

HIGHWAY DESIGN MANUAL

Chapter 10 - Roadside Design, Guide Rail, and Appurtenances

Revision 64

April 10, 2012

CHAPTER 10
ROADSIDE DESIGN, GUIDE RAIL AND APPURTENANCES

<u>Contents</u>	<u>Page</u>
10.1 INTRODUCTION	10-1
10.2 NEW, RECONSTRUCTION, AND FREEWAY 2R/3R PROJECTS	10-3
10.2.1 Clear Zones	10-3
10.2.2 Barrier Design Parameters	10-19
10.2.3 Barrier Types	10-42
10.2.4 Median Barriers	10-58
10.2.5 Barrier Terminals	10-79
10.2.6 Impact Attenuators	10-96
10.2.7 Developed Area and Large Volume Exceptions	10-111
10.3 EXISTING FACILITIES	10-126
10.3.1 Evaluation of Existing Facilities	10-128
10.3.2 Detailed Scope of Work Determinations	10-135
10.3.3 Documentation of Roadside Design Process for Existing Facilities	10-143
10.4 CONSTRUCTION ZONE GUIDANCE	10-147
10.5 SPECIAL TOPICS	10-148
10.5.1 Mailboxes	10-148
10.5.2 Fencing	10-150
10.5.3 Cattle Passes	10-156
10.5.4 Guide Posts	10-157
10.5.5 Barriers at Dead End Roads and Streets	10-157
10.5.6 Public Relations	10-158
10.5.7 Resetting Guide Rail	10-159
10.6 REFERENCES	10-163
APPENDIX A - SPOT EVALUATION OF DESIRABLE CLEAR ZONE WIDTHS	10-167
APPENDIX B - SUPPORT OF GUIDE RAIL OVER SHALLOW OBSTRUCTIONS	10-175
APPENDIX C – BARRIER IMPACT TESTING AND ITS RELATION TO IN-SERVICE PERFORMANCE	10-199
INDEX	10-207

ROADSIDE DESIGN

LIST OF FIGURES

Figure	Title	Page
10-1	Clear Zone Segments	10-8
10-2	Sample Table of Clear Zone Widths	10-10
10-3a	Basic Point-of-Need Determinations.....	10-22
10-3b	Crush Accommodation for Parallel-Type Proprietary Terminals.....	10-23
10-4a	Runout Lengths	10-25
10-4b	Left Side Runout Lengths	10-26
10-4c	Runout Length Alternatives	10-27
10-4d	Back Slope Anchorage for Weak Post Rail Systems.....	10-28
10-4e	Back Slope Anchorage for Heavy-Post Blocked-Out Corrugated Rail	10-29
10-4f	Clear Area Requirements behind Terminals.....	10-30
10-5	Maximum Lateral Offset.....	10-34
10-6	Deflection Reduction Factors.....	10-34
10-6a	Intermediate Posts Required to Reduce Rail Deflections	10-35
10-7	Guidance for Median Barrier Use on High-Speed Freeways and Expressways.....	10-59
10-8	Recommended Barrier Locations for Uneven Medians	10-68
10-9	Single Slope Concrete Barrier	10-69
10-10	Moveable Concrete Barrier	10-70
10-11	Truck Barrier	10-72
10-12	Terminals at Crossover Areas	10-78
10-13	Approved Sand Barrel Array for 90 km/h	10-100
10-14	Approved Sand Barrel Array for 100 km/h	10-101
10-15	Approved Sand Barrel Array for 110 km/h	10-101
10-16	Example Page of Roadside Design Summary	10-143
10A-1	Clear Zone Terminology and Nonrecoverable Slopes	10A-2
10A-2a	Sample Clear Zone Calculations-Cases I & II (Nonrecoverable Slopes).....	10A-4
10A-2b	Sample Clear Zone Calculations-Case III (Rock Cut)	10A-5
10A-2c	Sample Clear Zone Calculations-Case IV (Ramp Curve).....	10A-6
10A-2d	Sample Clear Zone Calculations-Plan of Varying Width Clear Zone.....	10A-7
10A-2e	Sample Clear Zone Calculations-Section for Uniform Clear Runout Width	10A-7
10B-1	Cable GR Adjustments over Narrow Shallow Obstructions to Post Driving.....	10B-6
10B-2	Cable GR Adjustments over Wide Shallow Obstructions to Post Driving	10B-7
10B-3	Cable Guide Rail Adjustments Involving Only Post Shortening.....	10B-8
10B-4	Weak Post W-Beam Guide Rail with 12' - 6" Typical Post Spacing – Adjustments for Shallow Obstructions to Post Driving	10B-10
10B-5	W-Beam GR with 6' - 3½" Post Spacing Over Shallow Obstructions (1 of 2).....	10B-11
10B-6	W-Beam GR with 6' - 3½" Post Spacing Over Shallow Obstructions (2 of 2).....	10B-12
10B-7	Box Beam GR w 6' Post Spacing over Narrow Obstructions to Post Driving	10B-14
10B-8	Box Beam GR w 6' Post Spacing over Wide Obstructions to Post Driving.....	10B-15
10B-9	Box Beam Guide Rail with 3' Post Spacing Over Shallow Obstructions.....	10B-16
10B-10	Accommodating Shallow Obstructions for HPBO with 6' - 3" Spacing	10B-18
10B-11	Accommodating Shallow Obstructions to Post Driving for HPBO W-Beam with Channel Backup and/or 3' - 1½" Spacing.....	10B-19
10B-12	Acceptable Base Plate Design & Bolting Options for Weak Post GR Systems..	10B-21

ROADSIDE DESIGN

LIST OF TABLES

<u>Table</u>	<u>Title</u>	<u>Page</u>
10-1	Recommended Basic Recovery Widths	10-5
10-2	Horizontal Curve Adjustment Factors (K_{oc})	10-5
10-3	Barrier Deflections for Standard Impacts	10-33
10-4	Minimum Shoulder Break Offsets to Back of Guide Rail Posts	10-50
10-5	Recommended Barrier Flare Rate Limits for Permanent Installations.....	10-80
10-6	Location of HDM Guidance on Roadside Design Process for Existing Facilities.	10-126
10-7	Acceptable Barrier Heights when Upgrading Existing Facilities	10-133
10-8	Recommended Minimum Flare Rates for Temporary Concrete Barrier	Chapter 16
10-9	Recommended Guide Rail Installation Time Allowances	10-158

6/28/2010

Revisions:

Page	Change
10-37 through 10-39	Updated Section 10.2.2.4 to use the 2011 AASHTO Roadside Design Guide Section 5.6.2.1.1 definitions for low speed, medium speed and high speed for curb usage.
10-134	Updated Table 10-7 to incorporate revised mounting heights and tolerances for cable and HPBO W Beam barriers.

CHAPTER 10

ROADSIDE DESIGN, GUIDE RAIL, AND APPURTENANCES

10.1 INTRODUCTION

The purpose of this chapter is to provide the designer with guidance on measures to reduce the number and/or severity of accidents when vehicles leave the traveled way.

The concept of a forgiving roadside environment was developed in the 1960s. A key element of the concept was the creation of "clear zones" within which a driver might recover control and return to the roadway or at least achieve significant deceleration before striking a fixed object. Where fixed obstacles could not be removed from the clear zone or modified with breakaway features, consideration would be given to shielding them to reduce the severity of vehicle impacts.

The American Association of State Highway and Transportation Officials (AASHTO) incorporated many of these new concepts into the text *A Policy on Geometric Design of Highways and Streets* (the "Green Book"). A second key publication is AASHTO's *Roadside Design Guide* which deals more directly with the content of this chapter. The designer should be familiar with the relevant roadside design guidance contained in those publications before developing special-case roadside designs that deviate from the guidance in this chapter.

Many of New York's state highways were modified or built to meet the early guidance. The guidance gradually evolved to reflect the results of crash test programs and in-service performance of early safety systems. As new facilities were built or major reconstruction projects were undertaken, roadside features were constructed to meet the design guidance prevailing at that time. As a result of the ongoing evolution of the guidance, there are many miles of state highway which have roadside features which do not conform or only partially conform to current guidance.

One intent of Chapter 10 is to present guidance for new or reconstructed facilities. This guidance is presented under Section 10.2 New and Reconstructed Facilities.

This chapter also provides guidance for assessing existing facilities to determine the number of safety concerns and nonconforming features that are present in the roadside area and the amount of upgrading that would be appropriate when work is performed on that existing facility. Roadside safety concerns are defined as features that may (1) increase the severity of a run-off-the-road (ROR) accident, or (2) change a ROR incident into a ROR accident, but are either located beyond the clear zone width or are within acceptable practice. With respect to roadside design, nonconforming features are features that do not conform to current practice and are typically within the clear zone width. They may range from mildly deficient to severely deficient. The cost of upgrading some roadside safety concerns might not be justified if the resulting benefit to public safety is very small. A key factor in judging which features should be upgraded

will be the relevant accident history of the facility when compared with other similar facilities. The guidance for performing an accident analysis will be found in Chapter 5 - Basic Design. The guidance for making upgrade judgments is presented under Section 10.3, Existing Facilities. Additional guidance for work on existing facilities is presented in Chapter 7 - Resurfacing, Restoration, and Rehabilitation (3R).

The use of barriers within construction work zones was previously contained in Section 10.4 Construction Zone Guidance but has been moved to HDM Chapter 16. Additional guidance for treatments of work zones is presented in Chapter 9 of AASHTO's *Roadside Design Guide*.

Section 10.5 Special Topics discusses additional features that are significant to roadside design.

10.2 NEW, RECONSTRUCTION, AND FREEWAY 2R/3R PROJECTS

The purpose of this section is to provide guidance for the design of roadside features on new construction, reconstruction, freeway Resurfacing, Restoration and Rehabilitation (3R), and freeway 2R projects. Guidelines for evaluation of existing highways are addressed separately in Section 10.3 Existing Facilities. Identification of safety concerns and nonconforming roadside features on reconstruction projects should follow the guidance of Section 10.3, while the design to remedy identified problems should follow the guidance of Section 10.2.

The general roadside design policy for new, reconstruction, and freeway 2R/3R projects is to provide satisfactory clear zones, whenever it is practical to do so, and appropriately designed barriers, when it is not. Section 10.2.1 introduces the clear zone concept and the hierarchy of design options for the treatment of potential safety hazards. Except as noted elsewhere in this chapter, if a fixed object is to remain closer to the traveled way than the clear zone width defined at that point, either the object should be shielded or an explanation should be provided in the project record. The design parameters for barriers are discussed in Section 10.2.2, followed by descriptions and selection guidance for roadside barriers, median barriers, terminals, and impact attenuators. Section 10.2.7 concludes with a discussion of the exceptions that may be appropriate for developed area and large-volume roadways.

10.2.1 Clear Zones

Under ideal conditions, a vehicle that inadvertently left the roadway would encounter an extensive, firm, flat, hazard-free area that would permit the driver to safely return to the roadway. Limitations on the availability of right of way, consideration of visual, historical, environmental, and other impacts, and the cost of cutting and filling usually require that the width of the hazard-free area be limited to values that will generally, but not always, provide adequate distance for recovery. Clear areas are those roadside border areas which are essentially without hazards. The width of the clear area varies almost constantly, both in relation to the location along the highway and, to a lesser extent, as a function of time. It is not practical to precisely document the irregular widths of the clear area, nor is it reasonable to precisely measure and maintain those widths. It is important, however, to ensure that an easily defined minimum width be maintained to provide some safety zone for the occupants of errant vehicles. The portion of the clear area width that the Department will ensure is kept essentially clear and sufficiently level to permit (but not guarantee) reasonably safe reentry to the highway or provide an opportunity for stopping is termed the clear zone.

NYSDOT defines the Clear Zone as that portion of the roadside border width, starting at the edge of the through traveled way, that the Department commits to maintaining in a cleared condition for safe use by errant vehicles. The width of the Clear Zone will be as last documented in the Design Approval Document, the Project Files, or in the contract documents. If warranted by special conditions, the Clear Zone may include occasional unshielded fixed objects, provided a reasonable rationale is documented.

Scoping/Preliminary Design Stage - During design, the process of addressing roadside safety, and particularly the selection of the clear zone widths, is normally a two part process. In the first part, the site should be inspected to determine what the general target for the minimum clear

zone widths should be. These values are recorded in the Design Approval Document (DAD), since the Project Development Manual (Report Shells, Draft Design Report, Chapter 3, §3.3.1.8, paragraph 2) requires that, "The minimum clear zone(s) for the facility, its basis, and what is proposed should be discussed." The selected values can be the result of a rather cursory inspection. While it may be reasonable on some projects to define a single target width for the entire length of the project, it is preferable, certainly during the detail design stage, that the widths be varied in a step-wise fashion to follow the widths that can be achieved.

From a safety perspective, the desired width at any station will be a function of the design speed, traffic volume, roadside slopes, and curvature of the roadway. From a practical perspective, the width should take into account environmental effects, cost considerations, social and other factors. Accidents will occur, regardless of the clear zone width provided. The selected clear zone width is a compromise, based on engineering judgment, between what can practically be built and the degree of protection afforded the motorist.

For new construction, the minimum width selected should attempt to at least meet the widths indicated in Table 10-1 and, for curved alignments, widths increased by the factors in Table 10-2. For reconstruction projects and for interstate and freeway 2R and 3R projects, the values in those tables are still minimum goals, but may be tempered by field conditions, accident history, and other factors. Barring a significant history of run-off-road accidents, non-freeway 2R and 3R projects may frequently be designed with clear zone widths that do not meet the Recommended Widths in Table 10-1. In heavily developed urban areas, right-of-way limitations may preclude devoting any significant space to effective clear zones. The Department should have control of any right of way on which a clear zone is specified, since we would otherwise be unable to prevent the introduction of fixed objects into that clear zone.

If a reasonable clear zone width can not be provided, installation of a barrier system should be considered as discussed later in this chapter. A reasonable width would be greater than, or equal to, the minimum judged appropriate. At the other extreme, a clear zone width could be considered unreasonably wide if the width was required due to the need to incorporate a high, traversable, but nonrecoverable slope. The designer should consider clear runout widths, mowing and erosion issues, traffic speed and volume, and other factors when judging whether or not to shield a high 1:3 fill slope. If their height exceeds 15 ft, there will be a tendency for vehicles to be redirected more steeply down the slope. Such slopes should generally not be included in the clear zone, but should generally be shielded, particularly if there is not a broad runout width at the bottom.

In general, smooth, obstacle-free cut slopes that are parallel to the road may extend into the clear zone, provided these cut slopes are not steeper than 1:2 and all slope intersections between the traveled way and the cut slope have been rounded sufficiently to make them traversable and to minimize destabilization of errant vehicles.

Because of the high speeds and volumes involved, the standards for interstates were made more stringent in AASHTO's January 2005 publication, *A Policy on Design Standards - Interstate System*. Specifically, fill slopes steeper than 1:4 are not to be specified in the clear zones of new or reconstructed interstate highways and side slopes of 1:6, or flatter, are desirable. Where steeper slopes are required within the clear zone, roadside barriers shall be installed.

Table 10-1 Recommended Basic Recovery Widths (BRW, in feet from travel lane)

Design Speed (mph)	Design AADT	Fill Slopes			Cut Slopes		
		≤1:6	1:5 to 1:4	1:3	1:3	1:4 to 1:5	≤1:6
40 or less	under 750	8	8	**	8	8	8
	750 - 1500	11	13	**	11	11	11
	1500 - 6000	13	16	**	13	13	13
	over 6000	15	17	**	15	15	15
45-50	under 750	11	13	**	9	9	11
	750 - 1500	16	18	**	11	13	15
	1500 - 6000	17	23	**	13	15	17
	over 6000	21	26	**	15	19	21
55	Under 750	13	16	**	9	11	11
	750 - 1500	17	22	**	11	15	17
	1500 - 6000	21	27	**	15	17	21
	over 6000	23	29	**	17	21	23
60	Under 750	17	22	**	11	13	15
	750 - 1500	22	29	**	13	17	21
	1500 - 6000	28	30	**	16	20	25
	over 6000	30	30	**	21	25	27
70 or greater	Under 750	19	23	**	11	15	15
	750 - 1500	25	30	**	14	19	21
	1500 - 6000	30	30	**	18	23	27
	over 6000	30	30	**	23	28	29

Adapted from AASHTO's Roadside Design Guide, 1996. 2006 AASHTO is essentially unchanged.

** Since recovery is less likely on unshielded, traversable 1:3 slopes, fixed objects should not be present in the vicinity of the toe of these slopes. Recovery of high-speed vehicles that encroach beyond the edge of shoulder may be expected to occur beyond the toe of slope. Determination of the width of the clear runoff area at the toe of slope should take into consideration right of way availability, environmental concerns, economic factors, safety needs, and accident histories. Note that the distances are wider for higher traffic volumes. This reflects a desire to provide greater protection where the traffic exposure and, usually, the frequency of incursions, are higher.

Table 10-2 Horizontal Curve Adjustment Factors (K_{oc})

Radius of Curve (feet)	Design Speed (mph)					
	35	40	50	55	60	70
3000	1.1	1.1	1.1	1.2	1.2	1.2
2500	1.1	1.1	1.2	1.2	1.2	1.3
2000	1.1	1.2	1.2	1.2	1.3	1.4
1700	1.1	1.2	1.2	1.3	1.3	1.4
1500	1.2	1.2	1.3	1.3	1.4	1.5
1300	1.2	1.2	1.3	1.3	1.4	-
1150	1.2	1.2	1.3	1.4	1.5	
1000	1.2	1.3	1.4	1.5	1.5	
800	1.3	1.3	1.4	1.5	-	
650	1.3	1.4	1.5			
500	1.4	1.5	-			
300	1.5	-	-			

Adapted from AASHTO's 1996 Roadside Design Guide

$CCRW = BRW \times K_{oc}$, where CCRW is the Curve Corrected Recovery Width, BRW is the Basic Recovery Width, and K_{oc} is the horizontal curve adjustment factor for the outside of curves. Refer to chapter Appendix A for application.

Detailed Design Stage - The second part of specifying clear zone widths occurs in Detailed Design. The design team should evaluate roadside conditions more closely. Defining segments with widths greater than the target minimum defined in the DAD will generally result in increased safety for the traveling public. Designers should be addressing both the specification of the clear zone widths for the project and the extent of the clear area beyond the defined clear zone. The clear zone width recorded in the DAD should be taken as the target for the minimum clear zone widths. The clear zone widths selected during detailed design should be shown in a table on the project plans or, if the project is without plan sheets, elsewhere in the contract documents.

The first detailed design step towards refining the DAD's target clear zone widths is to determine whether the roadside should be considered as a series of smaller segments to more closely fit the width variations in the area that will be maintained. For instance, it may be anticipated that the reasonable and prudent driver will have low operating speeds when approaching or negotiating a roundabout, and that a reduced clear zone width would be acceptable for a segment in that vicinity. Similarly, on many ramps, operating speeds will vary sufficiently that it will often be appropriate to apply different clear zone widths to different segments of the ramp.

On mainlines in general, wider segments need not be defined if less than 1000 ft in length and need not be treated separately from adjoining segments unless the increase in prevailing clear zone widths for the segments will be at least 5 ft. (See Figure 10-1.) However, if long segments are involved, committing to widths that are a few feet wider than elsewhere may be desirable. Where a detailed review of the roadside conditions indicates that there are segments where the DAD target widths can not reasonably be achieved, the designer should either (1) provide shielding if the obtainable clear zone width is considered inadequate, (2) design a narrower clear zone width for that segment, or (3) document the decision to retain the specific features that will be left within the clear zone if they are limited in number and/or are relatively close to the target clear zone width. Clear zone width decisions should be reviewed by appropriate members of the design team, including Traffic and Safety, Maintenance, Construction, Landscape Architecture, etc. The Regional Real Estate Office should be involved early in any discussions on adjacent development and right of way availability. Once the segment lengths and widths for the clear zones have been determined, that information should be recorded on the Plans in a Clear Zone table similar to that illustrated in Figure 10-2.

While the clear zone widths will generally be defined for long segments of the highway length, there may be instances where it is appropriate to determine what the desirable width would be at a specific station. AASHTO's *Roadside Design Guide* provides a methodology that may be used for that determination. That methodology has been adapted and is included as Appendix A of this chapter. In addition, the Roadside Design Guide is distributed with a computer application to permit calculation of cost-benefit ratios for individual fixed objects and roadside obstacles.

Beyond the Clear Zone Width – (See also Section 10.2.1.1 for shielding “dangerous at any speed” hazards beyond the clear zone.) Providing additional clear area beyond the defined clear zone width will generally increase safety for the traveling public. Where it is practical to do so, Design and Construction personnel should strive to develop additional clear area width, beyond the minimum required for the clear zone, provided such additional development does not conflict with environmentally sensitive areas or other such limitations and does improve safety. For new construction and other projects where the area that should be cleared is greater than existing, any intended clear area expansion should be shown on the plans. Typically this may be shown by indicating limits of clearing and grubbing. Since the Regional Landscape Architect (RLA) will be involved in setting the mowing limits on some projects, it is particularly important that, on those projects, the RLA be in agreement with the limits that are established for clearing beyond

the clear zone width. Regional Maintenance should also be consulted as they will eventually be responsible for keeping the area cleared.

The need for “clear runout widths” is one particularly important reason for some of the clearing that should be provided beyond the minimum clear zone requirement. The following concepts are critical to understanding this need. (See illustration in Appendix A, Figure 10A-2a.)

