are oriented approximately parallel to the main flow of traffic. They are typically used under driveway approaches, field approach entrances, access ramps, intersecting side roads and median crossovers. As with cross drainage structures, the primary objective should be to locate the parallel drainage structure outside the mainline clear zone, to design generally traversable slopes, and to match the culvert opening with adjacent slopes. Section 9.3.3 provides the MDT guidance for transverse slope rates.

Openings of parallel drainage structures within the clear zone should match the selected side slope and be safely treated if practical. Although many of these structures are small and present a minimal target, the addition of a road approach culvert end treatment (RACET) with pipes and bars perpendicular to the mainline traffic can reduce wheel snagging in the culvert openings. The *MDT Detailed Drawings* provide additional details in the design of the RACET. Provide a RACET for any pipe with a diameter of 15 inches or greater which has any portion within the clear zone.

Parallel drainage structures may be closely spaced in urban areas because of frequent driveway approaches and intersecting roads. In such locations, it may be desirable to convert the open ditch into a closed drainage system and backfill the areas between adjacent driveway approaches. This treatment will eliminate the ditch section and the transverse embankments with pipe inlets and outlets.

9.4 ROADSIDE BARRIERS

When considering roadside barriers, the design team should ask the question: “Does the installation of a barrier reduce the severity of off-road crashes?”

9.4.1 Barrier Types

The following sections describe the non-proprietary roadside barrier types MDT uses. Refer to the *MDT Detailed Drawings* for detailed design information on each barrier type. Subsequent to original publication MDT has developed a MASH policy for roadside hardware. Where a MASH system does not exist that meets the site application or MDT needs, exceptions are allowed when documented. Items not meeting MASH testing criteria but included in *MDT Detailed Drawings* are allowed without documentation when they are the best available treatments, i.e. intersecting roadway terminal sections (IRTs).

9.4.1.1 "W" Beam Guardrail

The "W" beam system with strong posts is a semi-rigid system. This system has a deflection distance of 4 feet. This guardrail system is the preferred system for high speed rural facilities where snow drifting is not a major concern. A major objective of the strong post system is to prevent a vehicle from "snagging" on the posts. This is achieved by using blockouts to offset the posts from the longitudinal beam and by establishing 6.25 feet as the maximum allowable post spacing for non-stiffened W-beam guardrail. Refer to the *MDT Detailed Drawings* for installation information and additional details on the types of "W" beam systems allowed for use on MDT facilities.

MDT has two guardrail "W" beam systems based on post types (wood and steel). Post selection for a project is at the Contractor's option. The Contractor is not required to use the same post type throughout the project. "W" beam systems used on curves with radii less than 150 feet are required to be shop bent.

9.4.1.2 Cable Guardrail

MDT currently only installs High-Tension Cable Rail. Low Tension Cable Rail is not approved for installation on MDT projects. MDT does use pre-stretched, tensioned cable in applications when cable rail is desirable. No standard detailed drawings exist for cable rail because they are generally proprietary items. For those situations, the rail has to meet criteria *(MASH, TL3)* and it has to be installed in accordance with the manufacturer's recommendations *(5)*. Most of the resistance to impact is supplied by the tensile forces developed in the cable strands. Upon impact, the cables break away from the posts, and the vehicle is able to knock down these posts as it is redirected by the cables. The detached posts do not contribute to controlling the lateral deflection. However, the posts which remain in place do provide a substantial part of the lateral resistance to the impacting vehicle and are therefore critical to proper performance.

Cable guardrail deflection is dependent on the system being used and the post spacing. Cable guardrail is typically installed with mower strips (paved strip under the rail) and socketed post holes to aid in repair and maintenance of the system.

Its use should be tempered by the following considerations:

1. **Snow**. Cable guardrail can be used where there is a problem with snow drifting or removing snow during plowing operations.
2. **Transitions**. Do not use cable guardrail to transition into a bridge rail.
3. **Slopes.** Do not use cable guardrail on fill slopes steeper than 2:1, unless the distance between the back of the posts and the break in the fill slope is at least 8 feet. For fill slopes which are 2:1 or flatter, provide a minimum 2 foot shelf between the back of posts and the break in the fill slope.
4. **Minimum Radius.** If cable guardrail is used on the outside of sharp radius curves, the post spacing may need to be reduced. See Exhibit 9-12.

5. **Maintenance**. In general, cable guardrail requires more maintenance after impact than the "W" beam guardrail. Therefore, the higher the probability of impact, the stronger the preference for the "W" beam system.

Centerline Radius	Maximum Post Spacing
≥ 700 feet	16 feet
≥ 440 feet & < 700 feet	12 feet
< 440 feet	Do not use cable guardrail

Exhibit 9-12
Cable Guardrail Post Spacing (On Outside of Horizontal Curves)

A cable barrier may also be used as a median barrier to contain and/or redirect errant vehicles. These barriers may help address the risks of cross median crashes on divided highways with narrow medians. MDT typically uses proprietary pre-stretched, tensioned cable guardrail in medians in order to close crossovers that are left in place and for preventing cross median crashes.

9.4.1.3 Box Beam Guardrail

Box beam guardrail (weak post) is a semi-rigid system with a dynamic deflection of 3 feet, 9 inches. Resistance in this system is achieved through the combined flexure and tensile stiffness of the rail. Posts near the impact are designed to break or tear away, thereby distributing the impact force to adjacent posts.

Box beam guardrail is generally used in snow drift areas and areas that require substantial snow plowing where cable guardrail is not acceptable (such as connecting to rigid barrier, i.e. bridge applications). Box beam guardrail used on curves with radii less than 715 feet should be shop-bent.

9.4.1.4 Concrete Barrier Rail

Concrete Barrier Rail (CBR) is typically used in narrow freeway medians to provide positive protection and separation of traffic. A tall wall barrier (46-inch barrier) may also be used in place of regular 32-inch barrier, if needed. The design team should check the line of sight over the barrier along the horizontal curves as described in Chapter 2, Section 2.8.1.1 to determine if the tall wall barrier is an appropriate installation. Anchored, cast-in-place CBR may also be considered on the roadside to shield rigid objects where minimal deflection distance is available (i.e., the object is less than 3.5 feet from the face of barrier). If a rigid object is not continuous (e.g., bridge piers), the design team may use a half-section CBR and provide the required installation details. All existing two-loop concrete barriers, including tall wall barrier, that needs to be moved for any reason during construction, must be replaced with *NCHRP 350 Recommended Procedures for the Safety Performance Evaluation of Highway Features or Manual for Assessing Safety Hardware (MASH)* compliant concrete barriers *(3, 5)*. This includes barriers that would be moved temporarily to perform paving and replaced in its original location. Salvaged two-loop barrier may not be used on Federal-aid highway projects for temporary or permanent installations.

9.4.1.5 Stiffened Guardrail

The use of stiffened rail should be considered when there is insufficient deflection distance behind the "W" Beam rail to the obstacle. Stiffened rail can also be used to increase post spacing to avoid conflicts with buried objects, such as culverts. Stiffened guardrail is comprised of a combination of reduced post spacing on either side of the obstacle and doubled "W" beams. The use of different post spacing and doubled rail sections depend on whether a point obstacle or a line obstacle is being shielded.

Refer to the *MDT Detailed Drawings* for post and rail configurations.

9.4.2 Barrier Selection

9.4.2.1 Performance Criteria

The barrier performance-level requirements should be considered when selecting an appropriate roadside barrier. MDT uses *NCHRP 350 Recommended Procedures for the Safety Performance Evaluation of Highway Features* and *MASH (3, 5)*.

Most barriers have been developed and tested for passenger cars and pickup trucks and offer marginal protection when struck by heavier vehicles at high speeds and more acute impact angles. Therefore, if passenger vehicles are the primary concern, the "W" beam, box beam, or cable guardrail systems will normally be selected. Locations with undesirable geometrics, high traffic volumes and speeds, high-crash experience, and/or a significant volume of heavy trucks and buses may require a higher performance-level barrier. This is especially important if barrier penetration by a vehicle is likely to have serious consequences.

9.4.2.2 Dynamic Deflection

The design team should also consider the dynamic deflection in barrier selection. Exhibit 9-13 provides the deflection distances for the various systems. If the appropriate deflection distance is not available, stiffen the railing system or use a CBR.

9.4.2.3 Maintenance

Another consideration in selecting the barrier type depends on maintenance of the system. Although the "W" beam can often sustain second hits, it should be repaired to standards and monitored frequently. In areas of restricted geometry, high speeds, high traffic volumes, and/or where railing repair creates hazardous conditions for both the repair crew and for motorists using the roadway, consider using the rigid CBR. The CBR also allows better control of roadside vegetation.

Exhibit 9-14 summarizes the advantages and disadvantages of the roadside barriers used on MDT facilities, as well as their typical usage.

Exhibit 9-13
Roadside Barrier Dynamic Deflection

Barrier Type	Dynamic Deflection Distances (Test Level 3)	Barrier Width	Min. Dist. From Face Rail to Obstacle
MGS – "W" Beam	3'-11"	1'-7"	5.5'
Stiffened "W" Beam – Point Obstacle 3'-1 ½" Post Spacing - Single Rail[1]	2'	1'-7"	3.6'
Stiffened "W" Beam – Line Obstacle 1'-6¾" Post Spacing - Doubled Rail[1]	1'-1"	1'-7"	2.7'
MGS Long Span – 25'-0" Span	7'-9"	1'-11"	9.7'
MGS Long Posts 2:1 slopes without widening	4'-4"	1'-7"	5.9'
Box Beam Guardrail	4'-10"	9"	5.6'
Concrete Barrier Rail[1 2]	4'-6"	2'-0"	6.5'
Anchored Concrete Barrier Rail[1]	1'-6"	2'-0"	3.5'

[1]NCHRP 350 Test – MASH Testing has not been completed for this item.
[2]Please refer to MDT Concrete Barrier Rail research for additional information.