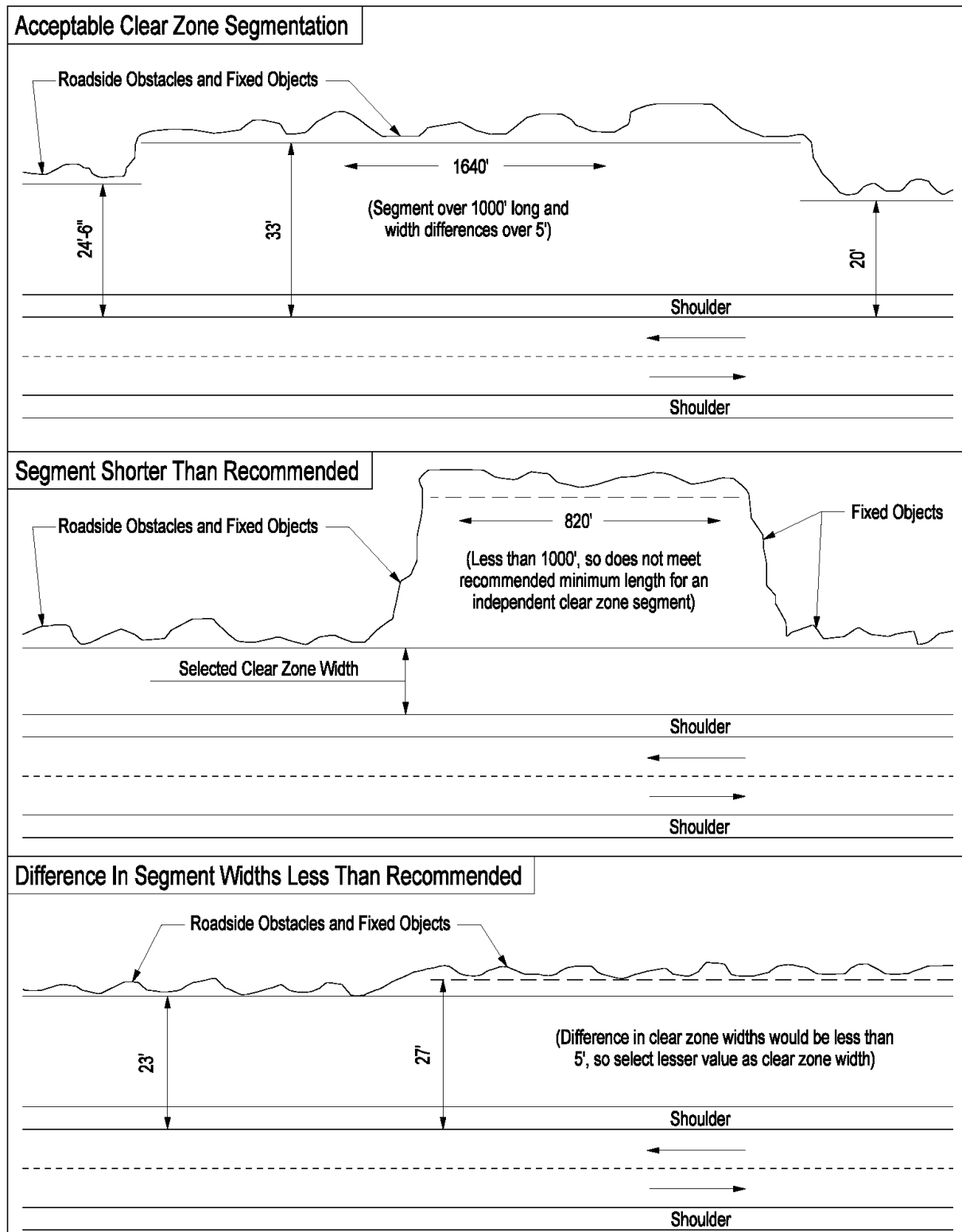
Traversable Slope. If a slope is smooth, not steeper than 1:3, and may generally be crossed safely, it may be considered traversable.

Recoverable and Nonrecoverable Slopes. If an embankment is level enough that the driver of an errant vehicle may recover control sufficiently to direct the vehicle back onto the road, the slope is said to be ‘recoverable’. If an embankment slope is steeper than 1:4, it is unlikely that a driver will be able to return an errant vehicle to the roadway. The vehicle will instead continue down to the bottom of the slope. Fill slopes steeper than 1:4 are therefore termed ‘nonrecoverable’. To minimize the potential for destabilization of the vehicle, all slope intersections should be rounded as noted in Chapter 3. Traversable (must be 1 on 3 or flatter), but nonrecoverable (steeper than 1 on 4) slopes with heights less than 15 feet may be present in the clear zone, but should not be considered as contributing significantly to a vehicle’s ability to slow down. Note, however, that on new or reconstructed interstate highways, slopes steeper than 1:4 should be avoided and, when their use is found to be necessary, should be shielded.

Clear Runout Width. This is the width of clear area that should be provided at the toe of an unshielded, traversable, nonrecoverable fill slope that starts within the Clear Zone Width. A vehicle that starts down a nonrecoverable slope will not slow significantly before reaching the bottom. At the bottom of such a slope, a relatively level area (~1:5) should be provided to give the driver an opportunity to slow or steer the vehicle. (Refer to Appendix A, Figures 10A-2d and 10A-2e for illustration.) The minimum value of this width should be 8 ft to accommodate the width of a passenger vehicle. FHWA has recommended that a width of 10 ft be provided for Federal Aid projects.

Clear Area Details - In addition to the clear runout widths, there are many locations where it will be desirable or necessary to provide an area that is substantially free of fixed objects, but does not meet the criteria to be considered as part of the clear zone. An example of necessary clear area, that is not considered to be part of the clear zone, is the area that is to be kept clear behind guide rail to provide for the deflection distance. An example of desirable clear area is the clear area that should be provided beyond a line of utility poles. In this case, while the clear zone might have been selected to end at the line of poles or the poles might have been moved back to the edge of the selected clear zone, it is desirable to carry the clear area back beyond the poles as far as is practical and convenient, provided there is no conflict with landscaping objectives.

Consideration should be given to segments where a curve is at the bottom of a long downgrade or obscured by a crest vertical curve and there is an increased possibility of a driver being “surprised” by the curve, in spite of warning signs. If a segment includes any accident-prone or “surprise” curves, extra clear area is desirable to address that additional potential for run-off-road accidents.

Figure 10-1 Clear Zone Segments (Matching Selection to Attainable Clear Area)

Slope Intersections – As covered in HDM Chapter 3, Typical Sections, Section 3.2.5.3, shoulder breaks are to be rounded to approximate a 4 ft vertical curve. The primary intent is to allow steady pressure of an errant vehicle's tires on the ground surface to enable optimal braking. Without rounding of the shoulder break, the slope would be effectively dropping out from under an errant vehicle much faster than gravity could act to hold the vehicle on the slope. While the suspension might push the tires onto the slope, the weight of the vehicle, momentarily, would not be applying the normal force needed to brake effectively. When inspecting existing highways, designers should check to see that the shoulder breaks have been adequately rounded. Additionally, there is the potential for debris to build up over time near the shoulder break. In extreme cases, this buildup can form enough of a ridge to potentially lift an errant vehicle just before it leaves the shoulder. Attention should also be given to placement of shoulder backup material to ensure that the material does not compromise the shoulder break rounding.

If reasonable shoulder break rounding is not provided, not only may the vehicle be effectively airborne for a moment, it will have a tendency to experience a harder bounce as it comes down onto the embankment. Following that bounce, it may be effectively airborne again, further reducing the effectiveness of any braking. The need for rounding is minimal with 1:6 side slopes, but increases proportionally as the difference between the shoulder and embankment slopes increases.

While rounding of the slope intersection at the shoulder break is important to the quality of the clear zone, it is not the only slope intersection that should be considered. Whenever an errant vehicle encounters an abrupt slope intersection that would require the vehicle to move up relative to the grade it is traversing, there is a potential for the front of the vehicle to dig into that slope. If the slope intersection is rounded to a relatively gentle sag vertical curve, the severity of that impact can be reduced. Unfortunately, since the front of a vehicle is usually several feet in front of its tires, a 4 foot vertical curve will just barely have begun to lift a vehicle's tires when its bumper contacts the slope. Where conditions permit, concave slope intersections should be rounded to at least a 12 ft vertical curve. However, if that can not be achieved, the amount of rounding that can reasonably be provided should be, as any rounding should have some positive effect on reducing impact severity. This consideration should be applied to any significant back slopes, base of embankment slope intersections, or transverse slopes that an errant vehicle is likely to encounter, particularly those within the clear zone.

While many experienced contractors are aware of the need for shoulder break rounding, others are not. To ensure that appropriate rounding of slope intersections occurs, the need should be indicated in the typical sections for a project. Similarly, where rounding of other slope intersections is deemed appropriate, the plans should identify those requirements to bidders.

Auxiliary Lanes and Ramps – When a ramp or auxiliary lane does not parallel the mainline, it should generally have a clear zone determination documented for it and measured from its edge of traveled way. The width may be, and generally will be, less than that for the mainline.

Where an auxiliary lane parallels the mainline, the designer should judge whether or not the clear zone width provided for the mainline satisfies the clear area width that is judged appropriate for the auxiliary lane. If additional clear area width is judged appropriate for the auxiliary lane, a separate highway clear zone segment should be identified, encompassing the portion of the auxiliary lane needing additional clear area width, and a clear zone width should be defined for that segment. That clear zone width should be measured from the edge of the through travel lane.

Clear Zone Documentation - In the project plans, carefully document the selected clear zone widths in a Table of Clear Zone Widths. (See Figure 10-2.) While the effective clear zone width will be reduced by the presence of a barrier system, it is not necessary to note those reductions anywhere in the project record. Note that there will be situations where it is not reasonable to move a potential hazard out of the clear zone or to provide shielding. In such instances, the object(s) may be left unshielded, but a note indicating that intent and an explanation are to be provided in the permanent record. In general, the degree of explanation for retention of nonconforming features should be commensurate with the degree of potential hazard presented by the feature.

If the decision is made early enough, the decision and explanation for retaining an unshielded object(s) should be in the DAD. If the decision is made during detailed design, the location of the unshielded object(s) is to be (1) indicated in the footnotes with the table of clear zone widths, (2) indicated on the plans and a brief note of explanation included (preferred option), or (3) described and explained in the project files (less reliable option for long-term retrievability). Short clear zone indentations may be similarly indicated. Examples of brief notes for plans are "Historic barn to remain", "Landmark well to remain", and "Four visually important/historic trees to remain."

During and/or at the end of construction, the EIC should inspect the site to verify that the last documented clear zone widths have been satisfied. Narrower clear area widths, or fixed objects left within the clear zone, should be recorded, preferably on record plans for future projects and maintenance activities, or in other permanent files. Rationales should also be provided.

Figure 10-2 Sample Table of Clear Zone Widths (to be included in Project Plans)

TABLE OF CLEAR ZONE WIDTHS

Start Station	End Station	Des. Clear Zone Width, ft
212+15, R	214+98, R	20 ft See note A
214+98, R	217+43, R	30 ft
217+43, R	219+77.5, R	22 ft See note B
A. Rock face, 15 ft offset, starts sta. 213+78 to remain. Too expensive to cut back. No accident history. B. Trees in wetlands, 15 offset, in vicinity of traversable culvert at 218+20, are to remain.		

10.2.1.1 Identification of Potential Hazards

(Refer to Section 10.3.1.2 for lists of specific features to look for at existing facilities.) For the purpose of discussing clear zones, a potential hazard will be defined as any feature that could cause significant personal injury when impacted by an errant vehicle that is otherwise being operated in an appropriate manner and in accordance with warnings or advisory information and speed requirements. The most serious and obvious hazards are those unyielding or fixed objects that could cause a sudden or instantaneous deceleration. Fixed objects are defined as potentially hazardous permanent installations of limited extent that can be struck by vehicles running off the road. Vertical reinforced concrete surfaces, such as bridge piers and abutments, yield the least of any roadside obstacles. In terms of the number of annual fatalities, however, trees are the leading killers due to their frequency and proximity in the roadside environment. Any tree over 4 inches in diameter may be considered a potential hazard depending on the type

of road involved and the distance from the travel lanes. Man-made objects such as utility poles, overhead sign structures, buildings, retaining walls, large drainage inlets and outlets, headwalls, and control boxes may also be considered potential hazards.

Some potential hazards may be classified as roadside obstacles. These differ from fixed objects in that roadside obstacles are of considerable length and are therefore generally much less practical to remove or relocate. Longitudinal retaining walls and rock cuts are examples of roadside obstacles. Topographic features may also be considered potential hazards. Abrupt positive changes in grade, transverse or longitudinal ditches, and drop-offs or cliffs can produce severe impacts. See Section 10.2.1.1 C for NYSDOT's recommended ditch design practices. Section 3.2.4 of AASHTO's *Roadside Design Guide* contains a discussion of preferred ditch cross-sections for longitudinal ditches. For new, reconstruction, and freeway 2R/3R projects, longitudinal fill slopes within the clear zone are to be shielded if they are steeper than 1:3. Exceptions are permitted for limited areas having steeper slopes such as those required around the standard end sections for transverse drainage pipes. (As noted in Section 10.3, fill slopes steeper than 1:3, but 1:2 or flatter, are permitted within existing clear zones on nonfreeway 3R projects, **provided** the slope is not more than 3 ft high, is not associated with accidents, and can not be readily filled to alter it a shallower slope.) Cut slopes steeper than 1:3, on the other hand, will generally not require shielding if they have smooth traversable surfaces. The designer should note that it will be difficult for Maintenance to prevent the development of trees on slopes steeper than 1:3. For a rough cut slope, the designer should consider all of the factors involved when judging whether or not to shield it.

Transverse embankments can cause errant vehicles to impact or to launch into the air, frequently returning to earth in an adverse landing pattern. Refer to Chapter 3 for guidance on the design of median crossovers and intersections with transverse embankments. Transverse ditches should be considered nontraversable if the normal water depth exceeds 1 foot or the side slopes are steeper than 1:6 for high-speed facilities (≥ 50 mph) or 1:4 for medium- and low-speed facilities.

Less obvious are hazards that would not significantly slow a vehicle but might result in objects entering the passenger compartment. Mailboxes (Section 10.5.1) and rails on fences (Section 10.5.2) are examples. Fire hydrants are generally not serious hazards since they are usually designed with breakaway features to prevent damage to the water main in the event the hydrant is struck. However, consult the Regional Utilities Engineer to evaluate critically located utilities as standpipes and nonbreakaway hydrants should be treated as potential hazards. Additional potential hazards are listed in Section 10.3.1.2.

It was a long-standing admonition that "guide rail itself is a hazard". This was especially true decades ago when the posts included concrete pillars, railroad rails, and stout steel sections. It is much less true now that barriers are required to pass newer crash testing criteria. While it is never a good thing for a vehicle to impact any object, the portion of guide rail systems between the terminals will usually be safer to encounter than any of the other alternatives. While some poor outcomes can be expected at elevated speeds, there will be very few circumstances where an accident with a serious outcome would have been better without the rail.

Unfortunately, in spite of extensive efforts, even the latest guide rail terminals are still the relatively risky portions of the barrier system. A wide variety of terminal designs have passed the NCHRP 350 crash test criteria, but the criteria do not cover all reasonable crash configurations, particularly vehicles in lateral skids. Additionally, actual field conditions often require terminals to be installed where slopes after the terminal are more adverse than the test setup. This can

easily increase the likelihood of rollovers. Because of the relatively greater risk posed by terminals (as compared to guide rail), consideration should be given to connecting adjoining runs of guide rail rather than leaving short gaps with terminals on both sides. This is particularly appropriate where the terminal costs are relatively high.

To update the above admonition, "Guide rail runs are a mild hazard. The largest part of that risk is in the lead terminal." Where the resulting clear area would provide a good opportunity for recovery, preference should therefore be given to eliminating or relocating the fixed object, roadside obstacle, or potential hazard, rather than placing guide rail in front of it.

A. Hazardous-at-Any-Speed Features

An important distinction should be noted between two types of hazards. Most hazards are fixed objects which require a high-speed impact to produce a fatality. The second type could produce a fatality even if reached at a fairly low speed. The designer should be aware of the distinction and consider providing extra protection when the hazard is a cliff, a deep body of water, a flammable liquids tank, or some other similarly hazardous feature. The extra protection should typically include the use of a more durable barrier system (preferably heavy-post or rigid) than would normally be warranted. Even if the feature is beyond the desired minimum clear zone width, serious consideration should be given to providing a durable barrier and an explanation should be documented if extra protection is not to be provided and there is a reasonable expectation that vehicles will reach the hazard.

B. Evaluation of Water Features

For much of the year, bodies of water in our climate can pose a major risk of hypothermia, even for healthy, young adult swimmers. Bodies of water should be evaluated with respect to the degree of potential hazard they pose. The hazardousness will be a combination of the amount of water and its accessibility. From greatest to least, the risk posed by different depths may be ranked as follows.

1. A vehicle can completely submerge, potentially resulting in the drowning of uninjured nonswimmers, disabled or elderly persons, or infants.
2. Water could fill an upright car to a point where an unconscious or injured driver or passenger would drown, typically assumed to be a depth of about 2 feet.
3. The water is shallow enough that an unconscious occupant would only drown if the car was overturned, a depth of at least 12 inches.

In general, designers should be concerned about bodies of water over 2 ft deep, or water courses with a normal base flow depth of over 2 ft, as these could cause a stunned, trapped, or injured occupant to drown. Fast moving bodies of water should be considered more hazardous than those that are still. Accessibility is a measure of the likelihood that a vehicle will actually reach the water. The designer should visualize the likely courses that an errant vehicle would have to the water. If a stream bank has many trees, a vehicle may not be able to get past them to get to the water. If the clear area is narrow, the number of possible paths to the water will be reduced.

Other factors to consider include: (1) the slope to the water, (2) the total distance in which to stop, and (3) the persistent or intermittent presence (flooding potential) of the water hazard.

C. Longitudinal Ditches

In a few situations, the width and depth of a roadside ditch is dictated by the amount of flow that the ditch needs to carry during storm events. More commonly and less expectedly, the depth of the ditch is controlled by the need to provide drainage for the base and subbase materials of the road. Without the opportunity for water to drain laterally out of those materials and into the roadside ditch, these materials would regularly become saturated. When vehicles drive over these saturated soil materials, the water acts as an incompressible fluid and pushes laterally out from under the load, carrying the fine portions of the soil with it. Eventually, with enough fines migration, pavement support is reduced and pavement deterioration begins, progressing to potholes or worse destruction. This movement of water under the impact of passing vehicles is referred to as “pumping” and is significantly worse with heavier vehicles. If the soil materials are not saturated, there will be small amounts of air in the soil and it will compress rather than forcing fine particles to move.

In some locations, the soils may be sandy enough or permeable enough that the subgrade can drain into those native soils without the need for a roadside ditch. In most instances however, either a roadside ditch or an underdrain system will be needed to provide drainage. Where a ditch is used, its depth will be influenced or controlled by the depth needed to drain the subgrade. In many cases, this depth will be greater than that needed to handle any normal overland flow volumes.

Between the need to handle overland flow and the need to drain the materials under the roadway, ditches need to be present along a very high percentage of the state’s highways. As such, they are a common and important element of the roadside and their effect on roadside safety must be carefully considered.

The effect of ditches on roadside safety is subject to factors which may each vary continuously across broad ranges. These include the depth of the ditch, its fore slope, its invert width, its back slope, and the firmness of the soils. Similarly, for any given ditch geometry, the speed of an impacting vehicles, its angle of departure from the road, the degree to which it is yawing off of its line of movement, and its static stability all influence what happens after a vehicle enters a ditch. The greater the speed, departure angle, or yaw, the more likely it is that an adverse outcome will result.

The effects of a roadside ditch on an errant vehicle can vary greatly.

- If the ditch is broad, shallow, and has smooth intersections between the slopes, a vehicle can cross the ditch with little more than a wobble.
- If the vehicle is leaving the road at a shallow angle, it may be able to safely traverse deeper ditches with slightly steeper slopes.
- In many instances, a vehicle tracking in a straight line off of the road will jump the ditch, its bumper and undercarriage will strike the back slope of the ditch, and it will bounce up the back slope. This often happens where back slopes are 1:3 or flatter.
- If the back slope is steep, 1:2 or steeper and the departure angle is relatively mild, the vehicle may strike the back slope and be redirected along the ditch.
- When a vehicle is leaving the road at a high angle, or is in a spin, an impact on the back slope can result in severe longitudinal decelerations, vertical accelerations, or lateral accelerations that can severely injure an occupant. Additionally, the vehicle may overturn one or more times. Multiple rollover accidents tend to be quite severe.

The extent to which a desirable ditch cross section can be provided is directly related to the amount for ROW that is available. If the depth of a ditch is fixed by the need to drain the subbase, the ditch slopes and invert width may be set by the amount of ROW available beyond the shoulder break.

When new highways are to be constructed, it is desirable that the amount of ROW purchased for the project be sufficient to permit the construction of traversable ditches. For projects on existing highways, if ROW is to be purchased, it is desirable that the width obtained be sufficient to permit the construction of traversable ditches. The difficulty of obtaining the additional ROW should be weighed against the degree of improvement to the cross section. If the added width is difficult to obtain and, in the engineer's judgment, does not result in a significantly safer cross section, the purchase should not be justified.

On existing highways, for projects where ditch work is an accepted component, but no ROW purchase is to be made, any ditch cross section will typically need to fit within the available ROW. If significant improvements to the cross-section can be readily made within the available ROW, they should generally be included in the scope of work. However, ditch work at a location may be skipped if the work will not result in significant safety improvements. In some instances, it may be possible to make arrangements to extend the back slope beyond the ROW line. The flatter back slope may improve roadside safety while also permitting an adjacent property owner to mow the gentler back slope.

Under some special circumstances, the use of stone-filled ditches may be appropriate. The NYS Thruway Authority has used this strategy for several years. The stone filling can provide a gentle, level surface that errant vehicles may traverse with little risk. At the same time, the porous stone filling permits drainage of the subbase to occur, provided the stone filling does not become clogged with washed-in material. The general criteria for its use to be acceptable are:

- Low volume of flow to be carried by the ditch
- Low risk of material being washed in to clog the stone
- High volume of traffic to warrant the expense
- A ditch section that would otherwise have a low degree of traversability.

The high volume of traffic should not be viewed as a requirement.

The guidance on ditches may be summarized as follows:

1. Ditches should be made as traversable as can reasonably be done within the existing ROW, topographic, and other constraints.
2. Ditch depths should not significantly exceed those required to handle flows or drainage of the subbase.
3. Ditches, even those that may be non-traversable in some cases, may be included within the clear zone, provided they are either traversable enough that a significant percentage of errant vehicle may be expected to traverse them without rolling over or that a large percentage of vehicles entering them at shallow angles will be redirected by the back slope without producing severe decelerations or severe rollovers.
4. If the ditch depth is such that a high percentage of vehicles that enter it may be expected to impact violently or roll over violently and the ditch is mostly within the clear zone, strong consideration should be given to shielding the ditch.

10.2.1.2 Treatment Options

The designer should consider, in sequence, the treatment options available to address hazards within the design clear zone distance. AASHTO's hierarchy was (A) Removal, (B) Relocation, (C) Modification, (D) Shielding, and (E) Delineation. However, in view of the fact that making an object traversable is generally safer than making it breakaway, the new hierarchy is:

- A. Remove
- B. Make Traversable
- C. Relocate
- D. Make Crashworthy
- E. Shield
- F. Delineate

A. Remove

Removal is the most straight-forward option, and usually the most cost effective from a long-term maintenance perspective. Whenever practical, hazardous features should be removed from the clear zone. As examples, rock outcrops may be removed, abandoned houses may be condemned and removed and additional fill may be placed to eliminate a steep side slope or transverse slope. Trees may be cut down and the stumps ground flush to the ground. There may be public opposition to the removal of landscape features that are considered important from visual, historic, cultural or community context points of view. Refer to Section 10.5.6 for guidance on public relations issues.

B. Make Traversable

This option assumes that a projecting feature may be altered so that it is flush with the ground surface or that a slope may be made level enough for a vehicle to traverse. In the first instance, this will typically only be possible for drainage inlets and outlets and a limited number of other man-made features. The removal of a protruding concrete headwall would be one example of making a feature traversable. Replacement with a flared end section would be another. This includes driveway pipe headwalls and pipes without standard end sections, both of which should preferably be replaced with acceptable traversable end section treatments or shielded. (Refer to Section 10.3.2.2 B for additional guidance on end sections.) Note that pipes may require extension to achieve traversable driveway embankment slopes.