Exhibit 9-14 Roadside Barrier Selection

SYSTEM	ADVANTAGES	DISADVANTAGES	TYPICAL USAGE
"W" Beam Guardrail	• Low initial cost. • High level of familiarity by maintenance personnel. • Can safely accommodate wide range of impact conditions for passenger cars. • Relatively easy installation. • Remains functional after moderate collisions.	• Cannot accommodate impacts by large vehicles at other than flat angles of impact. • At high-impact locations, will require frequent maintenance. • Susceptible to vehicular underride and override. • Susceptible to vehicular snagging (without rub rail).	• Non-freeways. • Freeways.
High Tension Cable Guardrail	• Low initial cost. • Improved underride/override protection. • Can safely accommodate wide range of impact conditions for passenger cars. • Relatively easy installation. • Most forgiving of all systems.	• Cannot sustain a second impact. • Cannot accommodate impacts by large vehicles. • Cannot be used with curbing. • Requires significant maintenance after an impact. • Cannot be placed on inside of any horizontal curve or on outside of horizontal curves with radii less than 440 feet • Cannot be used to transition to bridge rail. • Large deflection distance required.	• Areas where there are problems with snow drifting and snow plowing.
Concrete Barrier Rail	• Can accommodate most vehicular impacts without penetration. • Little or no deflection distance required behind barrier. • Little or no damage sustained for most vehicular impacts; therefore, least need for maintenance. • No vehicular underride potential or snagging potential.	• Highest initial cost. • For given impact conditions, highest occupant decelerations; therefore, least forgiving of barrier systems. • Reduced performance where offset between traveled way and barrier exceeds 15 feet • May be considered a barrier to wildlife movement	• In front of rough rock cuts. • Where high traffic volumes are present. • Where high volumes of large vehicles are present. • Where snagging is a concern. • As a median barrier. • Where little or no deflection area is available.
Box Beam Guardrail	• Can be installed on the inside or outside of any curve. • Less deflection distance than cable guardrail. • Considered an aesthetic type of barrier.	• High initial cost. • Cannot sustain a second impact. • Cannot accommodate impacts by large vehicles. • Requires significant maintenance after impact. • Cannot be used with curbing. • No small radius approach applications (IRTs)	• Areas where there are problems with snow drifting and snow plowing, and cable guardrail cannot be used.

9.4.3 Roadside Barrier Layout

9.4.3.1 Length of Need (General)

A roadside barrier should be extended a sufficient distance upstream from the obstacle (advancement length) to safely protect a run-off-the-road vehicle. Otherwise, the vehicle could travel behind the barrier and impact the obstacle. The design team should recognize that vehicles depart the road at relatively flat angles. Based on a number of field studies, the average angle of departure is estimated to be 10 degrees. The 80th percentile is estimated to be 15 degrees. These flat angles of departure result in the need to extend the barrier a distance upstream of the obstacle.

The following equation is used to determine the total barrier length for a given roadside condition:

$$L_{TOTAL} = L_{ADJACENT} + L_{OBSTACLE} + L_{OPPOSING}$$

Equation 9.4-1

Where:

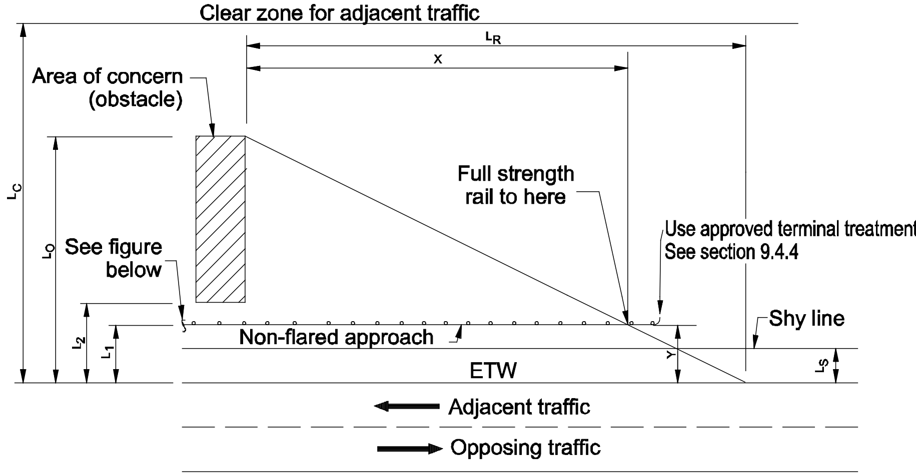
$L_{ADJACENT}$	=	The length needed in advance of the obstacle required to protect traffic in adjacent lanes.
$L_{OBSTACLE}$	=	The length of the obstacle itself.
$L_{OPPOSING}$	=	The length in advance of the obstacle needed to protect traffic in opposing lanes.

Only a portion of the terminal sections are included in the overall barrier length of need. See the *MDT Detailed Drawings* to determine the portion of the terminal section which may be included in the total length of need for the barrier.

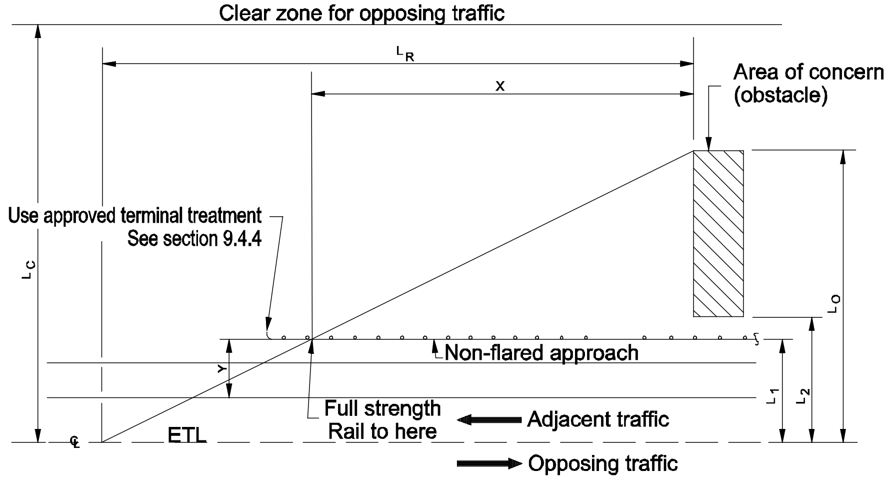
Exhibit 9-15 illustrates the variables that should be considered in designing a roadside barrier to effectively shield an obstacle. As noted in the exhibit, the shy line is the distance from the edge of traveled way beyond which a roadside object will not be perceived as an obstacle. When a roadside object is perceived as an obstacle, the motorist may reduce their speed or change vehicle position on the roadway. Exhibit 9-15 illustrates the use of non-flared barrier design.

Where fill slopes change within the advancement length of the rail, calculate the advancement length using the clear zone for each traversable slope shown on the cross sections adjacent to the obstacle. Compare the results and use the location that produces the shortest length of rail. Generally, do not interpolate intermediate locations of slope changes between cross sections.

Exhibit 9-15
Barrier Length of Need



Approach treatment for adjacent traffic (a)



Approach treatment for opposing traffic (b)

9.4.3.2 Length of Need (Embankment/Obstacle That Extends to Edge of the Clear Zone)

Once the appropriate variables have been selected, the required length of need in advance of the obstacle can be calculated from Equations 9.4-2 and 9.4-3. These equations are used when the obstacle is an embankment or a fixed object which extends to or beyond the clear zone:

$$X = \frac{L_R (L_O - L_1)}{L_O}$$

Equation 9.4-2

$$Y = L_1$$

Equation 9.4-3

Where:

X, Y = coordinates of beginning of barrier need.

L_C = recommended clear zone.

L_O = distance from edge of traveled way to back of obstacle (i.e., the lateral extent of the obstacle). For a fixed object, the lateral extent of the obstacle (L_O) is the distance from the edge of the traveled way to the far side of the obstacle. If the obstacle is an embankment or a fixed object that extends beyond the clear zone, L_O is measured to the outside edge of the clear zone (L_C); i.e., L_O = L_C.

Exhibit 9-16
Design Elements for Barrier Length of Need

Design Speed (mph)	Runout Length L_R (ft) Design Year Traffic Volume (AADT)				Shy Line Offset L_S (ft)
	>10,000	>5,000 ≤10,000	>1,000 ≤5,000	≤1,000	
80	470	430	380	330	12
70	360	330	290	250	9
60	300	250	210	200	8
50	230	190	160	150	6.5
40	160	130	110	100	5
30	110	90	80	70	4

L_S = shy line offset or distance at which barrier is no longer perceived as an obstacle by a driver

L_R = runout length

L_1 = distance from edge of traveled way to face of barrier.

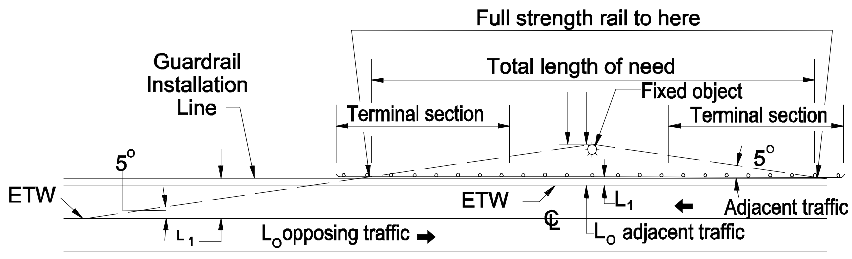
L_2 = distance from edge of traveled way to front of obstacle. ($L_2 - L_1$) should equal or exceed the deflection distance.

9.4.3.3 Length of Need (Obstacle Within Recoverable Clear Zone)

Use Equations 9.4-4 and 9.4-5 when the obstacle requiring shielding lies entirely within the clear zone, as illustrated in Exhibit 9-17.