Gratings may be placed across drain pipe end sections to permit vehicles (including mowing machines) to traverse the openings without dropping in. For transverse pipes, the Department has had satisfactory experience with the use of plain No. 8 reinforcing bars spot welded together on one foot centers. These grates may be used in sizes up to 6 ft by 8 ft. The grates should be held down with four bent No. 6 bars driven at least 2 ft into the ground. The grates should be of sufficient size to extend a minimum of 6 inches beyond the supporting edge of the opening. For details, see Item 603.0101 Culvert End Safety Gate.

Where traffic volumes are high and anticipated ditch flows are low, it may be reasonable to place an underdrain, filter fabric and stone filling in a ditch to allow an errant vehicle to have a more level surface across the ditch while still providing drainage of the subgrade.

To make a slope traversable, it may be flattened to a 1:3 or, for interstates, to a 1:4. In some instances, this flattening may be achieved with spoil material. For more details, see HDM Chapter 9, Section 9.3.13.

C. Relocate

Relocation consists of moving an obstacle to a point outside of the clear zone or, at a minimum, farther back in the clear zone. Fences, signs, traffic control boxes, drain pipe inlets and outlets, utility poles, small structures and, in some cases, ditch lines may frequently be relocated. Consideration may be given to attaching large overhead signs to bridge structures rather than placing supports in or near the clear zone. Note that, in areas where a design clear zone width significantly less than the desirable had to be selected, it is preferable for relocations to be made to beyond the desirable, rather than to just barely beyond the designed, clear zone width. Rather than placing guide rail exclusively for the purpose of shielding small- to medium-sized transverse culverts, preference should be given to extending the culvert and leaving a traversable embankment and a clear zone that is not compromised by a guide rail.

D. Make Crashworthy

When potentially hazardous features in the clear zone can not be removed, made traversable, or relocated, consideration should be given to making them crashworthy. A crashworthy object is one which has had its strength, shape, or rigidity changed to significantly reduce the severity of a collision.

In some instances, sign supports and lighting standards may not be conveniently relocated and it may be impractical to provide barriers. Where such sign supports and lighting standards are in hazardous locations, they should be provided with breakaway bases. Breakaway bases may be divided into two classifications, omnidirectional and unidirectional. The designer should evaluate the possible directions of impact when specifying a type. Acceptable details of omnidirectional breakaway bases for signs are included on the New York State Standard Sheets for series 645 items. Light standards are made breakaway by providing them with frangible aluminum transformer bases shown on Standard Sheets for series 670 items.

Numerous unidirectional breakaway bases are available. A list of approved types is maintained by the Materials Bureau. Breakaway bases or posts should be specified for signs located within the clear zone. Where possible, however, signs and poles should be located behind the deflection area of barriers which are required to shield other hazards.

Traffic signal poles can not be provided with breakaway bases since secondary accidents are likely to be caused by the mast arms or, where overhead span wires are used, the poles and signal heads falling back into traffic. In consideration of practicality, fluctuating and typically lower traffic speeds, and the poles' required proximity to traffic, shielding of traffic signal poles is not required. Where a barrier system is already required for other reasons, however, placement of the poles behind that barrier is desirable. No documentation is required for the decision not to shield signal poles. When traffic signal poles are required on facilities with speed limits of 50 mph or greater, the poles should be placed as far away from

the roadway as practicable.

In addition to the types above, systems have been developed for breakaway bases for timber utility poles. When a utility company indicates that relocation of a problem pole will pose undue difficulties and the Department determines that shielding is not a reasonable alternative, use of a breakaway base may be considered. Refer to Chapter 13 of this manual for a further discussion of utility accommodations.

The designer should consult with the Design Quality Assurance Bureau's Specifications and Standards Section for information on the approval status and availability of new or uncommon types of breakaway bases.

Rock cuts may be hazardous either as obstacles or as sources of rock fall. The Regional Geotechnical Engineer should be consulted to determine the potential risk of material falling from the slope and to discuss modification options that might be appropriate. One possible modification option for rough rock slopes (projections over 6 inches within the potential impact zone) would be to pour a smooth concrete wall against the rock to a height of 3 to 5 feet. Input should also be obtained from Maintenance and Landscape Architecture prior to selecting a treatment strategy.

E. Shield

If hazards can not reasonably be removed, relocated, or satisfactorily modified, they should be shielded. Shielding is defined as the placing of a protective device to prevent direct impact into a fixed hazard. Shielding is divided into two categories. The first, barriers, are typically designed to deflect a vehicle away from the hazards. Cable and weak post W-beam guide rails are examples of flexible barriers. Box beam and heavy-post W-beam are semi-rigid barriers. Concrete barriers are rigid. The second shielding category is impact attenuators. Although they may contain elements designed to deflect a vehicle away from their sides, their main purpose is to effect a controlled deceleration of vehicles that would otherwise crash into a fixed hazard.

The two categories of shielding are discussed in more detail later in this chapter. Sections 10.2.2, 10.2.3, 10.2.4 and 10.2.5 describe barriers. Section 10.2.6 discusses impact attenuators.

F. Delineate

To delineate is to provide warning about the presence of a fixed hazard. When a distinct, serious fixed hazard is present within the clear zone, and the hazard can not be removed, relocated, modified, or adequately shielded, it may or may not be appropriate to warn drivers of the potential danger. At night, reflective markers located well off of the road could mislead drivers as to the location of the edge of the roadway. Warning would be appropriate if there are obstructions in the shoulder, narrowings of the shoulder, or if the obstructions are relatively close to the road and the clear zone is level enough for the driver of an errant vehicle to recover sufficiently to maneuver and avoid the object. An example of an object within a broad clear area that might warrant delineation would be the end section of a transverse culvert, or its headwall, that might be hidden by tall grass. The warning should

consist of approved brightly colored reflective panels placed ahead of the tree, end wall, or similar fixed obstacle. For guidance on approved object markers and warrants for their use, refer to the national *Manual on Uniform Traffic Control Devices* (MUTCD) and its New York State Supplement.

On the other hand, if fixed hazards are present within the clear zone, but at locations where vehicles would not normally be operated, and/or there would be little opportunity to maneuver an errant vehicle, the designer should apply engineering judgment to decide whether or not the object should be delineated. Examples would include obstructions on steep side slopes, in wet, grassy areas, or obstructions that are too close to other obstructions at the edge of the clear zone to permit passing between them.

In addition to the delineation of hazards, MUTCD Section 3 provides guidance on the roadside delineation devices and placement to be used along various roadways. Experience has shown that a significant percentage of delineators have been destroyed by snow plows. Care should be taken to ensure that delineators are aligned beyond the areas that normally require plowing. Maintenance forces should be consulted to learn whether there are areas where there are reasons that plowing would be extended well beyond the paved surfaces, such as to maintain snow storage space in areas prone to snowdrift accumulation. In lieu of the standard metal-pole-mounted delineators described in Standard Specification 646 and shown on Standard Sheets 646 series, the Department permits use of Flexible Delineator Posts, Item 646.06XX. These posts are designed to spring back into position for at least the first ten times they are knocked down. Because they are roughly 50% more expensive than standard posts, they should not be used where they are unlikely to be hit, such as behind guide rail. These flexible posts have had fatigue problems where they have been weighted down with plowed snow for long periods. Some of the flexible posts have also developed problems where they were subjected to repeated gusts from high-speed trucks. Preferred locations include exposed areas at intersections and gores, along ramps and curves, and at islands and known problem areas. Preference should probably be given to using rigid delineators in areas prone to snowdrift accumulation and flexible delineators in unshielded areas with high traffic volumes and low snowfall amounts.

10.2.2 Barrier Design Parameters

Barriers are generally warranted as shields when a fixed object, roadside obstacle, or nonconforming (see Section 10.1) cross-sectional or drainage feature can not be removed from the clear zone. Refer to Section 10.3.1.2 B for lists that include features that typically warrant shielding. If in any instances it is determined not to provide shielding where it would normally be warranted, an explanation should be provided in the DAD or the project files, as appropriate. Barriers may also be warranted to shield hazards that are beyond the clear zone width. (See Section 10.2.1.1.) Barriers may be warranted to prevent access in certain instances, typically in urbanized areas. Barriers may also be used to separate opposing traffic. (See Section 10.2.4.)

When a barrier is needed, the protection must begin a certain distance ahead of the shielded hazard. The Department recognizes two criteria to determine the distance: the point of need (§10.2.2.1) or the run-out length (§10.2.2.2). The barrier type must then be selected (§10.2.3) such that its rated deflection distance (§10.2.2.3) will normally prevent a passenger car from striking nonremovable hazards behind it. The offset must be checked to see that the positioning of the barrier and other appurtenances is not conducive to letting a passenger car pass over or vault (§10.2.2.4) the barrier. Where guide rail is used in close proximity to steep slopes, the post length requirement should be checked (§10.2.3.5) and adjustments made to the anticipated deflections if extra-length posts are required. For barrier systems that may obstruct vision, the horizontal and intersection sight distances (§10.2.2.5) should be checked. Continuity (§10.2.2.6) should be checked due to the high cost and relative risk of terminals.

10.2.2.1 Point of Need

This first criteria used to determine where to start a run of barrier is applied to objects of limited lateral extent. As a practical limit, it assumes that most vehicles that leave the shoulder will be diverging away from the roadway at an angle of at least 15°. Relative to the shielded feature, the point at which the full protection of the barrier is needed is termed the point of need. The point of need is established by finding the intersection of the front face line of the barrier and the line drawn from the back of the obstacle to intersect the roadway at an angle of 15°. Vehicles that leave the traveled way upstream from this point, or at a steeper angle, will pass behind the obstacle. See Figure 10-3a.

On freeways, higher volumes and speeds are normal. Though the distribution of departure angles does not change significantly, the higher volumes mean that more vehicles may be leaving at low angles. Additionally, the higher speeds mean that those vehicles will be traveling farther from the road. Consequently, the point of need method should use 10° on interstates and freeways where design speeds are 60 mph or greater and either a new run of guide rail is being installed or existing runs are being relocated or replaced.

Relative to the run of guide rail itself, there is a point on the rail that is designated as the point of redirection. (Formerly, this point was also designated as a “point of need”, but relative to the rail.) It should be emphasized that this point of redirection does not establish the beginning of the barrier system. Rather, it indicates a point, downstream from which, the barrier may normally be expected to redirect an errant vehicle. Approach end sections and additional barrier normally precede the point of redirection. Upstream from the point of redirection, there may be portions of the barrier that can provide full redirective capacity, but the purpose of the terminal end is to minimize the consequences of colliding with the end of the rail, not to ensure redirection. Refer to the Standard Sheets for details on the different types of conventional (pre-

NCHRP 350) barriers, end treatments and the locations at which they provide point-of-need protection.

A rail system's nominal point of redirection is selected to be at or downstream from the point at which the rail is actually capable of redirecting an errant standard vehicle. Runs should be positioned longitudinally so that the point of redirection, relative to the rail, at least covers the point of need relative to the shielded feature. It is acceptable to position the run so that the rail's point of redirection is in advance of the shielded feature's point of need. The limiting factor will generally be the cost of the extra guide rail.

As discussed in Section 10.2.2.6, if the point of need for the end of one run is relatively close to the point of need for the start of the subsequent run, it may be acceptable and reasonable to connect the runs, thus eliminating the risk of the approach terminal and the cost of both terminals at the gap. Access for mowing equipment should be taken into consideration.

Shielding for steep side slopes should be based on the point of need method, where the potential hazard to be shielded is judged to be those portions of the slope that could cause a vehicle to roll over. Shielding should be provided for any path departing from the roadway at 15° or more (or 10°, as explained above) that would result in the vehicle crossing over a portion of the slope likely to cause it to roll over.

It was generally observed during the testing of the new NCHRP 350-compliant terminals that vehicles which struck at an angle downstream of the third post would redirect, while vehicles which hit at an angle upstream of the third post would "gate" through the terminal. There is the potential for vehicles to lose their steering when striking the lead end of a terminal and then to turn in behind the rail, towards the shielded object. (This was observed during one driverless test.) Typically, though, the topography behind the rail will tend to direct the vehicle away from the object. Designers should, however, watch out for topographic conditions that could redirect errant vehicles back towards shielded objects. (See last paragraph in this section.)

When tested at impact angles parallel to the road, the "parallel-type" NCHRP 350 terminals absorb crash energy over a significant "crush" distance. For this and the above reasons, there should be some distance between the first (farthest upstream) post of an NCHRP 350 terminal and a shielded fixed object. To simplify and provide a consistent location process for designers, the Department has selected 75 ft as the minimum separation that should preferably be provided for high-speed traffic, if there are no conditions restricting the point at which the terminal can be located. (See Figure 10-3b.) Where there are restrictions to how far upstream a terminal can be placed (typically due to the presence of a driveway or ramp), the minimum distance between the point of need and the first post in the terminal may be reduced accordingly. If the separation must be reduced close to or less than two post spacings, consideration may be given to relocating the driveway. In general, it will not be necessary to reassess the locations for existing NCHRP 350 terminals whose first post is at least two post spacings upstream from the point of need.

Vehicles striking gating ends of terminals should be afforded the same opportunity to stop as vehicles that are traversing the clear zone. Consequently, the clear zone width should extend past the lead end of a terminal until it is intersected by the line drawn to define the 15° (or 10° where applicable) line for the point of need. (See Figure 10-4f.)

Where practical, the recommended length of barrier may be reduced by terminating the barrier against a cut slope. Leaving an opening between the cut slope and the terminal may allow

vehicles to be guided along the slope and in behind the rail. This situation is to be avoided whenever practical, but due consideration must also be given to the possible need for maintenance access. The details of the termination should be adequate in most situations to prevent a vehicle from getting behind the barrier by either passing around the end or over the top. Refer to Figure 10-4d for plan details of the approach alignment for cable, W-beam, and box beam anchorage, to Figure 10-4e for heavy-post W-beam approach alignment, and to the Standard Sheet - Box Beam Guide Rail for section details of the termination of box beam against a back slope. Note that a Type I box beam end assembly should not be used when terminating against a back slope.

Where there is two-way traffic and the potential for wrong-way hits, both ends should be designed as approach ends if the downstream end is within the clear zone of the opposing direction of traffic. The clear zone width for the opposite direction traffic should be measured starting at the inside edge of its traveled way.

Where the shielding is only required for one-way traffic, the downstream (terminal) anchorage may be located at a right angle from the farthest downstream part of the obstacle, provided the total resulting length of the run is sufficient to develop the full redirective capability of the system and the terminal is a type that offers good lateral resistance, such as terminals that fasten to anchor blocks. In systems where the primary rail is not fastened to an anchor block, such as box beam terminals, extra length may need to be provided to minimize the possibility of vehicles pushing through a "soft" terminal end and striking the shielded object behind the rail. To determine the minimum downstream location of the last post relative to the last shielded object, 50 feet of rail should be provided past the point that is twice as far upstream from the shielded object as the shielded object is offset behind the rail. (Definitely see Figure 10-3a.)

Figure 10-3A Basic Point of Need Determination

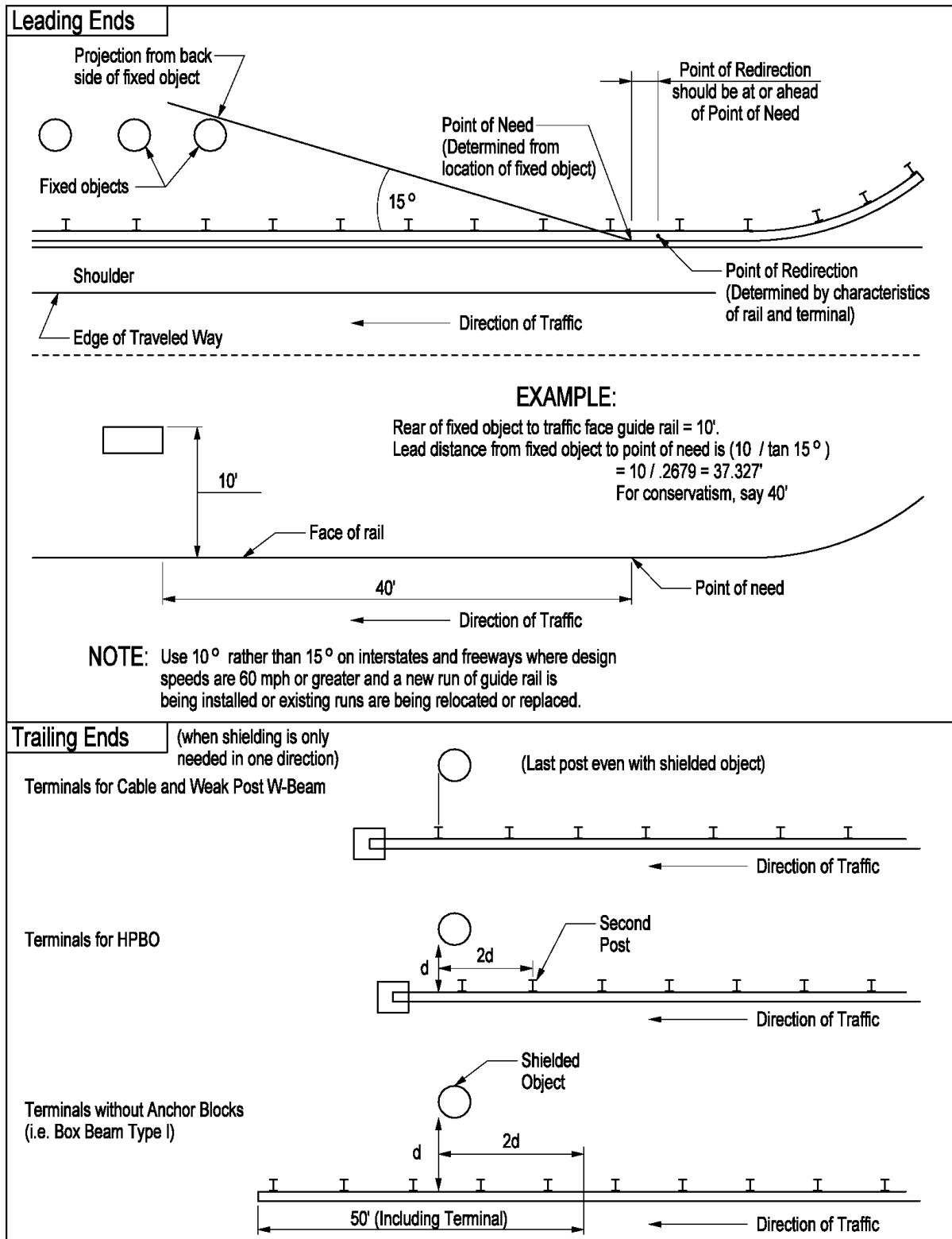
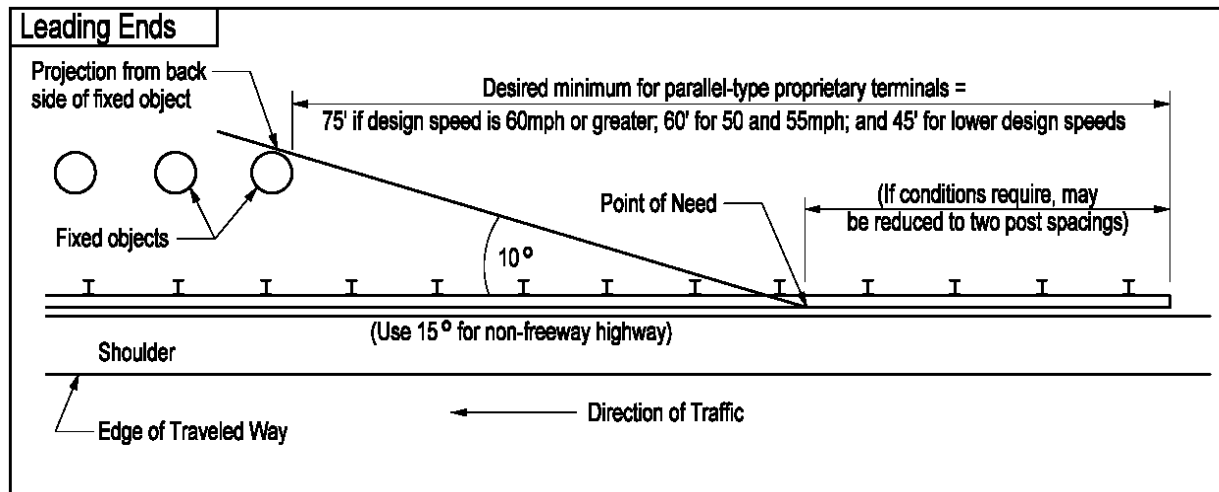


Figure 10-3b Crush Accommodation for Parallel-Type Proprietary Terminals

10.2.2.2 Runout Length

The second criteria for locating the start of a barrier system, "runout length", will typically only be applicable to highways with broad traversable clear zones.

"Runout length" is the length of clear area available parallel to and behind a barrier. For NYSDOT's design process, the runout length is measured from the start of a barrier to a "non-bypassable hazard". A "non-bypassable hazard" is any hazard or arrangement of hazards such that a driver running in the clear area parallel to the highway will be unlikely to find a safe route around or through them. Nonbypassable hazards may include bodies of water, nontraversable streams, creeks, and ditches, steep transverse embankments or hillsides (those with contours running perpendicular to the roadway), stands of trees, or hazards in a swale or in the clear runout width at the bottom of a slope. The abutment and embankment for a bridge passing over the highway will usually constitute a nonbypassable hazard, as well. The toes of such embankments should be well rounded on the side facing approaching traffic to give an errant vehicle an opportunity to run up the embankment, rather than impacting into it.

Where clear areas are broad and it is likely that an errant vehicle will be able to run parallel to the highway within the clear area, it is desirable that the "runout length" be made sufficient to permit a vehicle to stop before reaching the non-bypassable hazard. The recommended lengths are given in Figure 10-4a.

A runout length may be needed when there are hazards of large lateral extent (effectively non-bypassable) or when hazards are located in positions such that the topography would direct a vehicle towards the hazard.

However, if the narrowness of the clear area, or the slope or condition of the area behind the guide rail would make it unlikely that a normal path of an errant vehicle would parallel the highway and reach the nontraversable hazard, then it will not be necessary to extend the rail to provide the full runout length. As stated at the beginning of this section, providing full runout length is usually only a consideration where there are high-quality (wide, traversable) clear zones and clear areas such as are typically found on interstate and freeway facilities.

Note that the preferred solution would be to eliminate the hazards by removing the trees, flattening transverse slopes to make them traversable, etc. However, where a nonbypassable hazard cuts across a high-quality clear zone/area, adjoins the roadway, and can not be removed or suitably modified, a barrier should be provided, preferably extended out to a back slope or the limit of the clear zone to restrict access to the hazard, or located as guided by Figures 10-4a, 10-4b, and 10-4c. Where there is access to the clear runout area and it slopes (longitudinally) down to the hazard, consideration should be given to providing longer lengths than those recommended in Figure 10-4a. Where back slope anchorage (see Figures 10-4d and 10-4e) is not practical and full runout lengths can not be provided due to driveway access requirements, the barrier should begin as soon as possible following the access point. If the runout length thus provided falls well short of the recommended runout length, consideration may be given to providing an additional run of guide rail prior to the driveway. This will typically only be appropriate for high-speed highways with broad clear areas. See Figure 10-4c. Alternatively, the barrier may be run down the side road or driveway, but this option may require an easement in the case of a driveway.