Exhibit 9-17
Barrier Length of Need (Fixed Object Within Clear Zone

Note: Exhibit 9-17 is for a point obstacle only. For longer obstacles located entirely within the clear zone, add the length of obstacle to the length of need and calculate lengths of need from each end.



Equation 9.4-4

$$X = \frac{L_O - L_1}{\tan 5^\circ}$$

Equation 9.4-5

$$Y = L_1$$

Where:

X, Y = coordinates of beginning of barrier need.

L_O = distance from edge of traveled way to back of obstacle (i.e., the lateral extent of the obstacle).

L_1 = distance from edge of traveled way to face of barrier.

5° = departure angle.

For two-way traffic, use these formulas for the approach treatment for both the adjacent and opposing traffic. For one-way traffic, use these formulas for the approach treatment of the adjacent traffic and extend the barrier to the far side of the obstacle.

For obstacles located near the clear zone limit, check the necessary barrier length using both the L_R formulas (Section 9.4.3.2) and the 5-degree angle formulas (Section 9.4.3.3). Use the method that produces the shorter overall length of barrier.

9.4.3.4 Length of Need (Horizontal Curves)

The length of need formulas (Equations 9.4-2 through 9.4-5) are applicable to tangent highway alignment and where the roadside obstacle is on the inside of a horizontal curve. A vehicle leaving the roadway on the outside of a horizontal curve will generally follow a tangential runout path. Therefore, rather than using the theoretical L_R distance to determine the length of need, use a tangent line from the edge of the traveled way to the outside edge of the obstacle. The length of need is determined by intersecting the barrier installation line with the tangent line, as shown in Exhibit 9-18. This intersection can most readily be obtained graphically. If the tangent line is less than L_R, use this intersection. However, if the tangent line is greater than L_R, use the L_R distance from the back of the obstacle to intersect the installation line to determine the adjacent length.

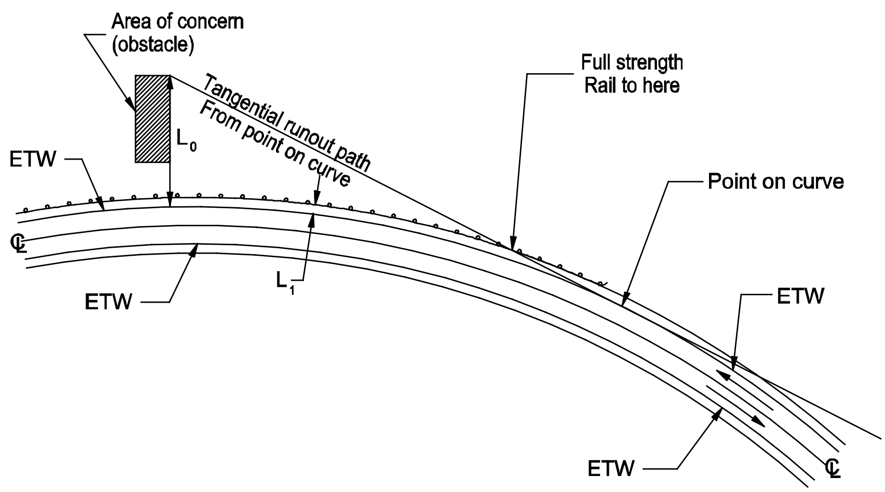


Exhibit 9-18
Barrier Length of Need
(Outside of Horizontal Curve)

9.4.3.5 Lateral Placement

Roadside barriers should normally be placed as far as practical from the edge of the traveled way. Such placement gives an errant motorist the best chance of regaining control of the vehicle without impacting the barrier. It also improves sight distance, particularly at nearby intersections. However, most barrier systems are installed at the edge of pavement to mitigate the shoulder widening necessary to provide a 10:1 (maximum) slope in front of the barrier as described in 9.4.3.7. Consider the following factors when determining barrier lateral placement:

1. **Deflection:** The dynamic deflection distance of the barrier, as measured from the face of the rail, should not be violated. Section 9.4.2.2 provides the deflection distances for the types of roadside barriers.
2. **Post Support.** At a minimum, provide 2 feet between the back of the barrier post and the slope break in a fill slope to provide adequate soil support for the post. If it is impractical to provide 2 feet behind the rail, long posts can be used on normal runs of rails (does not apply to bridge approach or terminal sections). The following options are available:
   a. **"W" Beam**
      i. 9-foot steel posts at the standard 6-foot, 3-inch spacing
      ii. 7.5-foot wood posts at the standard 6-foot, 3-inch spacing
      iii. 7-foot steel posts at 3-foot, 1.5-inch spacing
      iv. 7-foot wood posts at 3-foot, 1.5-inch spacing
   b. **Box Beam**
      i. 8-foot steel posts at the standard 6-foot spacing

Refer to the *MDT Detailed Drawings* for additional information.