As will be discussed later in the sections on terminals, only those terminals which have passed, or have been judged likely to pass, NCHRP 350 or MASH criteria are to be installed well within the clear zone of high-speed National Highway System (NHS) highways. Any use of conventional end sections on these highways should either be close to, at, or beyond the limit of the clear zone, or buried in a back slope. (Note that the turned down portion of a Type I box beam terminal is not to be buried.)

Figure 10-4a Runout Lengths

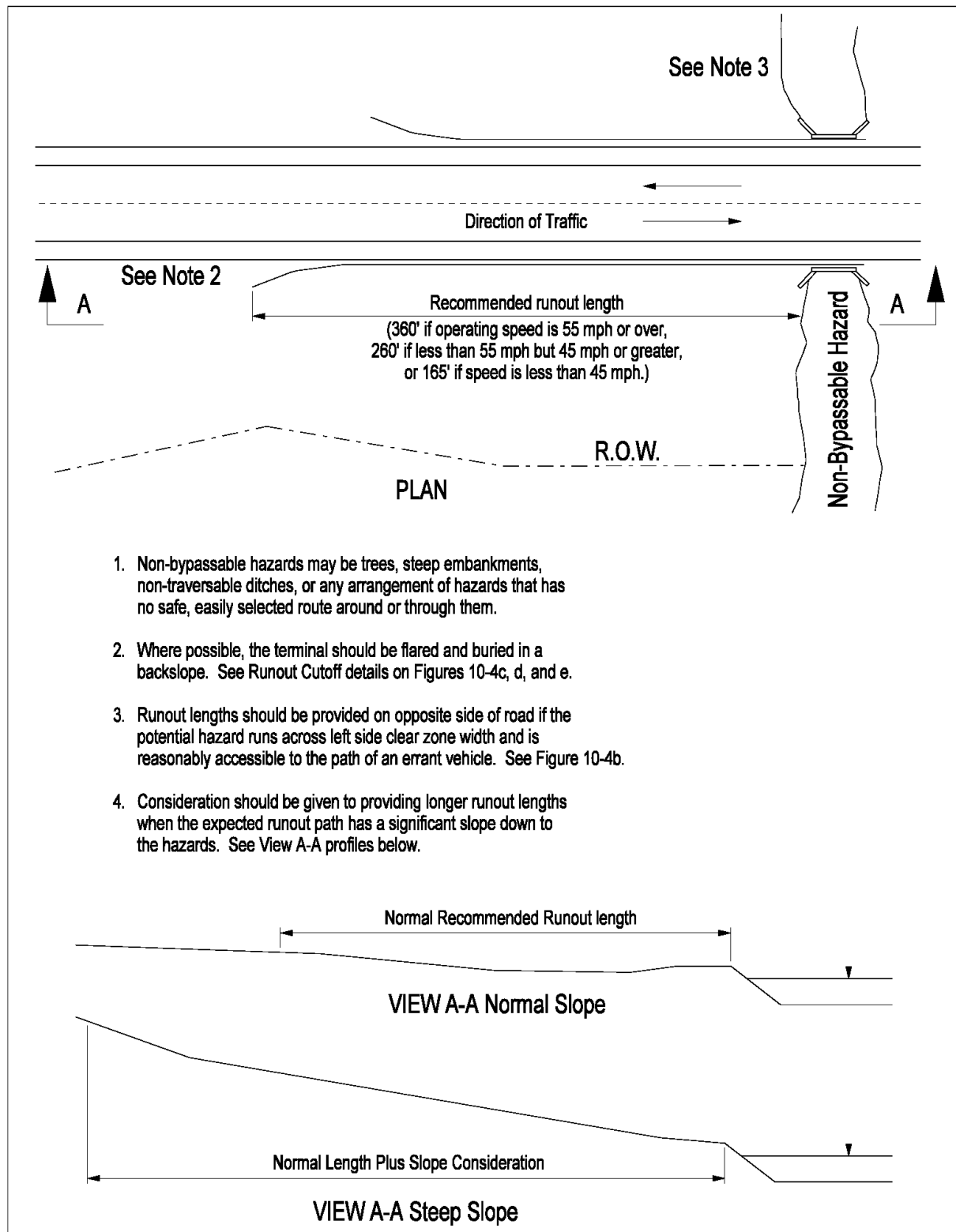


Figure 10-4b Left Side Runout Lengths

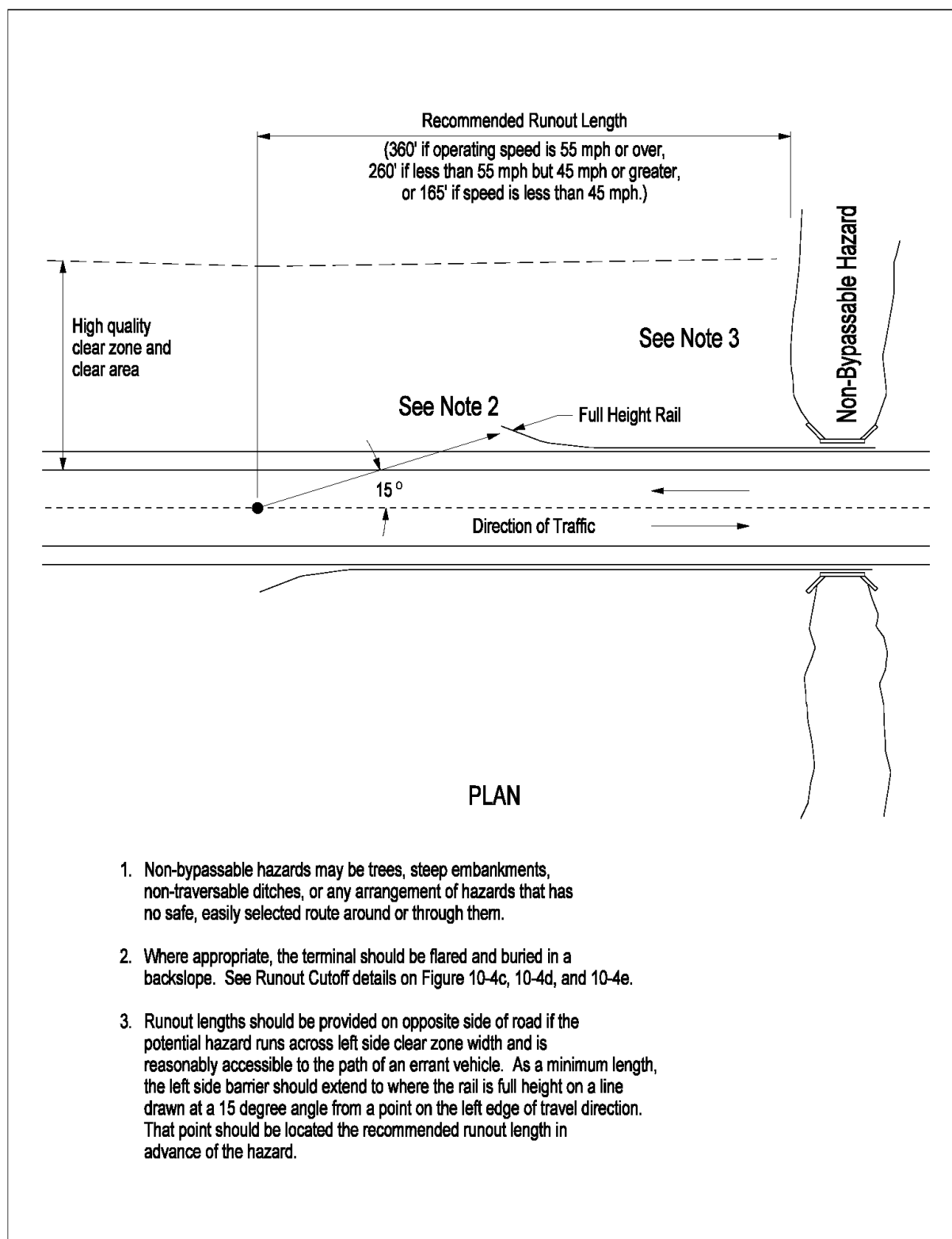


Figure 10-4c Runout Length Alternatives

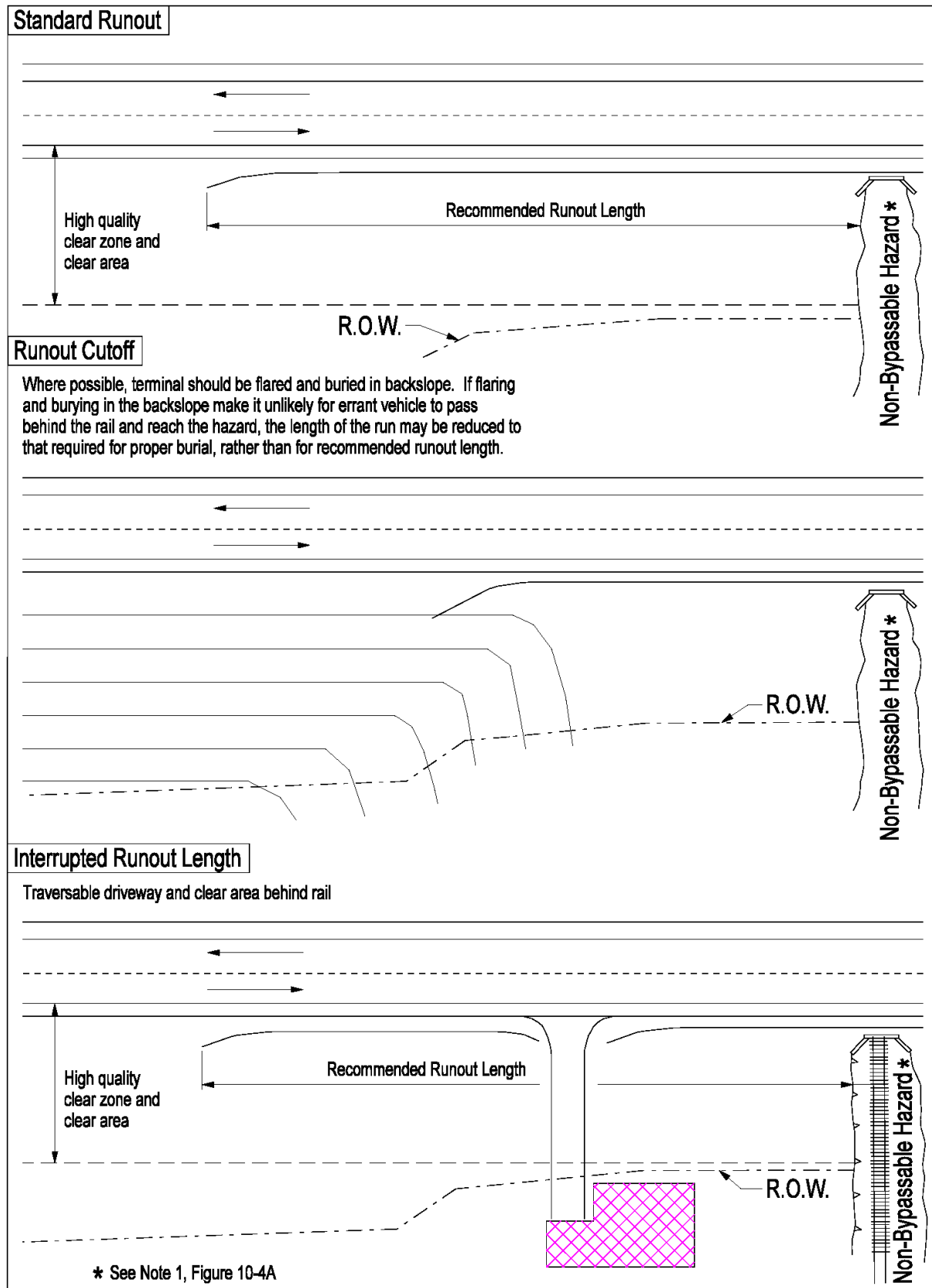
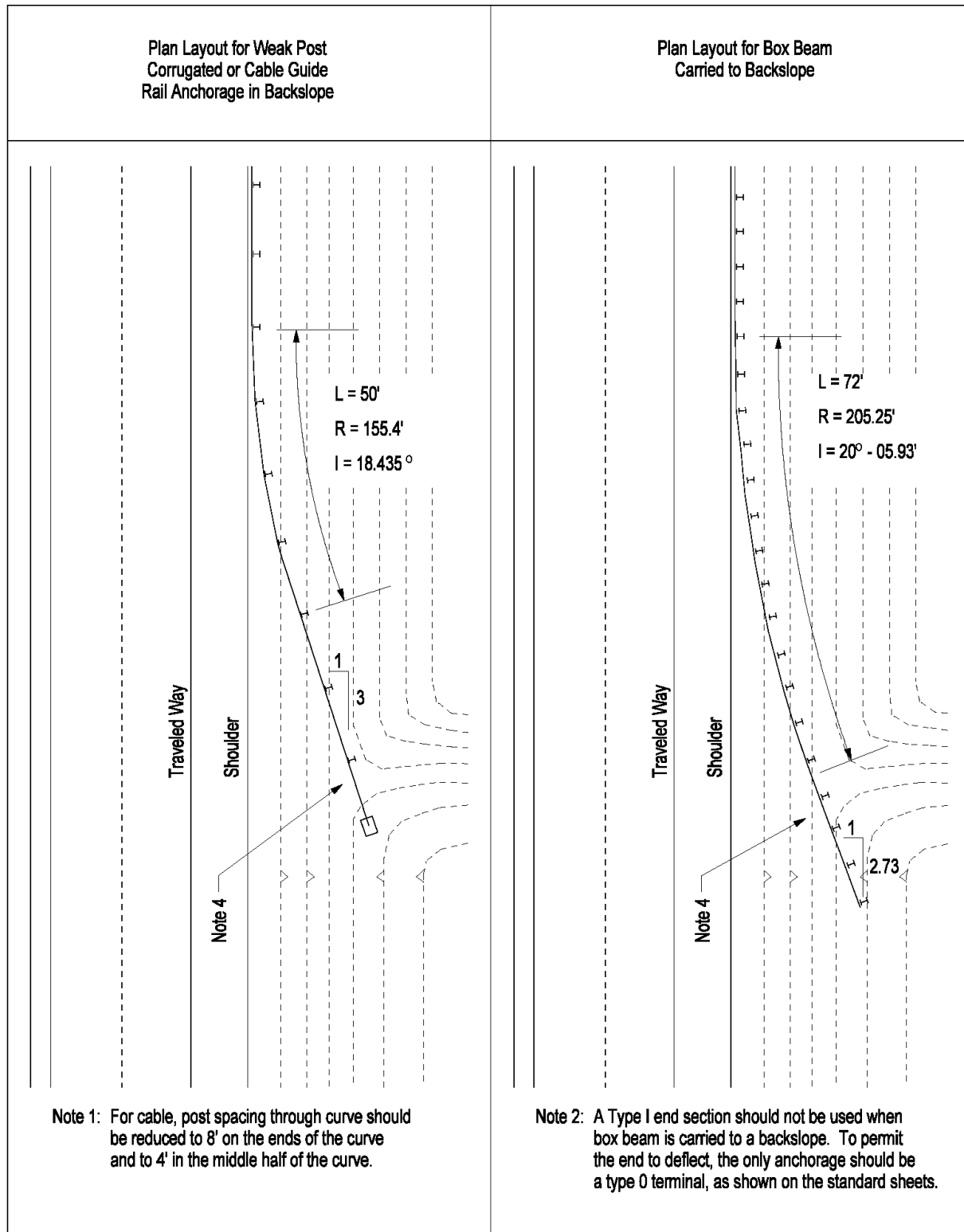


Figure 10-4d Backslope Anchorage for Weak Post Rail Systems



Note 3: Flare rates and curvatures shown are maximums. Lesser flare rates are preferred.

Note 4: Where rails cross ditch line, height should be low enough that errant vehicle will have initial impact with front of vehicle, not windshield.

Figure 10-4e Back Slope Anchorage for Heavy-Post Blocked-Out Corrugated Rail

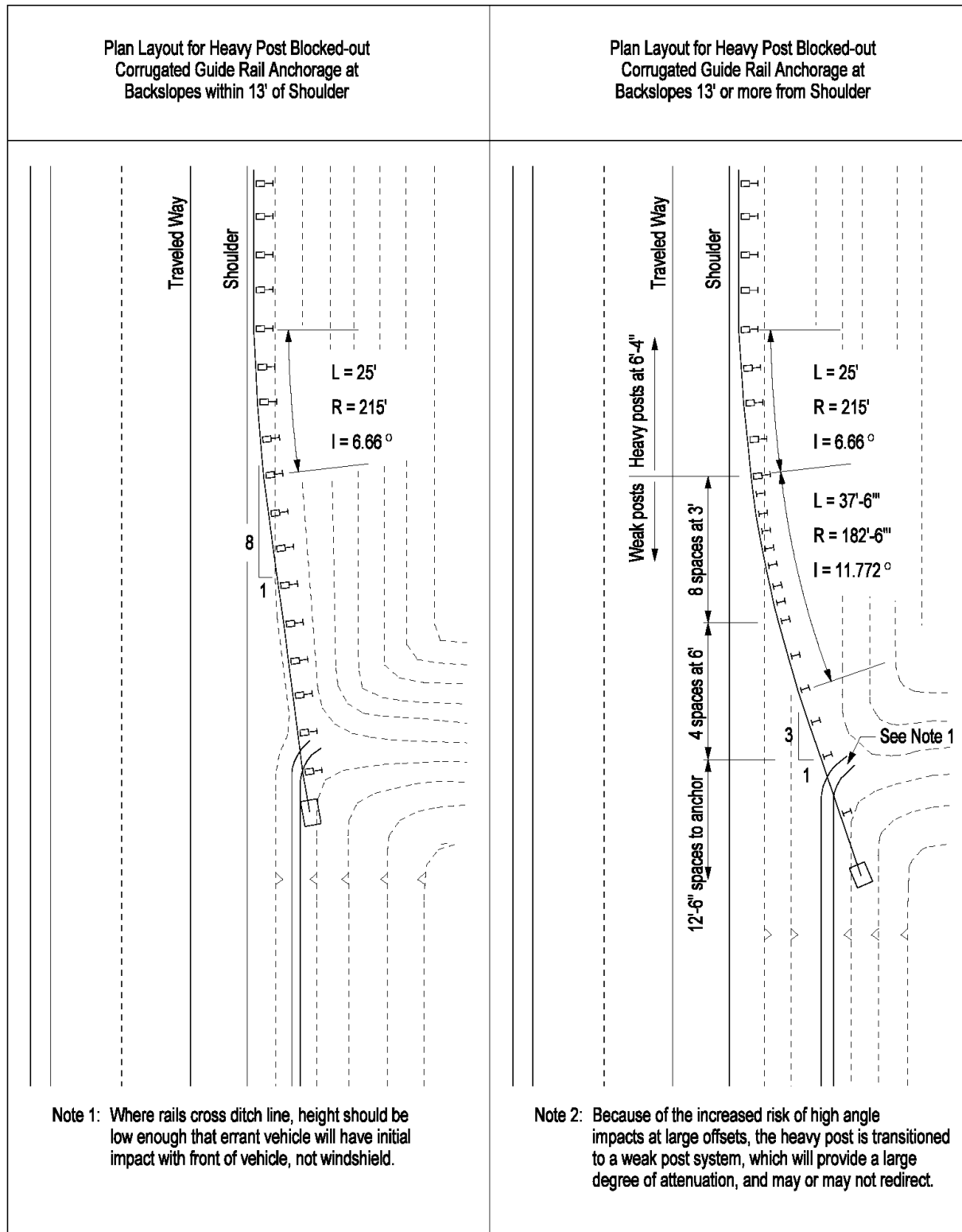
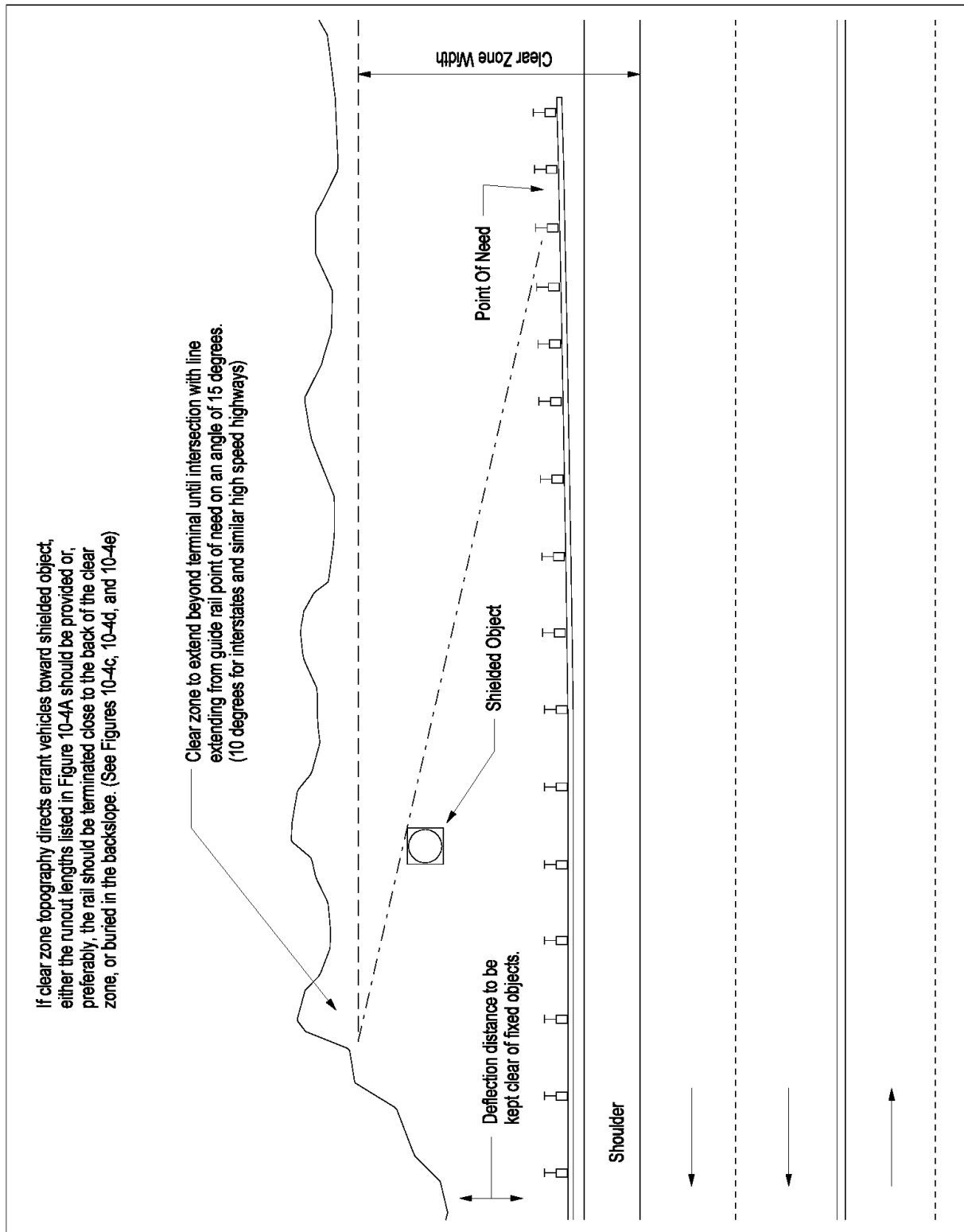


Figure 10-4f Clear Area Requirements for Gating Terminals



10.2.2.3 Deflection Distance

The "deflection distance" is defined as the lateral distance that the outside (side away from traffic) face line of a barrier will deflect when struck by an errant vehicle before that barrier system stops the movement away from the road. (Note: Deflection for heavy-post systems is measured as the deflection of the outside face of the posts. This distinction is made because weak post rail systems usually separate from the posts when struck, while heavy-post systems will often remain attached. The clear distance to an obstruction must therefore include an allowance for the width of the heavy post.) This distance will be a function of the vehicle's weight, speed, and angle of impact and of the strength or rigidity of the barrier system. The results of crash tests have been analyzed to develop a method for estimating the deflections that may be expected when a standard 4500 lb vehicle strikes different types of barriers at different speeds and impact angles.

Table 10-3 presents the deflection distances to be expected when various barrier systems are impacted at 60 mph by a standard 4500 lb vehicle at a 25° angle. Smaller deflections may be expected with lower speeds and when narrower roads tend to reduce the maximum lateral offset from which a vehicle may begin to veer towards the guide rail and thereby provide an upper limit to the normally anticipated impact angle. However, deflections do not decrease uniformly with reduced speeds as higher impact angles are possible at lower speeds. Figure 10-5 illustrates how to measure the maximum lateral offset for narrower roads. Figure 10-6 presents a graph of reduction factors that the normal deflection distances may be multiplied by to determine the smaller deflections that may be anticipated on narrow roads.

The deflection distance is an important parameter for two reasons. First, it determines the magnitude of the lateral deceleration. Flexible barriers, such as cable guide rail, allow a relatively gentle lateral deceleration. Rigid systems, such as concrete barriers, produce essentially instantaneous lateral decelerations which are more likely to result in injuries. This difference is the major safety factor favoring the selection of flexible systems. The second reason that deflection distance is important is that it determines the space that must be maintained between the hazard and the barrier. If a hazard were allowed to remain or grow within the deflection distance of a barrier, the longitudinal movement of an errant vehicle can still carry it into that obstacle, even if the lateral movement has been arrested.

The New York State Department of Transportation's policy with respect to guide rail selection may be summarized as follows:

1. The standard deflection of the selected system must be less than the lateral distance from the barrier to the nearest hazard that can not be removed or relocated.
2. With exceptions for specific conditions discussed later, the barrier system with the largest acceptable deflection should be selected when a barrier is required.
3. All removable hazards are to be removed from the area within the deflection distance of the selected guide rail. Maintenance work may be needed to prevent trees within the deflection distance from growing to more than 4 inches in diameter. Because the Department can not control development beyond the ROW line, the selection of a barrier system should ensure that its deflection will not extend off the ROW. Guide rail selection may be limited to systems with lesser deflections if there are fixed objects that can not be removed from behind the rail.

Occasionally, a guide rail system with a fairly large deflection may be selected for a long run within which length there is an obstacle closer to the rail than its deflection distance. If it is determined that (1) the object can not be moved out of the deflection distance, and (2) the rail choice should not be changed, then it will be necessary to reduce the deflection distance in the vicinity of the object. The normal procedure is to add additional back up posts in accordance with Table 10-3 to, in effect, stiffen the rail. Figure 10-6a illustrates the conventional plan arrangement of posts. If, during construction, objects are noted within the deflection distance of the rail system, then the responsible design representatives should be consulted by the Engineer in Charge (EIC). If the object is a utility responsibility, whether a utility pole, hydrant, or switch station, for example, the Regional Utilities Engineer should be promptly notified, in addition to Design.

Table 10-3 Barrier Deflections for Standard¹ Impacts

Barrier Type	Post Type (Deflection Category)	Post Spacing (feet)	Standard Deflection ⁹ (feet)
Cable Guide Rail and Cable Median Barrier ²	Weak Post (Flexible)	16	11 ⁶
		12	9'-6" ⁶
		8 ¹⁰	8
		4 ¹⁰	7
Corrugated W-Beam Guide Rail ³	Weak Post (Flexible)	12'-6"	8
		6'-3" ¹¹	6
		4'-2" ¹¹	5
	Heavy Post (Semi-rigid)	6'-3" 3'-1½" ¹¹ 3'-1½" ^{4,11}	4 ⁷ 2 ⁷ 1 ⁷
Box Beam Guide Rail ⁵	Weak Post (Semi-rigid)	6	5
		3 ¹¹	4
Corrugated Median ³	Weak Post (Flexible)	12'-6"	7
		6'-3" ¹¹	5
	Heavy Post (Semi-Rigid)	6'-3"	3
Box Beam Median ⁵	Weak Post (Semi-Rigid)	6	3
Concrete Safety Shapes	9 inch Embedment (Rigid)	-	0
	Temporary, Key-Joined (Rigid)	Ends Pinned ^{8A}	3'-3"
		Box Stiffened ^{8B}	2'-2"
		Fully ^{8C} Pinned	0'-8"

- Standard Impact is produced when a 2000P (Pickup truck, 2000 kg) test vehicle traveling at 60 mph impacts the barrier at a 25° angle.
- Must be properly tensioned and anchored to limit deflection to values shown.
- Must be properly anchored to limit deflections to values shown.
- With backup channel (for connection to rigid objects). Categorized as a rigid system. Deflection varies from 2ft at start of channel to 8 in immediately prior to connection to rigid structure.
- To develop beam strength, must be a minimum length of 125 ft, measured toe-to-toe (extreme ends of rail).
- To minimize rollover problems, barrier systems with deflections of more than 8 ft should not be used adjacent to slopes steeper than 1:2.
- Measured from outside face of post.
- End pieces should always be pinned, unless at least six pieces are present between end and first point where deflection is a concern. TCB Deflections are based on a 2270 kg (5000 lb) pickup truck.
- As in 8A, but box beam fastened across joints on worker's side. Areas where these deflection-limiting measures are desired should be clearly shown on the Work Zone Traffic Control Plan.
- All pieces pinned with four pins per piece, on worker's side only. Areas where these deflection-limiting measures are desired should be clearly shown on the Work Zone Traffic Control Plan.
- Where extra long weak posts are required, these deflections should be multiplied by 1.3.**
- Split spacing achieved by use of backup posts bolted to cable.
- Split spacing achieved by use of backup posts driven behind the rail, but not fastened to it.

Figure 10-5 Maximum Lateral Offset

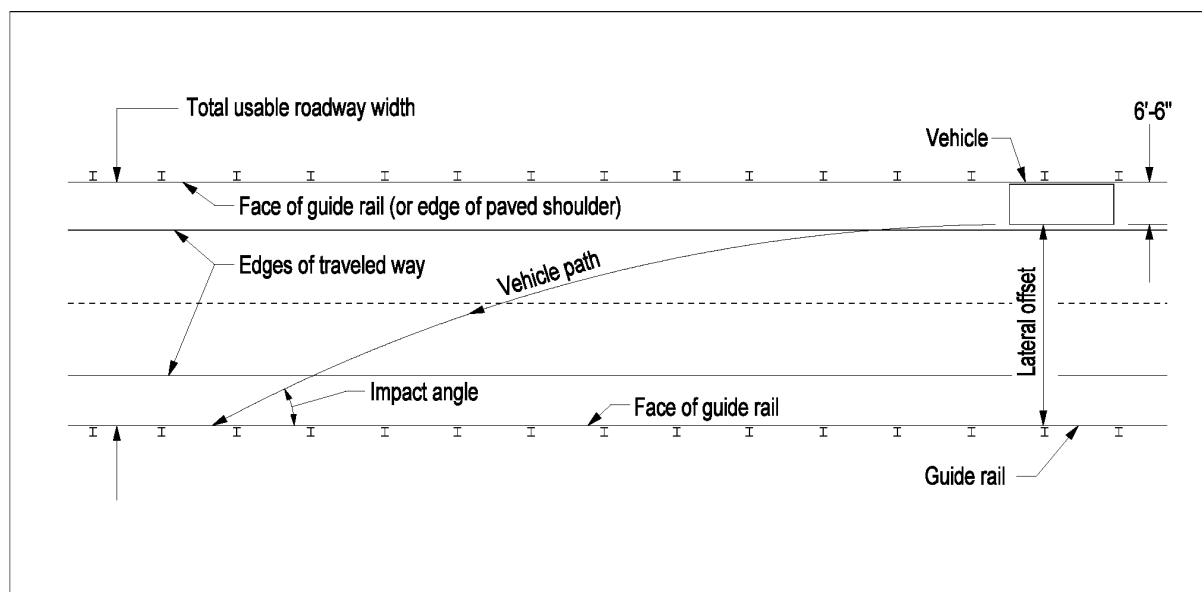
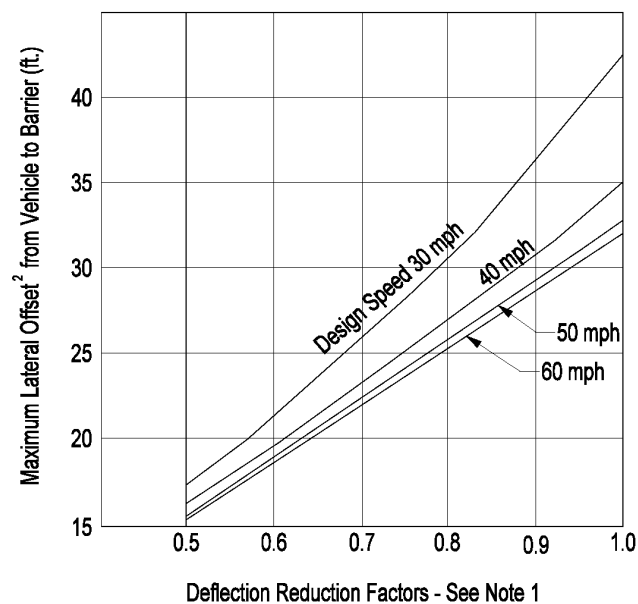


Figure 10-6 Deflection Reduction Factors

NOTES:

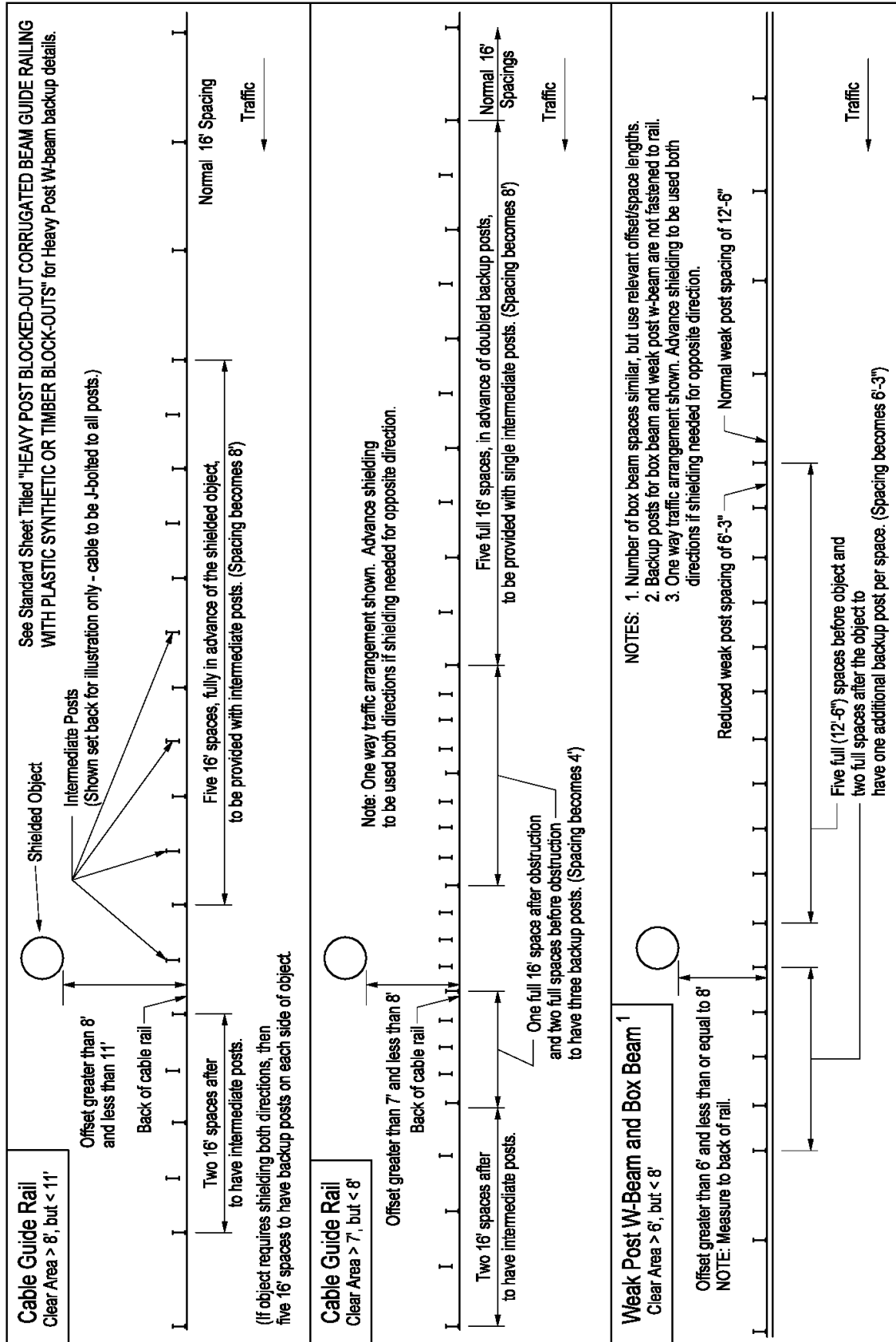
1. Factors shall not be less than 0.5.
2. As illustrated in Figure 10-5



EXAMPLE:

Assume the guide rail's standard deflection (obtained from table 10-3) is 8'.
 Assume maximum lateral offset (as defined in Figure 10-5) equals 26'.
 Assume the design speed is 50 mph.
 From the graph in this figure, the reduction factor is 0.8.
 Multiply 8' by 0.8 = 6.4'.
 Use a reduced deflection, due to the narrow offset, of 6'-5"

Figure 6A - Intermediate Posts Required to Reduce Rail Deflection



10.2.2.4 Vaulting Considerations and Policy on Curbs and Curb/Barrier Combinations

Vaulting is said to have occurred when a vehicle passes over a barrier. Vaulting is highly undesirable for two reasons. First, once the vehicle is past the barrier, it is free to strike the shielded object. Second, the vehicle will usually be airborne and more likely to roll over which usually causes a more severe accident. A distinction should be made, however, between the shielding portion of the barrier (downstream of the point of need) and the portion upstream from the point of need.

The portion that is upstream should not be shielding any fixed objects, as the area behind that portion of the rail should be clear back to, at least, the limit of the clear zone (see Figure 10-4f). Any vehicles that leave the road at a divergence angle of 15° or more (10° on interstates, etc.) and either gate through or pass over the barrier upstream of the point of need, should not encounter any fixed objects behind the rail until reaching at least the extension of the clear zone limit. While flaring the portion of the barrier upstream of the point of need away from the road, past the shoulder break, and down a slope may increase the likelihood that an errant vehicle will push through and over the barrier, the concern is offset by the lack of fixed objects behind the barrier and the speed reduction that will occur in the process of pushing through or over the barrier. Therefore, it is acceptable to flare the portion of the barrier upstream of the point of need down a sideslope. As in most cases, flatter sideslopes enhance safety.

For the shielding portion of the barrier (downstream from the point of need), efforts should be made to avoid conditions that could contribute to errant vehicles vaulting the barrier. The likelihood of vaulting may be increased where a barrier has been placed past the shoulder break and down a slope. Under these conditions, a high-speed vehicle diverging from the road at a high angle may momentarily have its bumper at a higher than normal height above the ground surface. This increased bumper height increases the likelihood of the vehicle going over the barrier. To minimize this risk, align guide rail posts at least 1.5 ft in from the shoulder break. Alternatively, align the guide rail at least 12 ft past the shoulder break, provided the slope is not steeper than 1:10 or, in the case of cable barriers, 1:6. (Tests have indicated that cable engages vehicles better than other rail systems do on a 1:6 slope.) While it is desirable to provide as much clear area as possible between the traveled way and an obstacle, there are additional considerations with guide rail. The condition of the surface is of critical concern. Unstabilized surfaces, including grassed areas, may become uneven over time, causing an errant vehicle to bounce and be more likely to vault a guide rail. Additionally, when guide rail is set well back from the road, there is an increased possibility of high angle impacts with consequent increases in accident severity and penetration rates. Preference should normally be given to locating the run of guide rail close to the edge of shoulder.

Curbing has been shown to be a major contributor to vaulting and destabilization problems, particularly at high speeds and with higher curbs. When the tires of an errant vehicle strike a curb, the impact tends to bounce the vehicle upwards which can contribute to vaulting or penetration of the rail. The problem is generally worst for curbs located more than 1 ft and less than 10 ft in front of the guide rail. In addition to the vertical bounce, striking the curb tends to slow one side of the vehicle. Both of these effects contribute to destabilization. When the destabilizing or vertical bounce effects act in combination with either the destabilizing effects of striking a concrete barrier or the large deflection of cable guide rail, unsatisfactory results may occur. **Therefore, do not place curbs of any height in front of concrete barrier (other than bridge barriers) or use (except in low-speed situations) in conjunction with cable barriers.**

A. Curbs and Curb/Barrier Combinations on High-Speed (>50 mph) Highways

- Curbing of any height is not to be used in conjunction with concrete barriers, attenuating devices, or cable guide rail.
- Due to its destabilizing effects, vertical faced curbing (formerly referred to as nonmountable) is not to be installed on new construction projects on high-speed highways (operating speeds greater than 50 mph) and is to be removed when practical on reconstruction projects. Vertical faced curb is not to be placed or permitted to remain along the mainline or in gore areas of interstates, freeways, or high-speed parkways. Refer to the Bridge Detail sheets for exceptions at abutments. Any other necessary exceptions are to be explained in the design approval documents.
- Mountable curbing of any height is not to be installed on new or reconstruction projects, except that, when curbing is necessary for drainage control on high-speed roads, mountable curbs with a maximum height of 4 inches may be used at the outside edge of shoulder where the shoulder is of the minimum width specified in Chapter 2 of this manual. Preference should be given to using the T100 traversable curb profile rather than mountable curb.
- Curbing is not to be placed along high-speed highways for the purpose of shielding pedestrians. Curbing is ineffective as a barrier, and, at high speeds, vehicles that come into contact with curbing are at increased risk of being pulled out of the traveled way and into areas frequented by pedestrians.
- Because of the vaulting concerns mentioned above, when it is necessary to use guide rail adjacent to mountable curbs on high-speed highways, the preferred location is within one foot of the face of the curb. The second place choice would be ten or more feet behind the face of curb. Placement in the zone between one and ten feet behind the face of curb shall be avoided unless the preferred locations are not reasonable options. Documentation of the latter choice should be provided if the unreasonableness of the other choices is not readily apparent.
- AASHTO's A Policy on Design Standards - Interstate System, 1991, further stipulates that, where it is necessary to use mountable curb and guide rail together, the face of the curb should be flush with the face of the guide rail or behind it. Where the 4 inch high, 12 inch wide gutter/berm is used as a curb at the outside of the shoulder width, the guide rail post should be placed as close to its back face as possible. This requirement applies to freeways as well.
- Theoretical studies have indicated the potential for curbs located under flexible or semirigid guide rail to increase the chances of vaulting or rollover. Therefore, the allowable deflection of barriers used in conjunction with mountable curbs should not exceed 4 feet.
- Whenever a parkway project calls for any curb to be located closer to the travel lane than a standard-width shoulder (see Chapter 2 of this manual for design criteria), the 4 inch (100 mm) high, 12 inch wide T100 traversable curb or other approved traversable design is to be used. Examples of this would be curbed, raised, grass shoulders on parkways or curbed reduced shoulder sections approaching a bridge.

B. Use of Curb and Curb/Barrier Combinations on Medium-Speed Highways (with Design Speed of 45 mph to 50 mph)

- Curbing of any height is not to be used in conjunction with either concrete barriers or cable guide rail.
- Curbing is not to be used in conjunction with attenuating devices.
- The designer should judge whether the project area conditions are typically rural, in which case the high-speed guidance presented as Section A, above, should be followed, or whether the conditions are predominantly urban or developing urban, in which case the guidance presented in this Section B should be followed.
- Mountable curbing may be used in conjunction with rail systems other than cable, but because of the vaulting concerns mentioned above, when it is necessary to use guide rail adjacent to mountable curbs, the placement preferences should be as noted in Section A above.
- The T100 traversable curb profile is acceptable for use with any guide rail at any offset.
- As general guidance, vertical-faced curbs (formerly referred to as nonmountable) may be used, but should only be used where justified by present or anticipated pedestrian traffic. Note that vertical-faced curb has little redirective or shielding capacity and is meant primarily to discourage the mingling of vehicular and pedestrian traffic. Because of destabilization problems, guide rails should preferably be no farther than 1 ft from the face of vertical faced curb. (Even though the effect is most pronounced between 1 ft and 10 ft, there is still a potential for vehicles to destabilize when striking a vertical faced curb and to vault a barrier even if it is located 10 ft or more from the curb.)
- As mentioned above, theoretical studies have indicated the potential for curbs located under flexible or semirigid guide rail to increase the chances of vaulting or rollover. Therefore, on highways with design speeds of 45 mph to 50 mph, the allowable deflection of guide rails used in conjunction with mountable or vertical-faced curbs should not exceed 5 ft.
- Since vertical faced curb has little redirective capacity (for the low-speed range it may redirect low angle impacts), efforts should be made to address clear zone concerns behind curbs exposed to traffic rather than being satisfied with the 18 inch lateral clearance requirement discussed in Chapter 2 of this manual. The designer should try to maintain the quality of the clear zone by limiting the number of obstructions behind the curb and should try to maintain the quantity, or width, of the zone by locating any required obstructions as far from the curb as possible.

Note: The AASHTO guidance on curbs originally recognized high-speed, medium-speed, and low-speed highways. The 2001 AASHTO *A Policy on Geometric Design of Highways and Streets* consolidated the medium-speed into the low-speed design category.