3. **Shy Distance.** Barrier should be installed at the edge of the shoulder and should provide a minimum distance of 2 feet from the face of the rail to the edge of the traveled way. For some roadway widths, this practice will not meet the requirement of the shy line offset as presented in Exhibit 9-16. In these cases, installing the guardrail at the shy line offset distance is not practical and is not recommended.
4. **Shoulder Widening.** Provide a minimum distance of 2 feet between the edge of the traveled way and the face of the rail. If this distance is not available on the existing shoulder, additional widening will be necessary.

9.4.3.6 Placement in Conjunction With Curbs

For rural (outside the boundaries of urban areas) roadways and urban roadways where the design speed is greater than 45 miles per hour, do not place curbs in front of roadside barriers. Where curbs are used in conjunction with roadside barriers on low-speed facilities, the face of the barrier should be in line with the face of the curb (i.e., at the gutter line). Do not use curbs higher than 4 inches with a barrier on new construction facilities. Existing curb installations higher than 4 inches may remain if the installation otherwise meets MDT criteria. Measure the height of the barrier from the pavement surface (e.g., where curbs are on bridges). A weak post system, such as cable or box-beam guardrail, cannot be used in conjunction with curbing.

9.4.3.7 Placement on Slopes

Slopes in front of a barrier should be 10:1 or flatter. This also applies to the areas in front of the flared section of guardrail and to the area approaching the terminal ends. See the *MDT Detailed Drawings*.

9.4.3.8 Transitions

Barrier transitions are necessary to join two systems with different structural and/or dynamic characteristics. For example, this occurs when guardrail approaches a bridge parapet or CBR installation. The *MDT Detailed Drawings* provide details for the bridge approach section. See the *AASHTO Roadside Design Guide* for additional discussion on barrier transitions *(2)*.

9.4.3.9 Minimum Length/Gaps

Short runs of barrier have limited value and should be avoided. Generally, a barrier should have at least 100 feet of standard rail section exclusive of terminal sections and/or transition sections (does not include rail connected to structures or other blunt ends). Short gaps between runs of barrier are undesirable. Therefore, gaps of less than 165 feet between barrier termini should be connected into a single run. Exceptions may be necessary for access, or other project considerations.

9.4.4 Terminal Treatments

Barrier terminal sections present a potential roadside obstacle for run-off-the-road vehicles. However, they are also critical to the proper structural performance of the barrier system. The selection and design of the terminal end section should be carefully coordinated with the barrier system's purpose and length of need. The design team should review the *MDT Detailed Drawings* or manufacturer's specifications to determine what portion of the terminal section can be applied to the length of need.

New terminal systems are continually emerging to address safety problems, and devices are being improved in response to an increased understanding of safety performance, a changing vehicular fleet, the emergence of new materials and other factors.

See the *MDT Detailed Drawings* for details on the design and placement of acceptable roadside hardware.

9.4.5 Roadside Hardware Supports (Mailbox Supports)

Where roadside hardware (e.g., sign supports, illumination poles, traffic signal poles, mailboxes) cannot be reasonably located outside of the clear zone, they should be made breakaway or shielded with a roadside barrier or impact attenuator. This section discusses the criteria specifically for mailbox supports. For sign supports and luminaires, the design team should coordinate with the Traffic Engineering Section.

Mailboxes and newspaper tubes served by carriers in vehicles may constitute a roadside obstacle, depending upon the placement of the mailbox. The design team should make every reasonable effort to replace all non-conforming mailboxes with the designs that meet the criteria in A Guide to Mailbox Safety in Montana, the *AASHTO A Guide for Erecting Mailboxes on Highways*, and the *MDT Detailed Drawings (6)*.

In general, mailboxes should meet the following criteria:

1. **Heights.** Mailbox heights are usually located so that the bottom of the box is 3.3 feet to 4 feet above the mail stop surface.
2. **Post.** The maximum strength supports that should be used are nominal 4-inch-by-4-inch wood posts or 4-inch diameter wood posts or 2-inch diameter standard galvanized steel pipe post, embedded no more than 2 feet into the ground. The use of concrete anchors is not acceptable.
3. **Multiple Mailboxes.** To reduce the possibility of ramping, multiple mailboxes should be separated by a distance at least equal to three-fourths of their height above ground.
4. **Neighborhood Delivery and Collection Box Units (NDCBU).** NDCBU is a cluster of 8 to 16 locked boxes mounted on a pedestal or within a framework. Because the total mass for the NDCBU may range between 100 pounds and 200 pounds, they are considered a roadside obstacle. NDCBUs are intended to be located in trailer parks, apartment complexes and new residential subdivisions. If there is no alternative, locate NDCBUs on low-speed facilities in conjunction with mailbox turnouts and outside of the clear zone.

Ramping is the result of objects (e.g., multiple mailboxes) forming an inclined surface that can cause a vehicle to vault during a collision.