C. Use of Curb and Curb/Barrier Combinations on Low-Speed Highways with Design Speeds of less than 45 mph.

- Curbing of any height is not to be used in conjunction with concrete barriers.
- Curbing is not to be used in conjunction with attenuating devices.
- As general guidance, vertical-faced curbs may be used in low-speed situations (less than 45 mph). Note that vertical-faced curb has little redirective or shielding capacity. When used in conjunction with guide rail, the rail should generally be placed within 1 ft of the face of the vertical faced curb. However, offset is not critical, as there is little risk of vaulting at these lower operating speeds. Where the rail is being placed for the protection of pedestrians, a system with an appropriately low deflection distance should be selected. See the Bridge Detail sheets for exceptions at abutments. See Chapter 18 of this manual for details of treatment for the back side of guide rails to reduce the potential hazard that posts represent when in close proximity to sidewalks or bicycle paths.
- Mountable curbing may generally be used in low-speed setting in conjunction with any type of guide rail.

10.2.2.5 Horizontal and Intersection Sight Distances

Concrete barriers and, to a lesser extent, W-beam obstruct visibility. Where either of these barriers are needed on the inside of curves, the horizontal sight distance should be checked in accordance with the criteria for safe stopping distances presented in Chapter 2 of this manual and Chapter III of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004. In addition, some of the sites where glare screens are most needed are sites where horizontal sight distance is most likely to be affected. The designer should check to determine whether the above conflicts exist on a given curve and should carefully weigh the alternatives before selecting the barrier configuration. Options to consider are:

1. offsetting the barrier to the inside of the curve enough to obtain the required sight distance,
2. flattening or extending roadside slopes so the barrier may be moved farther from the traveled lanes,
3. using cable or box beam barriers as opposed to the more obstructive W-beam or concrete barriers, and
4. providing overhead lighting to aid night-time visibility.

Nonstandard feature justification will be required if sight obstructions can not be eliminated. Note that the fourth option above is a mitigation measure that will still require nonstandard feature justification if the sight distance is inadequate. Where the plan location of W-beam or concrete barrier indicates the potential for sight obstruction, the effects of any sag vertical curves should be taken into consideration to determine whether the line of sight may be above the top of the barriers.

10.2.2.6 Continuity and Access Gaps

Because of the large cost of anchor blocks or crash attenuating terminals relative to running lengths of guide rail and the potential hazard that end sections represent, short gaps of less than 100 ft should not be left between rail installations, unless gaps are required for access. (Note, however, that the Type I and Type IIA box beam terminals are inexpensive compared to their running lengths and may be considered relatively safe if placed at or near the back of the clear zone.) If expensive terminals would otherwise be required, gaps of up to 200 feet may be closed. Refer to Section 10.2.5 for guidance on the treatment of barrier terminals at access gaps. Chapter 3 of this manual provides guidance on the use of access gaps.

A related consideration is the need for emergency stopping areas where the shoulders are relatively narrow and there are long runs of rail. In such situations, a vehicle may not be able to move fully onto the shoulder and out of the traveled way. Where the right-side shoulders are less than eight feet wide and the runs of rail exceed 2000 feet, consideration should be given to providing an intermediate stopping point with a width of at least eight feet between the edge of traffic and the guide rail.

10.2.2.7 Shielding of Pedestrians

In general, it will not be appropriate to provide shielding for bicyclists and pedestrians. Exceptions might include settings such as bridge sidewalks where there will be (1) no reason for pedestrians to cross the road, (2) no reason for passengers to get out of vehicles, and (3) a constricted pedestrian space that would prevent them from being able to avoid an errant vehicle. Where high-speed, high-volume traffic will be near high-volume pathways, consideration should be given to providing a barrier to protect users of the pathway from errant vehicles. Even in medium-speed situations, the use of barriers between heavy traffic and jogging paths in park-like areas could contribute significantly to the peace of mind of the pedestrians. As stated elsewhere, vertical faced curbs are only effective at redirecting lower speed vehicles that contact the curb at very shallow angles.

In heavy traffic areas where pedestrians will frequently be present and using medians as a refuge area, use of curbing should be considered to delineate and help separate pedestrian and vehicular traffic. However, even vertical faced curb does not provide positive shielding. It may be appropriate to provide positive shielding, particularly if the median design includes numerous other fixed objects. One typical treatment is to place heavy, ornamented posts (bollards) in the median next to the crosswalk area. At intersections, bollards should be offset at least 3 feet to minimize the potential for problems with oversized vehicles. When bollards are used, they should be strong enough, and anchored firmly enough, to prevent an errant vehicle from shearing the bollard and reaching the pedestrians. It is not appropriate to design a bollard or its anchorage system in a manner that, when struck, would permit it to become a missile flying into opposing traffic or the pedestrians it is intended to protect. When the pedestrian traffic is seasonal, consideration may be given to using removable bollards. By removing the bollards during winter months, snow plowing may be facilitated and a potential hazard will be eliminated.

Another means of protecting pedestrians is to provide precast concrete barriers with sections other than Jersey Barrier shapes. One low profile alternative that was developed and crash tested by the Texas Department of Transportation consists of long concrete blocks with a height of 20 inches and reverse 1 on 20 slopes on the faces (wider at the top than the bottom). The

individual units are approximately 2 feet wide and should have weights around 2 to 3 tons. Aesthetic treatments could include textured, raised aggregate, or colored faces. As with the bollards, installation and removal could be performed seasonally. Bollards and barriers are likely to produce severe collisions for errant vehicles and therefore should only be resorted to in instances where there is either a history of vehicles striking pedestrians in the refuge island, or where it is judged likely that such an accident could occur.

10.2.3 **Barrier Types**

There are four types of barrier in common use in New York: cable guide rail, corrugated metal or W-beam guide rail, box beam guide rail, and concrete barriers. They are discussed in the following subsections in order of increasing rigidity. W-beam may be mounted on either weak posts or heavy posts (see Section 10.2.3.5) and, in the latter case, is much more rigid.

The selection of an appropriate barrier is primarily governed by safety considerations and secondarily by cost. In general, the most flexible barriers will have the lowest lateral deceleration rates and will perform better at gradually redirecting an errant vehicle. Unfortunately, barriers with large deflections may not perform well adjacent to steep slopes. Additionally, when a flexible system is struck, it will usually require extensive repair work before it will function properly again. In areas with frequent accidents, this may result in a significant accumulation of time during which the barrier is not operational. Also, the regular presence of repair crews must be considered as a potential hazard, both for the motorist and for the workers themselves. In such circumstances, use of a heavy-post blocked-out corrugated barrier or a rigid concrete barrier may be warranted, as they seldom require repair work. Refer to Section 10.2.4.1 for further discussion.

The safety of a given barrier system will also vary depending on the type of vehicle involved. Most barrier systems presently in service have been crash tested with either a standard passenger car or a standard and a lightweight car. Recently installed systems were crash tested with a 4450 lb pickup truck and a small car. As a result, the barrier systems are well adapted to the protection of the most common vehicles, but may not be well adapted to larger vehicles such as vans and tractor trailers. The point should be stressed that the barrier systems that have been developed are a **compromise** intended to provide protection for occupants of the average, more common vehicles in a fleet with broad diversity. Preference should be given to improving clear zones where practical rather than simply installing barriers. However, it should also be pointed out that, with modern testing and improvements, barriers, and particularly terminals, are much less likely to contribute to unfavorable outcomes than they once were. While lateral decelerations on stout barrier systems can still be very harsh, the results of collisions with other fixed objects will almost always be more severe, especially if the effective clear area is at or less than the recommended clear zone width.

Because of their size, buses and large trucks are not well protected by W-beam guide rails. Box beam is unlikely to rupture, but may get pushed down under large-tired vehicles. Cable stands the best chance of capturing a vehicle, but the extra vehicle weight may cause larger than normal deflections. If the cable is adjacent to an embankment, large vehicles may still reach the slope. With their higher centers of gravity, they will be more likely to roll over, even on relatively mild slopes. Concrete barriers function best for large vehicles and higher barriers reduce the chance that the large vehicles will trip and flip over the barrier. The designer should review the distribution of vehicle types expected on a finished project as a factor in selecting appropriate barrier types. The Design Quality Assurance Bureau should be consulted for barrier selection and design guidance for areas where truck penetration is deemed unacceptable.

In some situations, it may be desirable to evaluate the cost of providing a barrier system for comparison to other options such as buying right of way so slopes may be flattened. When evaluating the cost of a barrier system, the designer should consider (1) the initial cost of the system, (2) the cost of the types of repairs that may be required, (3) the frequency at which the various repairs will be required, and (4) the anticipated relative safety benefit. The first factor may be estimated from previous bid prices which are published in the Department's "Weighted

Average Item Prices". The second factor should be available from maintenance records for that Region or, for new roads, predictions may be obtained by the use of the computer program *Roadside*. The third factor may be estimated based on a combination of traffic projections, accident history data, and maintenance records. The fourth factor will generally be based on professional judgment and consideration of such concerns as frequency, type, and severity of accidents. In some situations, the potential for damage to adjoining property and road closures due to truck overturning should also be considered.

In general, the initial cost of weak-post W-beam will be about twice the cost of cable guide rail. Heavy-post blocked-out W-beam will be about three times the cost of cable guide rail. The cost of box beam will be about four times the cost of cable, and the cost of concrete may be as much as ten times the cost of cable. The maintenance costs may be significant for weaker systems and will be strongly controlled by traffic conditions.

10.2.3.1 Cable

Various types of cable guide rail have been used in New York State since the early 1900s. The older configurations are still in service along some rural roads. The currently accepted standard details for cable guide rail are shown on the Standard Sheets for 606 items (<https://www.nysdot.gov/main/business-center/engineering/cadd-info/drawings/standard-sheets-us/606>). The system is designed to yield more readily than any of the other barriers. The $\frac{3}{4}$ inch cables are fastened to light metal posts. At impact, the cables are intended to engage the vehicle either in grooves they form in the sheet metal or around projections such as bumpers. As the vehicle impacts the cable, the posts are bent aside and the lightly fastened cables pull away from the connections. Lateral movement is arrested by the combined effect of the bending of the posts and the tension built up in the cables.

Since it is essential that the cables develop tension to restrain the vehicle, each end of the run must be anchored. Details of the terminals are discussed in Section 10.2.5.1. To limit the total deflection distance, it is important that the system provide adequate tension in the cables prior to an accident. This requirement imposes a limitation on the curvature at which the cable guide rail may be installed. To guard against the maintenance problem of having the posts pulled over by the centripetal force from the cable tension, the system should typically not be installed on curves with a centerline or horizontal control line radius of less than 715 feet when using 16' post spacing, 440 feet when using 12' post spacing, or 200 feet when using an 8' post spacing. To avoid potential lean problems where cable guide rail would be placed on a tight radius, one of the following actions should be taken.

- Whenever it is reasonably possible to do so, eliminate the need for railing in the affected area.
- Use another type of guide railing that may be installed on the radius.
- Transition from cable to box beam before the area of the tight radius.

As indicated on the Standard Sheets, intermediate anchors should be used, if necessary, to limit the length between terminal sections to 2000 ft or less. Continuous runs which exceed that length may experience unacceptable amounts of thermal expansion and contraction. When measuring for payment, the overlapped sections are to be treated as separate runs.

There are also minimum length concerns for cable runs. On short runs, it is likely that all of the cable will be pulled from the posts, significantly increasing the deflection distance. Anchor to

anchor lengths of less than 200 feet should be avoided and lengths of less than 100 feet should not be used.

The main advantages of cable guide rail are that it:

- produces the lowest deceleration rates,
- has the lowest initial cost,
- is relatively easy to repair,
- provides the least obstruction to snow plow cast,
- does not induce snow drifting, and
- produces little visual obstruction.

The last advantage is both a safety consideration and an aesthetic consideration.

The disadvantages of cable guide rail are that it:

- requires the largest distance between the barrier and the shielded object,
- may develop lean problems on tight curves,
- requires repair after almost every impact,
- old style anchor blocks may experience pullover after repeated impacts into the run,
- should not be used adjacent to slopes steeper than 1:2, unless its post spacings are reduced to limit its deflection to 8 feet or less,
- may have performance issues adjacent to vertical or mountable curb on medium- or high-speed highways,
- requires regular maintenance to maintain tension,
- may have problems stopping low frontal geometry vehicles from passing under the rail system,
- requires that a large area behind the guide rail be maintained free of trees larger than 4 inches in diameter, and
- is the least effective barrier for reducing headlight glare.

Note that extra length posts may be required when guide rails are used adjacent to steep slopes and that use of those posts should be assumed to increase the deflection distance by 30%. Refer to Section 10.2.3.5. Because of the increased deflection distance, cable guide rail should generally not be used in situations that would require the use of extra length posts.

Cable guide rail may be warranted if:

- the appropriate clear zone width can not be economically obtained,
- the hazards are beyond, or can and will be removed from within, the relevant deflection distance of the cable, and
- any adjoining slope is 1:2 or flatter.

Because its impact durability is so poor, cable guide railing should generally not be installed on highways with AADTs in excess of 5,000 vehicles per lane per day. However, cable guide rail may be used for roads with higher traffic volumes if the correspondingly increased effort can be made to provide timely repair and maintenance and it is believed that repairs can be made safely. Distance from traffic will reduce hit frequency and increase the safety of repair operations. Regardless of volume, the use of an approved barrier system other than cable will be acceptable if it is anticipated that there would be significant problems with maintaining a

cable system in that location.

10.2.3.2 W-Beam

W-beam (corrugated beam) guide rail may be mounted on either a weak post or blocked-out on a heavy post. The difference in the two post systems is discussed in Section 10.2.3.5. In many respects, the systems are similar except for the increased rigidity of the heavy-post system. Section A, below, describes the weak-post W-beam and is generally applicable to heavy-post except as noted in Section B.

A. Weak-post W-beam

W-beam guide rail consists of lengths of corrugated steel sheeting with a cross-section shape similar to a W. These are bolted directly to S3 x 5.7 I-beam posts with 5/16 inch bolts. Note however, that when extra posts are added as backup, these are not to be attached to the rail. The connection bolts are designed to permit the rail to separate from the posts on impact so that the rail will stay with the vehicle rather than being pulled down under it by the posts. In addition to the connection bolts, there is a support bolt positioned at the bottom edge of the rail. These support bolts were added to the system soon after it was placed in service. It was noticed that some connection bolts were shearing under the load of snow and ice that sometimes adhered to the rail. The support bolt is not intended to affect impact results. Refer to the Standard Sheet for 606 series items for details of the W-beam system.

Weak-post W-beam (G2) was been a Department standard for many years. It successfully redirected four-door sedans during the NCHRP 230 testing. NCHRP 350 moved to a 2000 kg pickup truck as the primary test vehicle. Due primarily to the higher center of gravity of the pickup truck, the weak-post W-beam failed high-speed NCHRP 350 crash testing and briefly fell out of favor. The system was modified and retested. The modified system (Modified G2) passed the NCHRP350 high-speed crash tests at test level 3. The weak post W-beam, in modified form, is once again acceptable as a TL3 barrier. The modifications consisted of moving the rail splice off of the support post, adding a backup plate at the support post, and raising the working height of the rail.

Many runs of original G2 weak post W-beam were installed prior to NCHRP 350 and remain in service. Because existing runs of weak-post W-beam rail will generally function satisfactorily for most of the passenger fleet, it was not judged necessary to have a separate program to replace them. In some instances, however, an accident analysis may indicate a significant number of crashes on a W-beam guide rail and a high percentage of penetrations. In those instances, either the Modified G2 or an alternative system should be installed. (Note that, on lower volume roads, it may be helpful to examine more than three years of accident data to get a statistically significant evaluation of the penetration rate.)

The Department has decided to either retrofit existing runs of weak-post corrugated barrier to meet Modified G2 details or replace the old G2 with a different rail system on reconstruction projects with operating speeds in excess of 50 mph. It has also been decided to replace this system on 3R type projects on freeways. On other 3R projects, replacements of existing weak-post W-beam with another system may be made at the discretion of the Regional Design groups, but will not be considered necessary unless the first three of the following conditions are met or the last one is met:

- the operating speed is over 50 mph,
- the rate of reportable accident impacts on the weak-post W-beam guide rail exceeds 0.3 crashes/year/mile, and
- the percentage of impacting vehicles that penetrate through, over, or under the weak-post W-beam guide rail exceeds approximately 10%,
or
- the subject highway is an interstate or similar high-speed, high-volume facility.

Note, however, that replacements are encouraged if convenient for the particular project or if the run of existing guide rail requires significant work to be done, particularly if the run has a history of penetrations or rollover accidents.

With regard to 100% State-funded repair and maintenance contracts, weak-post corrugated guide rail and median barrier may be repaired and maintained, without replacement, under these contracts on facilities of all types, although replacements are encouraged in the situations noted above.

When W-beam is installed, individual pieces of corrugated beam must be mounted so that, for the normal traffic conditions (as opposed to a temporary construction condition), the trailing end of each, rather than the leading end of the next section downstream, is exposed to the predominant flow of traffic. That is, the direction of overlapping should shield the leading (upstream) ends. Individual sections of W-beam are fastened together so they can develop longitudinal tension and a restraining component similar to cable guide rail. As with cable guide rail, it is essential that the W-beam be properly anchored and continuously connected to provide the tension component. In addition, W-beams have significant lateral rigidity and therefore have lower deflection distances than cable. This lateral rigidity also requires that W-beam must be shop curved for installation on curves with radii of less than 150 feet. Because of their lower deflection distance and their degree of in-plane rigidity, W-beam guide rail may be used adjacent to steep slopes. Refer to Section 10.2.3.5 for limitations on how close the supporting posts may be placed to the shoulder break.

The main advantages of W-beam guide rail are that:

- its lower deflection distance permits it to be placed closer to a hazard than cable guide rail may be,
- the system is more durable than cable, as the damage from a mild hit affects only the impacted zone rather than the entire run (as with cable), and
- the system is significantly less expensive than box beam or concrete barriers.

The main disadvantages of W-beam are that:

- its deflection distance does require a significant separation from shielded hazards,
- it is rigid enough to be considered a mild hazard in itself (though much less of a potential hazard than almost any other fixed object),
- it is more visually obstructive than cable,
- it frequently needs repair after being hit,
- it has a long-term tendency to be pushed over by the lateral force of snow plowing,
- exposed segment ends may present a snagging or spearing hazard to wrong way traffic,

- it may act as a snow fence and induce drifting, and
- in accordance with the NYSDOT Guidelines for the Adirondack Park, “corrugated beam guide rail (W-beam) shall not be used” within the Adirondack Park.

W-beam guide rail may be warranted when:

- the appropriate clear zone width can not be economically obtained,
- site conditions do not permit the use of cable, and
- the rail can be positioned so the distance from a nonremovable hazard to the roadside face of the rail meets or exceeds the relevant deflection distance.

B. Heavy-post Blocked-Out W-beam

To remedy the high repair incidence while still providing a yielding system, the heavy-post blocked-out W-beam guide rail was developed. The blockout piece holds the rail away from the post to reduce the chance that part of an impacting vehicle will extend under the rail and snag on the posts. The heavy posts are much stouter than the weak posts and snagging on them could cause a vehicle to turn and roll over. The typical details are shown on the Standard Sheets for 606 items. To limit deflections and the potential for pocketing and wheel snagging, the typical post spacing is only 6'-3". The main advantages of heavy-post blocked-out corrugated beam guide rail are that it has a low deflection distance and it can survive mild hits with minimal need for repairs. The main disadvantage of the system is that it produces more severe lateral deceleration of impacting cars than do the weak-post systems. A secondary disadvantage of the HPBO system is its total width, which can be difficult to fit between the paved shoulder and a steep shoulder break. The heavy-post system may be warranted where barrier is needed and the traffic volume exceeds 50,000 vehicles/day. The decreased safety due to the high rigidity is offset by the increased safety obtained by limiting repair interruptions. In instances where a guide rail is needed but there is not enough clear area to accommodate cable, either heavy-post blocked-out W-beam or box beam are the logical alternatives to weak-post W-beam guide rail.

10.2.3.3 Thrie Beam

Thrie beam is a corrugated steel rail similar to W-beam, but with three corrugations instead of two. The third corrugation increases the height of the section from 12.25 inches to 20 inches. The section is significantly stiffer as a result, and can be placed to provide shielding over a larger vertical range. Because it is a comparatively expensive product, its uses along mainline highway sections have been limited. Its chief use in New York to date has been as a transition section between the yielding W-beam guide rail along highways and the unyielding concrete parapet walls on bridges. Refer to the Bridge Detail sheets for further information on the thrie beam transitions.

Thrie beam has also been used as a side component in some proprietary impact attenuators. In special instances, the Department has used thrie beam to assist in rockfall control along highway rock cuts.

The main disadvantage of thrie beam is its cost, and, in particular, the cost of the transition piece. For the foreseeable future, thrie beam will not be used in New York for normal highway use.

10.2.3.4 Box Beam

This railing is a square structural steel tube, 6 inches on a side with a 3/16 inch wall thickness. The rail is significantly more rigid than a W-beam and must be shop curved for radii under 720 feet. Details of the system are shown on the Standard Sheets for 606 series items. The system develops most of its redirective strength through beam action and therefore does not require anchor blocks. Note that runs must be at least 125 feet in length (measured as full length of rail, toe to toe, of terminals) for the system to develop its intended deflection resistance.

The main advantages of box beam guide rail are that:

- It requires less space for deflection than an equivalently supported W-beam.
- Its splice connection detail practically eliminates spearing problems.
- It is less of a visual obstruction than W-beam.
- It has a stronger, more rigid rail element and is therefore better at bridging between points of support. (When struck, the corrugations in W-beam tend to flatten, reducing its beam strength and increasing its tendency to fold around objects behind the rail, rather than supporting itself as a rigid beam against them. This only becomes an issue when vehicles strike the rail and cause more than the standard deflection or objects are present within the deflection distance.)

The main disadvantages of box beam guide rail are that:

- It is less forgiving than cable or weak-post W-beam guide rail.
- It is significantly more expensive than cable or weak-post W-beam guide rail (but only about 20% more expensive than heavy-post blocked-out corrugated rail).
- It is more difficult to repair.
- Significant repair delays may occur if damaged rail must be replaced with sections shop-curved to the correct radius.

Box beam guide rail may be warranted when either of the following conditions apply:

- The appropriate clear zone width can not be economically obtained and the available space between any nonremovable hazard and the edge of shoulder is adequate for box beam but not for cable or W-beam on weak-posts.
- It is necessary to transition to a rigid barrier system.

10.2.3.5 Post Systems

Whenever guide rail or fence posts are being positioned, the location should be checked for the presence of underground utilities.

Most of the barriers discussed above (heavy-post, blocked-out W-beam being the exception) are supported on "weak-posts". These posts are S3 x 5.7s, designed to bend aside when struck, rather than contributing to vaulting or rapid deceleration problems. Depending on the system and rigidity desired, weak-post spacing may vary from as much as 16 feet to as little as 3 feet. (See Table 10-3.) The reduced post spacings are achieved through the use of backup posts which provide additional lateral resistance. The backup posts for W-beam and box beam rails are not fastened to the rails. This is intended to minimize the potential for snagging. All weak-posts require soil plates to enhance their lateral resistance to impacts. In some cases, the light steel I-beam posts may be bent back into position and reused. Because the posts are weak, however, they require maintenance after most of the impacts. In locations with a high frequency of accidents, the downtime and repair costs can be significant problems.

The "heavy post" is a W 6 x 9 (or W 6 x 8.5), which is approximately four times as rigid as the weak-post, and must, therefore, be considered as more of a potential hazard. To minimize the danger of vehicles snagging on the posts below the rail, the rail is blocked-out in front of the posts. The traditional metal block-out has been replaced with a solid block-out that provides 7.5 inches of separation between the rail and the post (versus the traditional 6 inches). The solid block-outs are to be made of either wood (Standard Specifications 710-20 and 710-13, issued by EI 97-016) or plastic and synthetic (Standard Specification 710-26, issued by EI 99-035). Steel block-outs should not be reset or used for repair of damaged HPBO guide rail. To maintain the usable shoulder widths, heavy steel posts should now typically be positioned 10 inches from the edge of usable shoulder.

When additional rigidity is needed in the heavy-post system, the post spacing may be reduced from its normal spacing of 6'-3" to 3'-1½". At this spacing, soil plates are required to be welded to the posts. The plates are positioned just below ground surface. They serve to increase the area of soil that is resisting overturning at impact. To ensure that a sufficient amount of soil is present to provide the lateral resistance, posts should be placed no closer than 1 foot to shoulder breaks where the embankment slope is steeper than 1:4.

In addition to the steel heavy-post system, a pressure-treated wood post system with brown rail was used as an aesthetic treatment along some parkways. (Rustic, A-588 steel rail is no longer to be installed.) The posts and blockouts are 8" x 8". To maintain the usable shoulder widths, the front of the wood post should be positioned at least 10.25" from the outside edge of the usable shoulder.

A. Extra Length Posts

When the recommended offsets from the back of the posts to the shoulder break can not be achieved, the lateral soil support at impact may not be adequate. To compensate, extra long posts, Items 606.48xx, should be used. Note, in the item specification, that the soil plates are placed deeper than on the standard posts. Extra long posts should be used when the embankment slopes away from the normal shoulder break at steeper than a 1:2 slope. Extra long posts should not be used past the shoulder break. (The shoulder break is the line of intersection of the plane of the embankment with the plane of the shoulder slope and

should normally be located 2'-3" from the outside edge of the usable shoulder.) In situations where the normal offset and embankment slopes can not be used, Table 10-4 provides guidance on post selection as functions of slope, offset and soil type.

When 7 foot posts are required, the weak-post guide rail deflections should be considered to be 1.3 times the values in Table 10-3.

The designer should note that the driving of any post requires that extra care should be exercised in locating underground obstructions such as utilities, shallow culverts, and top of rock. As part of the normal design process, all utility companies with known facilities within the project limits need to be contacted to ascertain their facility locations. Street lighting conduits, ITS facilities, and telecommunications lines are particularly susceptible due to the fact that they are often approved for shallower depth installations.

Table 10-4 Minimum Shoulder Break Offsets (in feet) to Back of Guide Rail Posts

Embankment Slope	7'-0" Long Weak Posts (S3x5.7)	5'-5" Long Weak Posts (S3x5.7)	7'-0" Long Heavy Posts (W6x8.5)	6'-0" Long Heavy Posts (W6x8.5)
1:3	0.0	0.5*	0.0	1*
1:2.5	0.0	1*	0.0	1.5
1:2	0.0	1.5	0.0	2
1:1.5	0.5	2.5	0.0**	2.5

*Use 7 foot long posts if post is within 6 inches of the minimum offset and the soil is sandy or weak.

(Example: With embankment slope of 1:2.5, sandy soils, shoulder break at 16 inches from back side of weak-post, use 7 foot extra long post since 16 inches is within six inches of the one foot minimum shoulder break offset.)

**Do not use with an offset of less than six inches in sandy or weak soil.

B. Vegetation Control Strips

Vegetation management is an important element to be considered when designing a project. Vegetation management is needed along roadsides to prevent the growth of (1) vegetation that would reduce safety by obscuring sight distances, (2) trees that would be potentially hazardous fixed objects, and (3) vegetation that would encroach into the shoulder area and effectively reduce the shoulder space available for safe walking and bicycling. A particular maintenance problem is the area close to and under guide rail. Mowing machines are difficult to maneuver in these locations and, even with very careful use, can not be fully effective at controlling vegetation adjacent to posts. Furthermore, unintended contact can result in damage to both mowers and posts.

Two different control measures have typically been used as alternatives to mowing: total vegetation control herbicides or an optional (hot-mix asphalt) Vegetation Control (formerly "Mowing") Strip beneath the rail to suppress plant growth. The Department continues to strive to reduce the use of herbicides.

It is part of the Department's vegetation management policy to encourage the use of vegetation control strips (VCS) under guide rail when that use will contribute to reducing the Department's use of herbicides. The typical VCS shall consist of hot-mix asphalt with a minimum thickness of 3 inches. (Lesser thickness were not durable.) The width of the VCS will be dependent on the specific site conditions. In the normal shoulder section, the

shoulder break is 2'-3" beyond the edge of shoulder and the width of the strip that can reasonably be compacted will be limited to 2 feet for embankment side slopes of 1:6 or steeper.

Where the presence of a wider, sufficiently level area behind the rail permits placement and compaction of asphalt, the mowing strip should extend to 20 inches beyond the guide rail and posts to make mower control easier.

Rail-type median barriers and flared-back guide rail can normally be accessed from both sides. The aesthetic benefits to managing the vegetation by mowing may be sufficient to warrant that effort. Furthermore, running paved strips diagonally down a slope runs the risk of concentrating sheet flow and inducing erosion. However, if it is determined that vegetation management under a rail is required, but that mowing is not practical, then preference should generally be given to using a VCS rather than resorting to a total vegetation control herbicide. Where the guide rail or (rail-type) median barrier is not adjacent to the shoulder and there will be mowed areas between the shoulder and the railing, the width of the VCS should be 3 feet, except that a width of 5 feet should be used for HPBO median barrier. The strip should be positioned to permit equal mowing offsets from either side of the rail system. Where vegetation control strips are needed and the guide rail is not adjacent to, but is less than 5 feet from the edge of a shoulder, the space between the shoulder and the mowing strip should typically be paved, unless it is judged that a mowed space has sufficient aesthetic or storm water management value to warrant the effort and risk of mowing.

Where guide rail flares away from the road, the VCS, if required, should follow the line of the rail. This would typically result in a triangular area requiring mowing between the rail and traffic. To minimize the danger to both the mowing crews and the traveling public, the mowing strip should be widened to cover the area between the shoulder and the railing in areas where both (1) the distance between the edge of traveled way and the railing is less than 13 feet and (2) the traffic volume exceeds 2000 vehicles per day.

Measurement will be made on the basis of the number of tons satisfactorily placed and compacted. Where the VCS can be placed as an extension of the shoulder paving operations, the quantity will be included in the shoulder items. Where the VCS must be placed separate from the shoulder paving operations, payment will be under Item 608.020101 M Asphalt Concrete Sidewalks, Driveways and Bicycle Paths and the corresponding Plant Quality Adjustment Factor (Item 608.020110).

10.2.3.6 Concrete Barriers

In some situations, it is necessary to provide for redirection without deflection. In these instances, a rigid concrete barrier may be appropriate. The New Jersey Department of Transportation developed a cross-section that flared out at the base. It was intended that the base would deflect tires on low angle hits, thereby minimizing property damage. This shape came to be known as the Jersey Barrier and has been widely used. Details for the shape and the half section are shown on the Standard Sheets for 606 series items.

One potential problem with the standard Jersey shape, and with similar shapes that have “toes” projecting out in front of the face, is the possibility for small vehicles that impact at an unfavorable angle to ride up the face and roll over. To minimize the likelihood of this occurrence, the surface of the shape should be smooth to reduce the traction of tires that impact the barrier. Also, the height of the vertical face of the toe should not exceed 3 inches. Taller toe faces have been shown to increase the tendency of vehicles to “climb” the barrier. (Some of this “climb” may be due to the sloped portion above the toe being raised to where the frame of the vehicle strikes that inclined surface.)

Foundation and overturning support conditions for half sections should be reviewed for the specific conditions of use. A 9 inch embedment is typical for most soil conditions. The designer should consult the Regional Geotechnical Engineer for any special foundation design requirements.

A specific concern with concrete barriers, particularly precast barriers with their more frequent joints, is the possibility that an impacting vehicle might cause one segment to displace laterally, which would then permit the vehicle to strike the end of the next segment. Several measures may be used to help avoid this problem and ensure that all segments act as one continuous barrier. First, for precast and cast-in-place (set-formed) half section barriers, either backup posts and continuity connections are to be used or compacted earth berm backfill is to be placed as shown on the Standard Sheets. For slip-formed, half-section barriers, since the longer lengths provide for substantially more massive segments, backup is only required at the expansion joints. Where the available space allows, properly embedded full sections may be used. Their wider base and greater mass will generally permit their use without backup or continuity connections.

Because of the added threat posed when vertical elements, such as bridge piers, are in close proximity behind concrete barriers, extra measures should be taken to reduce the likelihood of vehicles climbing or leaning over the top of the barriers. As shown on the "Pier Protection" Standard Sheets, a box beam should be mounted to the top face of the Jersey-shaped barrier to limit vehicle climb. Although no testing has been performed to confirm the premise, it is anticipated that the box beam would also help to limit roll angles and "lean over" of tall vehicles. Details of the above options are, as of this writing, presented on the 606 series Standard Sheet titled "Pier Protection". Because the Pier Protection arrangement is essentially a rigid system, its use should be limited to the cases where it is specifically warranted. The arrangements on the Standard Sheet "Pier Protection" should be used when a bridge pier exists so close to the roadway that placement of guide rail, with its corresponding deflection distance, could not be made without encroaching onto the shoulder. (NOTE: It is anticipated that, soon after this chapter is issued, new standards for pier protection will be issued. The anticipated changes are intended to protect piers from damage by large truck impacts. The revised pier protection barrier is anticipated to be a 42" single slope barrier if 10 ft or more from the pier, and a 54" single slope barrier if closer to the pier.)

Other concrete barrier alternatives have been successfully used for protection of large vehicles. These have primarily involved increased heights, either as vertical extensions of half shapes or straight-faced walls. If the designer encounters a situation that may warrant a nonstandard concrete barrier, the Design Quality Assurance Bureau should be consulted for information on acceptable options. Refer to Section 10.2.4.9 for a description of innovative barriers.

The main advantages of concrete barriers are that they:

- provide redirection when there is no space available for barrier deflection,
- require very little maintenance or repair, and
- may effectively block headlight glare.

The disadvantages are that they:

- are unyielding hazards that may produce severe decelerations at all but low-angle impacts,
- may restrict horizontal sight distance,
- have a high initial cost,
- may interfere with drainage, and
- are considered aesthetically unappealing and visually obstructive. (See 10.2.3.7 B.)

Concrete barriers are warranted where positive redirection must be obtained and very little deflection space is available.

10.2.3.7 Barrier Options for Aesthetically Sensitive Areas

Designers will occasionally encounter projects where visual considerations are a major priority. The conventional barrier types may not be considered appropriate from an aesthetic standpoint. The systems that are briefly described below provide some alternatives. Other designs may prove acceptable. In general, these systems will be more or much more expensive than the standard alternatives. There may also be some reduction in safety. For these reasons, there should be strong reasons for using one of these systems instead of one of the normal standard types. In any event, before proposing use of an 'aesthetic barrier', it should be verified that the system has had an adequate safety evaluation. Any new systems proposed for use should be reviewed by the Design Quality Assurance Bureau.

A. Brown Steel Guide Rail Systems (formerly Rustic)

In the early 1970s, several park agencies and environmental groups requested that the Department use brown guide railing in some park areas. This was desired as a way of "branding" the park areas in a manner similar to the brown and yellow signs used for the same purpose. At about that time, the steel industry had marketed A588 steel, an alloy with copper in it that was supposed to weather to a rust brown and then leave a surficial coating, a "patina", that would significantly retard any subsequent rusting action. This material was used to produce steel guide rail which was installed in a steadily increasing number of aesthetic settings.

Unfortunately, it turned out that this patina-forming process did not function adequately

when the rail was placed in settings where there were regular moisture and elevated salt levels, conditions typical for roadside settings. Rustic rail replacements were needed much more frequently than desired. In 2007, the Department decided to phase out the use of A588 for guide rail. New projects should no longer specify any A588 guide rail. It is anticipated that essentially all runs of A588 guide rail will be removed from service by 2017.

Extensive experiments were conducted to identify a durable means of coating galvanized steel to a brown color, but all have shown aesthetic deterioration within a few years of installation. To maintain the desired aesthetics, coated rail would need to be periodically repainted or recoated. Because of the distraction that regular field repairs would create for tourist traffic, as well as the risk to the crews, the Department decided that only locations of special aesthetic value, such as scenic overlooks, rest areas, fishing areas, and some special gateway locations, would receive special aesthetic treatment, such as painting, powder coating, or the use of timber-faced steel guide rail. In most other locations where A588 guide rail has been used, that rail will be replaced with plain galvanized guide rail.

B. Stone-faced and Textured Barriers

The primary reason for having stone facing or textured surfaces on barriers is to establish or reinforce an identity for an area, or to complement or reflect existing features of historic districts, downtown redevelopment, historic restorations, or tourist areas. From a purely aesthetic perspective, the ideal appearance (colors, textures, materials, scale, etc.) will be reflective of the immediate environment's context.

There are however, other factors that must be considered when selecting aesthetic treatments for barriers. For example, while the context might call for a laid-up wall of natural stone, few roadside situations, for reasons given below, would be appropriate for such a treatment. Instead, such barriers often need to be reinforced concrete walls or, at the least, include one in their construction.

To provide an appealing appearance to a concrete barrier, its surface may be textured by using formliners, acid etching, sandblasting, etc., and coloring may be added through surface applications or mixed integrally into the concrete.

The location of a barrier should be taken into consideration, before considering aesthetic treatment. If in a location where it is likely to get struck by snow plows or errant vehicles, then a durable barrier design should be selected. Some designs use surface-applied stains to color the concrete. Stains are also often used when more than one color is desired i.e., simulating different colored stones, or to emphasize a formliner texture. When struck, some of the stained surface concrete will be broken off, exposing the unstained concrete underneath. Depending on the stain coloration that was originally used, the raw concrete may be highly visible. To minimize this aesthetic problem, and also when a uniform color is desired throughout, integral color additives can be mixed in with the concrete so that the color is present even after a surface has been knocked off. Another possibility is to specify aggregate with a color that blends better with the integral color. For instance, a limestone aggregate will provide a gray to dark gray color, while the typical pea gravel will tend towards yellow and brown. Some manufactured lightweight aggregates can provide a reddish color.

There are five primary safety concerns with stone-faced and textured barrier walls.

- Redirective capability
- Disaggregation
- Vehicle climb
- Vehicle snagging
- Continuity

Redirective capability refers to the barrier's ability to withstand the impact of a vehicle and redirect its path back along the road. If a barrier can overturn as it is being impacted, the impacting vehicle is likely to ramp up and over the barrier. If the barrier breaks apart, the vehicle may similarly go beyond it. This is particularly a concern for laid-up or mortared stone barrier walls. While such a barrier, when new, may have well-adhered stones, a prolonged exposure to freezing and thawing is likely to leave the mortar and stone loose. When subject to impact, the upper stones may fly, while the lower stones act to ramp the vehicle up and over. For this reason, real stone barrier walls should be reserved for locations that are not safety-critical, such as low-speed environments, scenic overlooks, and rest areas.

Concrete barriers have occasionally been broken by high-speed impacts or large-vehicle impacts. The reinforcing and thickness of the concrete should take into consideration the anticipated operating speeds and vehicle weights.

A vehicle does not have to pass beyond a barrier for breaking of the barrier to have a serious consequence. With either a stone or concrete wall, if a portion of the wall breaks out the vehicle may collide with the end of the broken out section. Stone-faced barriers should therefore include a reinforced concrete core wall to prevent a vehicle from passing beyond.

Disaggregation refers to portions of a barrier subjected to impact becoming missiles that may endanger people beyond the barrier. The critical locations for this concern would be where the barrier is on an overpass or adjacent to or above an area where people are likely to be present. The type of barrier of greatest concern would be those having some form of capstone that could be knocked loose. In general, capstone designs should be avoided in such locations. If such a design is considered important to the historic or aesthetic character of a location, the capstone should be mounted well onto a dowel set firmly into the barrier. Additionally, consideration should be given to having the traffic-side face of the stone set at least half an inch back from the face of the barrier.

Vehicle climb refers to the tendency of vehicles to rise when they strike barriers. This tendency becomes more pronounced as the face of the barrier becomes less vertical. Additionally, the spinning tires often come into contact with the face of the barrier and create a lifting effect. Smooth walls, such as are supposed to be present on Jersey-shaped and single-slope barriers, tend to minimize this effect. When texture is added to a barrier for aesthetic effect, the texture will provide a better surface for the spinning tire to "grab". With excessive texturing, vehicles can roll over as a result of climbing the roughened face. For concrete surfaces exposed to vehicle impact, texturing should not be used on faces with slopes in excess of 21 on 4 (the slope of Single Slope Barrier) and steeper faces are preferred.

The California Department of Transportation tested several texturing designs to determine which would or would not be considered safe. Their website provides useful information and

is located at http://www.dot.ca.gov/hq/LandArch/barrier_aesthetics/index.htm. NYSDOT generally endorses California's research results and guidance on texture. In particular, the width of "joints" between "stone courses" should not exceed 1 inch and the depth of the joint should not exceed ½ inch. Any greater texturing should be on the upper part of the barrier and should not extend down into the primary contact zone for frame and tires, which is taken to have a height of 2 feet. Additional coverage may be found in NCHRP Report 554 - Aesthetic Concrete Barrier Design, which is posted at: http://www.dot.ca.gov/hq/LandArch/barrier_aesthetics/nchrp_rpt_554_small.pdf

Vehicle snagging is said to have occurred when the corner of an impacting vehicle experiences enough friction against the textured wall to slow that side of the vehicle relative to the rest of the vehicle. When this occurs, the vehicle is likely to begin to yaw (spin) towards the barrier. In some cases, the vehicle may end up sliding sideways down the highway, potentially progressing into a rollover accident. To minimize this potential, the effective surface roughness of features running up and down the face of the barrier should be minimized. This roughness would be affected by the amount of projection of any such texturing from the face, the number of such projections, and beveling of the projecting edges. Any such projecting features should not extend more than ½ inch beyond the face of the barrier.

Continuity refers to the barrier's ability to act as a continuous structure. With any precast systems, there will be a joint between the individual pieces. Unless there is a reliable connection across the joint, there is a risk that an impacted piece will lean back, exposing the end of the next piece to direct impact by the errant vehicle. As little as two inches of differential lean could permit severe vehicle deceleration.

A variety of specialized stone-faced and textured masonry wall designs have been used on New York's state highways, but none have been accepted as "standards". As experience with some of the newer products is gained, it is anticipated that specific designs will become accepted and their details made available on our Internet site.

For some examples from other states that have been used across the United States, FHWA has a "Roadway Aesthetics Showcase" website, available at: <http://gallery.companys39.com/flh/>

C. Timber-faced Steel Guide Rail Systems

The purpose of these systems is to provide the strength and continuity available with a steel guide rail, but to provide the appearance of wooden elements. Because such systems derive their strength primarily from the steel elements, the cost of the steel portion alone is usually equivalent to that of a steel guide rail with similar deflection distances. The wooden elements add to the cost, resulting in a barrier system that is generally about three times as expensive as a steel system. As a consequence, steel-timber systems should only be used where the aesthetic need justifies the added expense. The systems may be suited for use on certain parkways, scenic overlooks or scenic highways in the Adirondack, Catskill and Southern Tier regions as is deemed appropriate in consultation with the Regional Landscape Architect. Several systems have been installed as 'special case' uses on Department projects. These include 10606.4771 M "Steel Backed Timber Guide Rail with Timber Posts and Blockouts", 10606.4791 M, its median barrier equivalent, and 08606.1801 M for a single steel-backed timber rail element fastened to steel posts. Before considering

use of any of these on a project, the designer should verify with DQAB that the system is still approved.

Terminals are a problem with any timber-steel rail system as the wood is not ductile like the steel and so will not be amenable to a yielding terminal. At present, there is no acceptable terminal for the generic steel-backed timber guide rail.

One proprietary system that has passed crash testing is the “Ironwood Guide Rail and End Terminals” issued as items in the 91606.13 M through 91606.2350 M series. This system has a “peeled log” appearance. The manufacturer can also provide this system in a squared timber. Its use is authorized on an “experimental” basis, meaning that it has been crash tested successfully, but the Department has not yet had enough satisfactory field performance with it to accept it for general or widespread operational use.

The Ironwood consists of an 8” diameter “peeled log” timber rail with a ¼” thick steel channel embedded into and bolted to it. This composite rail is attached to 5'-3" long S 3 X 5.7 steel posts set 38" into the soil and spaced six and a half feet on centers. Each post includes a 2' by 8" soil bearing plate (steel spade plate.) The exposed front portion of each post is clad by a routed, 6¾" diameter timber post. This post cladding provides an all-wood appearance to the barrier from the traffic side of the installation.

Ironwood Guiderail will follow a curve of 180 ft radius, inside or outside, when the standard four meter long rails are used. If shorter two meter rails are used, Ironwood Guiderail will follow an 80 ft radius curve, again inside or outside. More sharply curved radii are possible with custom splice plates and special timber rails. The manufacturer should be contacted if more sharply curved radii pieces are needed.

The preferred termination method at approach ends is to carry the Ironwood Guide Rail “full height” into the back slope, burying and anchoring the ends there. The recommended flare rates are:

- 1:14 at 62 mph (100 km/h)
- 1:10 at 45 mph (70 km/h)
- 1:7 at 30 mph (50 km/h).

The Ironwood manufacturers have received FHWA approval for using a Type III box beam terminal with a transition to their rail. While the result meets the safety criteria, the juxtaposition of the timber and the box beam is rather harsh aesthetically.

Ironwood products are manufactured and distributed by Structures of Ironwood, LLC., P.O. Box 600, Saranac Lake, NY, 12983, tel. (518) 891-1669.

10.2.4 **Median Barriers**

Median barriers differ from roadside barriers in that they are designed to withstand impacts from either side. Descriptions of the various types of median barriers are presented below in Sections 10.2.4.4 through 10.2.4.6 and in 10.2.4.9. The design of medians is discussed in Chapter 3 of this manual. Barriers may be warranted in medians to either (1) reduce the potential frequency of crossover accidents, (2) limit access, or (3) shield potential hazards, fixed objects, steep slopes, etc. When objects within the median require shielding, it will typically be necessary to use roadside barrier. When a median warrants a barrier system purely for separation of opposing traffic, median barriers will usually be the preferred choice both for economy and for the added clear area that they permit when compared with using roadside barriers on both sides of the median. Sections 10.2.4.2 and 10.2.4.3 present barrier design guidance for wide and narrow median geometries. Figure 10-7 is a graphical summary of the guidance for use of barriers in medians on high-speed (50 mph or greater) freeways and expressways.