9.5 MEDIAN BARRIERS

9.5.1 Warrants

The following summarizes MDT median barrier criteria:

1. **Freeways.** Exhibit 9-19 presents the warrants for a median barrier based on median width and traffic volumes. The traffic volumes are based on a minimum 5-year projection. In the areas shown as optional, the decision to use a median barrier will be based on construction and maintenance costs and crossover crash experience. A median barrier may be warranted on medians not within the optional or warranted area, if a significant number of crossover crashes have occurred.
2. **Non-Freeways.** On other highways, judgment should be used to determine median barrier warrants. On highways without full access control, the median barrier should be terminated at intersections where it has been determined that an opening will be provided. In addition, lower speeds will reduce the likelihood of crossover crashes. Therefore, on non-freeway highways, the design team should evaluate the crash history, traffic volumes and speeds, median width, alignment, sight distance, and construction costs to determine the need for a median barrier. Exhibit 9-19 can be used for guidance.

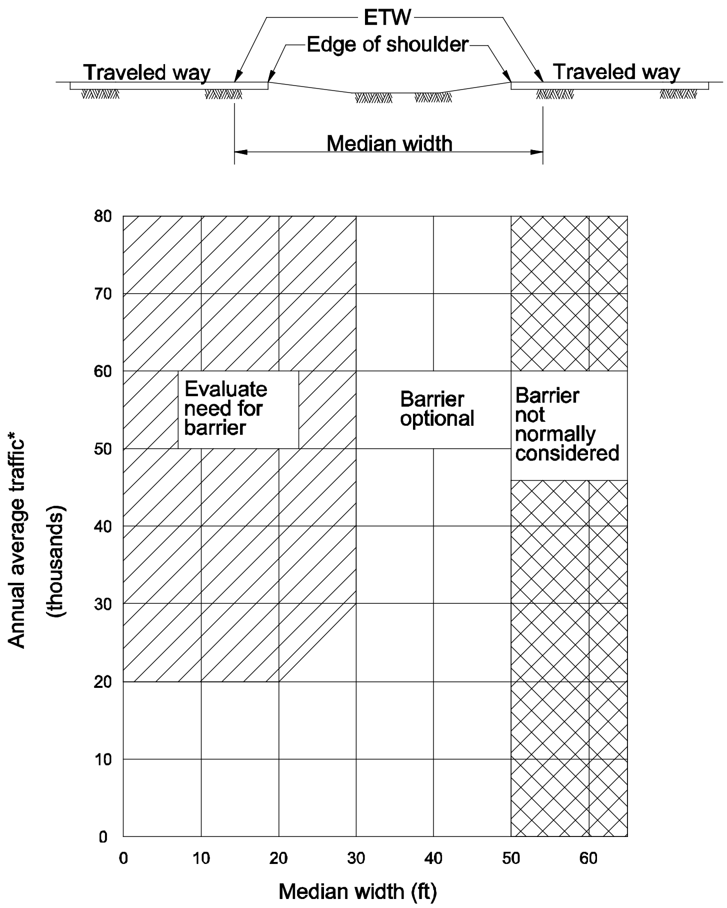
9.5.2 Types

When a median barrier is warranted, due to narrow medians, MDT's policy is to only use a Concrete Barrier Rail (CBR). The CBR is a rigid system which will rarely deflect upon impact. A half-section CBR may be necessary where the median barrier should divide to go around a fixed object in the median (e.g., bridge piers). In this situation, the obstacle is typically encased within concrete to create a level surface from CBR face to CBR face.

The "W" beam guardrail is typically used within the median to protect the driver from isolated obstacles (e.g., bridge approaches or piers). The design team should review Section 9.4.3 and the *MDT Detailed Drawings* for the design and placement criteria of "W" Beam guardrail within the median; i.e., the median is treated as a "roadside" in these cases.

MDT has used pre-stretched, tensioned cable within the median to address crossover crashes and to close median crossovers left in place. For such installations, MDT requires the posts be socketed for ease of maintenance, and require the rail meets TL-3 criteria. Use information provided in the *AASHTO Roadside Design Guide* for additional guidance on best practices for placement in the median *(2)*.

Exhibit 9-19
Median Barrier Warrants



* Based on a minimum five-year projection

9.5.3 Median Barrier Layout

Much of the information presented in Section 9.4.3 on roadside barrier layout also applies to concrete median barriers (e.g., length of need, flare rates). The following presents criteria specifically for the layout of concrete median barriers:

1. **Flared/Divided Median Barriers**. It may be necessary to intermittently divide a median barrier or to flare the barrier from one side to the other to shield a fixed object in the median. The fixed object may be shielded by one of these methods:
   a. A fixed object may be encased by a CBR.
   b. A half-section CBR may be used on both sides to shield a fixed object.
2. **Barrier-Mounted Obstacles**. If trucks or buses impact the CBR, their high center of gravity may result in a vehicular roll angle which possibly will allow the truck or bus to impact obstacles on top of the CBR (e.g., luminaire supports). If practical, move these devices to the outside and make them breakaway, or provide additional distance between the barrier and obstacle by using a flared/divided median barrier.

3. **Terminal Treatments**. As with roadside barrier terminals, CBR terminals also present a potential roadside obstacle for run-off-the-road vehicles. Give careful consideration to the selection and placement of the terminal end. For the terminal ends of concrete barrier rail, see *MDT Detailed Drawings.* See Section 9.6 for more information on end treatments.

9.6 END TREATMENTS

9.6.1 General

End treatments are protective systems that prevent errant vehicles from impacting fixed obstacles by either decelerating the vehicle to a stop after a frontal impact or by redirecting it away from the obstacle after a side impact. The *AASHTO Roadside Design Guide* describes three types of end treatments, including: Anchorages, Terminals and Crash Cushions (Impact Attenuators) *(2)*.

Anchorages are devices that anchor a flexible or semi-rigid barrier to the ground to develop its tensile strength during an impact. This type of end treatments is not considered crashworthy; therefore, they are typically only used on a trailing end of a barrier on a one-way roadway or on a barrier that is located outside of the clear zone. Terminals are similar to anchorages, as they also anchor a barrier to the ground. Terminals are considered crashworthy and are typically used at the end of a barrier within the clear zone *(2).*

Impact attenuators, which are also known as crash cushions, can be attached to or placed in front of concrete barrier rails or other rigid fixed objects. Impact attenuators are also adaptable to many roadside obstacle locations where longitudinal barriers cannot practically be used (e.g., bridge piers and non-breakaway sign supports). Section 9.4.4 previously discussed various types of terminal treatments. The remainder of this section provides details for impact attenuators.

9.6.2 Warrants

Impact attenuator warrants are the same as barrier warrants. Once an obstacle is identified, the design team should first attempt to remove, relocate, or make the obstacle break away. If the foregoing is impractical, then consider an impact attenuator.

Impact attenuators are most often installed to shield fixed-point obstacles which are too close to the traveled way to allow room for other types of barriers and are more likely to sustain a head-on impact. Examples include exit gore areas (particularly on structures), bridge piers, and non-breakaway sign supports. Impact attenuators are often preferable to guardrail to shield these obstacles. Site conditions and costs will determine whether to use a barrier or impact attenuator. Impact attenuators are the only type of terminal section used for CBR requiring an end treatment.

9.6.3 Impact Attenuator Types

Refer to the *MDT Detailed Drawings* for information on the types of acceptable impact attenuators. All impact attenuator types are patented, and the design team should contact the manufacturer for additional information on impact attenuator installations.

9.6.4 Impact Attenuator Design

Once an impact attenuator has been selected, the design team should ensure that its design is compatible with the traffic and physical conditions at the site. The following sections will provide criteria for the basic input parameters for impact attenuator design.

9.6.4.1 Performance Criteria

All impact attenuators must be certified as having passed the performance criteria in *NCHRP Report 350 Recommended Procedures for the Safety Performance Evaluation of Highway Features* or *MASH (3, 5)*.

9.6.4.2 Design Procedures

Refer to the *MDT Detailed Drawings* for the lengths required for each design speed to determine the appropriate length of the different impact attenuators approved for use by MDT.

9.6.4.3 Placement

Several factors should be considered in the placement of an impact attenuator:

- **Level terrain.** All impact attenuators have been designed and tested for level conditions. Vehicular impacts on devices placed on a non-level site could result in an impact at the improper height which could produce undesirable vehicular behavior. Therefore, the attenuator should be placed on a level surface or on a cross slope not to exceed 5 percent.
- **Curbs.** No curbs should be present on new projects at proposed impact attenuator installations. On existing highways, all curbs should be removed at proposed installations if feasible, particularly those that are 4 inches or higher.
- **Surface**. A paved, bituminous or concrete pad should be provided under the impact attenuator.
- **Orientation**. The impact attenuator should be oriented to accommodate the probable impact angle of an encroaching vehicle. This will maximize the likelihood of a head-on impact. The proper orientation angle will depend upon the design speed, roadway alignment and lateral offset distance to the attenuator. Generally, the attenuator should be aligned parallel to the adjacent traffic. See the manufacturer's data for more information.
- **Reserve Area.** The design team should, as early as practical in the project design process, determine the need for and approximate dimensions of

impact attenuators. This will avoid late changes which could significantly affect the project design.

9.7 REFERENCES

1. Montana Department of Transportation (MDT). *MDT Baseline Criteria Practitioner's Guide.* MDT, Helena, MT, 2021.
2. American Association of State Highway and Transportation Officials (AASHTO). *Roadside Design Guide, 4th Edition*. AASHTO, Washington, D.C., 2011.
3. Ross, Jr., H. E., et. al. *NCHRP Report 350: Recommended Procedures for the Safety Performance Evaluation of Highway Features.* TRB, National Research Council, Washington, D.C., 1993.
4. Marzougui, D., et. al. *Performance Evaluation of Low-Tension Three-Strand Cable Median Barriers.* Transportation Research Board of the National Academies, Washington, D.C., 2007.
5. AASHTO. *Manual for Assessing Safety Hardware (MASH)*. AASHTO, Washington, D.C., 2009.
6. AASHTO. *A Guide for Erecting Mailboxes on Highways.* AASHTO, Washington, D.C., 1994.