In general, appropriate barriers should be installed in medians when:

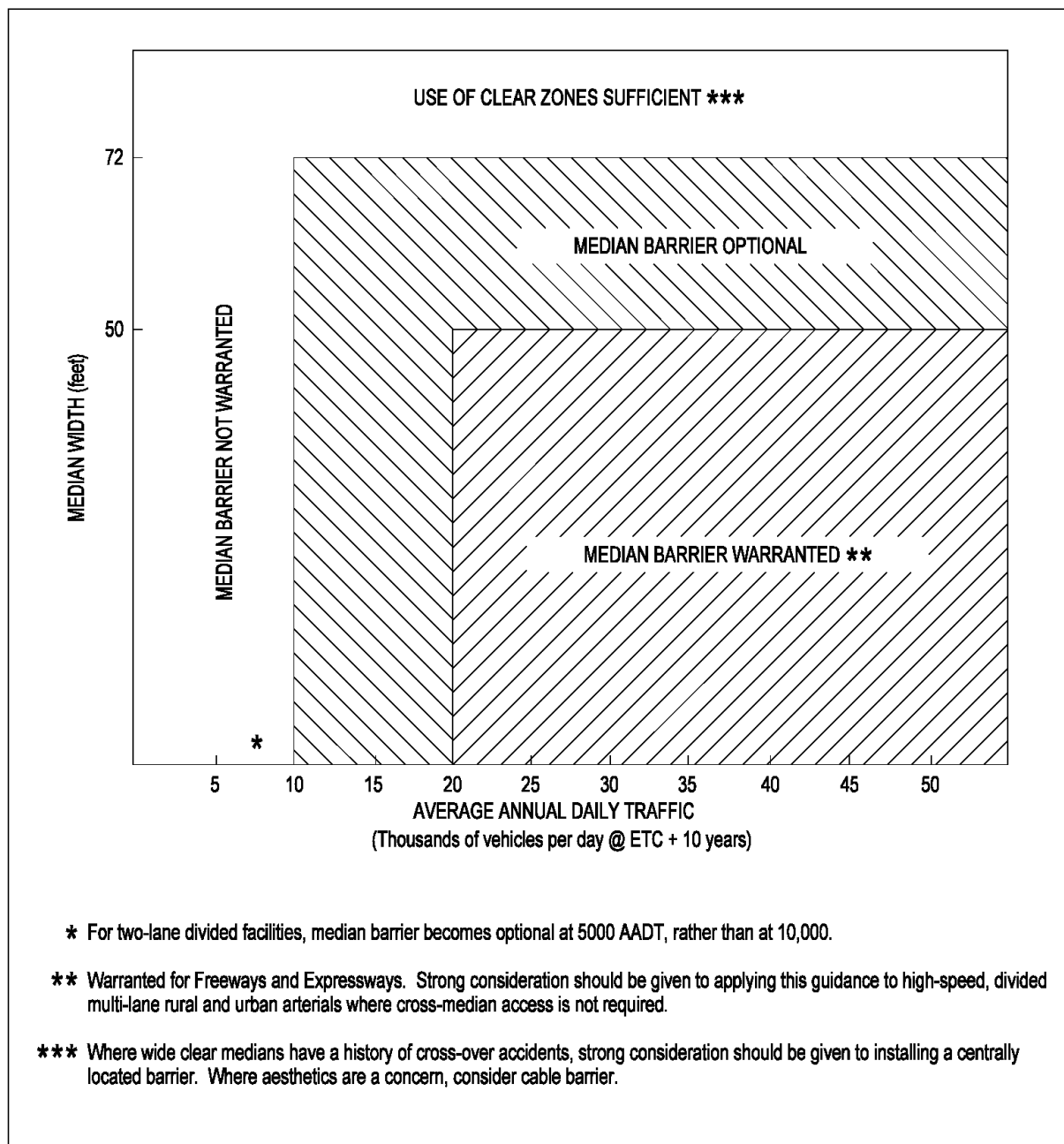
- As announced by EI 07-023, median barriers are now warranted on freeways and expressways with high-speed (50 mph or greater), high-volume ($AADT \geq 20,000$) traffic, the median is level (slopes $\leq 10\%$) and less than 50 feet wide,
- an existing facility has a history of median crossover accidents,
- potential hazards within the median of a limited access highway compromise the clear zone width for one or both directions of traffic,
- midblock turns need to be limited and there is not adequate space for a raised median,
- opposite direction ramps are adjacent to each other, or
- wrong-way movements would otherwise be possible onto exit or entrance ramps.

Additionally, if an existing facility has a history of accidents related to headlight glare from opposing traffic, this factor should be taken into consideration when determining whether a median barrier would be appropriate. In this case, the need for glare screens on top of the barrier (Section 10.2.4.7) should also be evaluated.

Median barriers should generally not be used on cross slopes which exceed 1:10. Cable median barrier (Section 10.2.4.9 D) may be used on slopes up to 1:6. Placement of barriers in uneven medians is discussed in Section 10.2.4.8. Both the deflection distance of the selected median barrier and its placement within the median should be such that it will not deflect into either stream of opposing traffic when subjected to a standard impact (described in Note 1 of Table 10-3). When selecting an appropriate type and location of barrier for narrow, curved medians, the designer should review the horizontal sight distance requirements. Similarly, intersection sight distance requirements should be reviewed when selecting a type and location of a median barrier at intersections.

While not required by the warrants shown in Figure 10-7, consideration should be given to placing cable median barriers in the middle of wider, traversable medians on high-speed highways, particularly where the AADT exceeds 5000. The central location will minimize the potential for damage by snow plows and from brush hits, while providing an unobtrusive, low cost means of limiting the number of head-on, cross-median fatalities. Where provision is needed to permit mowing machine access, breaks in the runs should be provided, with the ends overlapped in the direction of traffic.

Figure 10-7 Guidance for Median Barrier Use on High Speed (50 mph or greater) Freeways and Expressways



10.2.4.1 Traffic Volume and Maintenance Considerations

A. Mainline

As with roadside barriers, traffic volume and maintenance considerations are key issues in median design. On high-volume divided highways, a cross-median accident greatly increases the probability of a severe outcome. Higher volumes also increase the maintenance problems as barriers will tend to be hit more often. If they are one-hit barriers, they will be ineffective more often as they await repair. High volumes hamper repair work, which is, in turn, an increased danger to both the motorists and the workers. Where possible, the median barriers on high-volume roads should be positioned so that repair and emergency vehicles can approach at least one side of the barrier without encroaching on travel lanes. For example, rather than placing a median barrier in the middle of a 13 foot wide median, it may be offset to permit an 8 foot emergency parking width on one side. Concrete median barrier, however, should normally not be set more than 10 feet from the edge of the traveled way as higher angle, more severe impacts become more likely with increased distance from the traveled way.

B. Adjacent Ramps

The selection of a median barrier to use on adjacent, opposite-direction ramps may be influenced by numerous factors. If an existing ramp has a history of frequent impacts, then a durable barrier, typically concrete, should be favored, due to its ability to resist damage. Minimizing the need for frequent repairs minimizes the risk for repair crews and the likelihood of accidents due to drivers being distracted by the repair crew. While impacting a concrete barrier may be harsher than impacting a steel barrier, the narrowness of most ramps and the likelihood that drivers will have slowed before entering the ramp should minimize this factor.

If the ramps are handling a lot of truck traffic, metal barriers may not be sufficient to prevent trucks from tipping over the rail. The extra height and rigidity of a concrete barrier may be preferred.

Where ramp volumes and barrier impact rates are low, the risk of a vehicle encountering an opposite direction vehicle if it breaches the barrier is low. With those low volumes and low impact rates, an economical barrier such as Weak-Post W-beam may be used. This barrier will function adequately for most passenger vehicle impacts.

While box beam median barrier is a reasonably safe option for adjacent ramp, its posts are easily damaged, shop curved rail pieces may be difficult to replace, and the repair operations are more complicated than with W-beam systems. As a convenience consideration, box beam median barrier should generally be avoided where opposite direction ramps are in close proximity.

10.2.4.2 Wide Medians

For the purposes of this document, wide medians will be defined as those with widths that exceed the relevant Desired Minimum Clear Zone distance (see Appendix A) for either direction of traffic.

Unlike the passive threat of stationary hazards, opposing traffic is a mobile, active threat. Clear zone widths should only be relied upon for traffic separation under special conditions. Each of the following cases is considered sufficient to permit the use of clear zones instead of median barriers for traffic separation.

1. The median width exceeds 72 feet.
2. The AADT is less than 10,000 vehicles per day.
3. For medium- and low-speed highways (<50 mph), the desirable clear zone width for each direction is satisfied between the edges of traveled way using a symmetrical depressed median with slopes of 1:6 to 1:4, inclusive, or a raised berm median with berm slopes of 1:4 or steeper.

These allowances shall not be applied to existing facilities with a significant history of crossover accidents. Where the median geometry and traffic conditions are between those given above and the warrants given in Section 10.2.4, barriers are not required in medians, but should be considered, with the final decision being based on the designer's professional judgment and consideration of the many factors involved.

10.2.4.3 Narrow Medians

For the purposes of this document, narrow medians will be defined as those with widths less than the relevant Desired Minimum Clear Zone Width (see Appendix A) for either direction. Median barriers should be considered for all narrow median, limited access highways.

For narrow-median highways, where access is not limited, the need for median barriers is a function of the traffic volume and speed and the number of barrier openings required for median crossings. Barrier end treatments at openings are, in themselves, mild hazards and, if too many are required, the barrier may not be advisable. Barriers may not be warranted on narrow medians in each of the following cases.

1. The AADT is less than 10,000 vehicles per day (5000 for two-lane divided facilities).
2. The operating and design speeds are less than 45 mph.
3. The distance between required median openings is less than 300 feet and the median width is at least 10 feet.

These allowances shall not be applied to existing facilities with a significant history of crossover accidents. Where the median geometry and traffic conditions are between those given above and the warrants given in Section 10.2.4, barriers are not required in medians, but should be considered, with the final decision being based on the designer's professional judgment and consideration of the many factors involved.

In developed areas with medians less than 10 feet wide, frequent openings in median barriers should be avoided as the terminals at each opening require a more expensive treatment and

constitute more of a potential hazard than a continuous run of barrier without openings. If median barrier is warranted in medians less than 10 feet wide, midblock openings should be eliminated or separated by 300 feet or more.

Where median barriers will be close to traffic, and particularly where there are curves, appropriate delineation should be provided on or above the barrier.

10.2.4.4 W-Beam Median Barriers

There are two forms of W-beam median barrier: the weak-post system and the heavy-post blocked-out system. Both have two W-beams, one on each side of the post. The typical details are shown on Standard Sheets for 606 items. The advantages and disadvantages of W-beam median barriers are similar to those for W-beam used as roadside guide rail. The restrictions on the use of weak-post median barriers on high-speed facilities are the same as those for weak-post guide rail. (Refer to Section 10.2.3.2 A.) Table 10-3 lists the deflection distances required with standard impacts for the different W-beam mounting arrangements. The heavy-post W-beam system is significantly more impact-durable than the weak-post. The disadvantage of this increased durability is that the increased rigidity tends to produce more severe lateral decelerations. However, the accidents are generally less severe than those involving rigid concrete barriers.

W-beam median barriers may be the appropriate choice when:

- There is sufficient space in the median to accommodate both the barrier and its deflection distances on either side (to arrest the lateral movement of impacting cars before they enter opposing lanes).
- A more flexible barrier than concrete is desired. Note, however, that the heavy-post is considered a semirigid system and has the same warrants as concrete median barrier discussed in Section 10.2.4.6.

For new projects, the heavy-post system should be selected over the weak-post system if either:

- The design speed is 50 mph or greater.
- The median is less than 22 feet wide and the AADT exceeds 40,000 vehicles per day.
- The location is likely to receive more than one hit during a single icy weather event. Likely locations might include curves that follow long tangents, long downgrades or crest vertical curves, curves that are shaded, or where maintenance or accident records indicate a problem.

For new projects on the National Highway System, the heavy-post system shall be selected over the weak-post system if the operating speed is greater than 45 mph.

10.2.4.5 Box Beam Median Barrier

The box beam median barrier is a weak-post system similar to the roadside box beam guide rail. The main difference is that the median box is wider and its wall thicker. Its dimensions are 6" by 8" with a ¼ inch wall thickness. Its standard deflection is listed in Table 10-3 and is greater than that for the heavy-post W-beam median barrier, but less than for the weak-post W-beam median barrier.

The disadvantages of box beam median barrier are that it:

- must be shop curved for curves with radii less than 1525 feet,
- is heavy to work with,
- is likely to have posts bent out of service on even mild hits,
- can not be conveniently bent back into shape, and
- has less vertical range for protection against vaulting, under-run and headlight glare.

The main advantages of box beam median barriers are that it:

- may be the most economical choice, depending upon prevailing supply conditions,
- produces lower lateral deceleration on impact (more forgiving) than either concrete median barrier or heavy-post corrugated median barrier, and
- may be considered aesthetically preferable.

Its use may be warranted when:

- a median barrier is warranted and
- a barrier with more deflection can not be used.

Because of the cost differential between median barrier systems, where permitted, it is advantageous to transition from box beam median barrier to weak-post corrugated beam median barrier when the deflection criteria no longer warrants the use of the box beam median barrier, but continuation of a median barrier is appropriate. Refer to the 606 series Standard Sheets for details of the transition.

10.2.4.6 Concrete Median Barrier

Concrete median barriers (CMB) are similar to the concrete roadside barrier discussed previously. The main difference is that it is designed to be hit on either side. This requires extra base width which provides greater stability. The barrier is assumed not to deflect upon impact by personal passenger vehicles. Therefore, impacts are more likely to be severe. Another potential disadvantage is that CMBs may contribute to horizontal sight distance problems on curves with narrow medians and/or median shoulders.

The main advantages of concrete median barriers stem from their durability. They are:

- seldom out of service, so there is
- little potential for accidents related to repair and maintenance operations, and
- their maintenance costs are low.

In addition, the barrier is more easily seen than others and is the most effective barrier at preventing crossover accidents and reducing headlight glare problems.

The use of concrete median barrier may be warranted whenever:

- a median barrier is required on a freeway, expressway, or parkway with a free-flowing operating speed of 50 mph or greater,
- the clearance from the edge of travel lane to the barrier is less than 10 feet (or the barrier is placed at the edge of wider shoulders) and
- the peak average volume exceeds 12,000 vehicles/lane-day (Level of Service C).

The types of concrete median barrier are shown on the Standard Sheets for series 606 items. There are several types of concrete barrier. Currently, the type most commonly used by the Department is the Single Slope barrier shape. Additional types may be used and are discussed in Section 10.2.4.9 Innovative Median Barriers.

The single-slope concrete median barrier may be used for any barrier applications that the standard NJ barriers were used for, as the warrants for the two barriers were the same. The single-slope concrete median barrier was crash tested in accordance with the requirements of NCHRP Report 350. The reports of the tests are published in *Transportation Research Record 1302* (TRR 1302). The single-slope concrete median barrier has several advantages over the standard NJ shape. The following is a partial list.

- Increased safety, especially for the small car, because of lower roll angles.
- The extra height and thickness of the barrier will increase its strength and mass. Therefore, it will better contain a large vehicle.
- The extra height will lessen headlight glare without the use of glare screens.
- Resurfacing of the roadway adjacent to the barrier that changes the grade by more than 3 inches may be made as long as the resurfacing does not reduce the height of the barrier to less than 32 inches.
- The grade from one side of the barrier to the other can differ without the necessity of a complex asymmetrical barrier, provided the height of the barrier on the high side is not less than 32 inches.
- The single-slope barrier is easier to construct because of its simple shape.

Two possible disadvantages surfaced in the research report. The first is that computer simulations indicate that the occupant risk of the single-slope concrete median barrier is slightly higher than the New Jersey barrier. However, the crash tests indicated that the occupant risk was within the limit of NCHRP Report 350. The second is that the extra height may reduce the sight distance of the operator of a vehicle. In addition to the standard crown width of 8 inches (see Figure 10-9), a 12 inches wide version is permitted for mounting of objects such as light poles. However, mounting of large objects on median barrier should only be resorted to if other locations are not reasonable.

Due to its long history of use as the primary concrete barrier in New York, the New Jersey Barrier was often referred to simply as 'Concrete Median Barrier'. There has been an almost complete shift to the use of single-slope median barrier in recent years. The Jersey barrier was used in several widths and a variant, the "F" shape, is now also being used with a greater height as an Innovative Median Barrier called the Truck Barrier (see Section 10.2.4.9). The Type "A" (symmetrical, narrow-stemmed, 6 inch crown width) median barrier is for general use in all cases where it is not required to accommodate truck traffic or to mount lamp posts or other similar objects on top of the barrier. Where appropriate for urban truck traffic, the Type "B" barrier, with a 9 inch crown width, should be the minimum width used.

There are numerous situations in urban areas where the most economical and most effective location for a light pole, sign, or similar object would be on top of a concrete barrier in a narrow median. Unfortunately, mounting such objects on top of concrete median barrier may create a risk that the object could be struck and knocked down into opposing traffic or that it could snag a leaning vehicle and act as a fixed object. In general, preference should be given to alternatives that do not require mounting objects on concrete barriers where they could potentially be struck. As stated above, the risk of such an accident occurring increases with the narrowness of the

barrier, the size of the vehicles in traffic, and the traffic volume, but decreases with increasing barrier height. When it is deemed important to mount an object on top of a concrete median barrier, the risk of striking such object during an accident should be minimized by increasing the effective barrier width in advance of the mounting location, on both side of the barrier, in order to minimize the chance of a vehicle leaning and contacting the object. Light poles mounted on median barriers are inconvenient and potentially dangerous to service. For this and the above reasons, mounting of light poles on median barriers should be avoided unless there are compelling factors favoring that placement.

In general, the Jersey-shaped concrete median barrier (32" tall) should be considered too low to mount large objects on. Even when the Type "C" barrier, with its 12 inch crown width, is considered, mounting large objects on Jersey barrier should be avoided for speeds over 45 mph.

Where trucks and large vehicles are not permitted, 42" high concrete median barrier may be used when it is deemed necessary to accommodate lamp posts or similar objects on top of the median, provided that at least four inches of separation are present between the face of the barrier and the side of the mounted object. However, on high-speed facilities, consideration should be given to even wider crown widths. When objects are mounted on top of the barrier and within eight inches of the face, box beam should be mounted to the top face to limit the vehicle climb and lean. As noted previously, although no testing has been performed to confirm the premise, it is anticipated that the box beam would help to limit roll angles and "lean over" of tall vehicles. The box beam should be tapered on the approach end to reduce the chances of snagging. For a typical taper example, see the details on Standard Sheet M606-33, Transition between Box Beam Guide Rail and Single Slope Half Section Concrete Barrier. Longitudinally, the three feet of taper on the box beam should precede the mounted object by at least ten feet. The box beam should extend at least two feet past the mounted object. If there are any breaks in the plane of the face, the box beam should be bent or cut and welded to follow the contour. Downstream from the five initial bolts shown on the Standard Sheet, additional connecting bolts should be provided on a spacing not to exceed four feet.

Where truck traffic is permitted and it is deemed necessary to mount structures on top of the median barrier, the barrier should be widened and/or raised to reduce the chances that a vehicle impacting the barrier will contact the mounted structure. The preferred minimum separation is 18" between the face of the barrier and the side of the mounted object. Where space is restricted, the barrier height may be set at 54" or greater, a face to object separation of at least 12" used, and a box beam bolted to the upper face (as described above) to reduce vehicle lean. Where more space is available, the width of the barrier should be increased, either locally at the structure, or continuously where a series of structures need to be mounted at regular intervals. Local widening may be achieved by lapping median barrier at the mounting point and filling the space between them to create a wide mounting surface.

10.2.4.7 Glare Screens

While glare screens are not barriers, they can be a useful addition when there is a need to block headlight glare from opposing traffic. Glare screens are vertically mounted panels that may be fastened in series to the tops of concrete median barriers, box beam barriers, and the posts of heavy-post barriers. Several different fastening arrangements and screen designs have been developed.

Glare screens may be warranted on divided highways where there is a significantly increased chance of headlights shining directly into the eyes of drivers. Typical situations would include gradual curves where the inside roadway surface is slightly elevated above the outside roadway surface.

Glare screens should be considered where frontage roads carry traffic opposing the mainline. Glare screens may also serve to minimize "rubbernecking" in construction zones.

It has been the Department's experience that glare screens are a valuable safety device that should be used wherever it is appropriate. However, because of maintenance issues, increased height concrete barriers should be considered as an option to limit glare problems where concrete median barriers are to be placed or poured. Glare screen paddles have been particularly susceptible to snowplow damage when used on guide rail, but have fared better on higher concrete barriers. Even on concrete barriers, however, paddles or panels get broken off. While damage can be conspicuous and the replacement effort can be complicated by access concerns and rusted bolts, in appropriate locations, the benefits justify their use.

10.2.4.8 Uneven Medians

In many instances, medians will divide highways into roadways at different elevations. The resulting uneven median will influence the selection of an appropriate position for a median barrier. In general, the median barrier should be placed on the high side of the median since a decline will extend the required clear zone width while an incline will decrease it. However, if the maximum slopes do not exceed 1:10, a central placement should be used to maximize the clear zone space available to both roadways (note a possible exception in 10.2.4.1 for narrow medians). Barriers should be placed at any median side where the appropriate clear zone width can not be reasonably obtained due to the presence of fixed objects. The various cases are displayed in Figure 10-8, which is adapted from AASHTO's *Roadside Design Guide*. In all cases, it is assumed that a barrier is, in fact, warranted.

Narrow, uneven medians may present special design challenges. The Regional Geotechnical Engineer should be consulted on any applications where a barrier must be placed on a steep slope or where consideration should be given to constructing a wall that will serve both as a retaining wall and as a barrier. In such instances, the bottom of the wall exposed to traffic should have the same shape as one of the currently approved concrete barriers. Note that vertical faces at least 42 inches tall are included in that category. Various types of asymmetrical concrete barriers have been developed and used for narrow, uneven medians.

10.2.4.9 Innovative Median Barriers

The 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) mandated that 2.5% of the median barriers installed each year by any state on Federal-aid projects on the National Highway System (NHS) be of an innovative design type. With the Transportation Equity Act for the 21st Century (TEA21), that mandate was dropped. Consequently, several median barrier systems that were being classified as innovative are now being upgraded to standard items. This process will take some time and may not result in all of the innovative types being made standard. Until the issue is fully resolved, designers should continue to use the following barriers in appropriate situations.

Movable Concrete Barrier
Truck Barrier (Extra High)
Self Restoring Median Barrier
Modified Thrie Beam Barrier

These median barriers are briefly discussed in the following sections. The designer may consult the Design Quality Assurance Bureau for a description of any additional systems that are under consideration. It should be noted that the Movable Concrete Barrier is a proprietary system which requires additional approval as described in HDM Chapter 21, Section 21.3.

A. Single-Slope Barrier (Now considered standard, 10.2.4.6, rather than innovative)

B. Moveable Concrete Barrier

The moveable concrete barrier (MCB) consists of a set of concrete barriers that are pinned together to form an articulated chain. A special transfer and transport vehicle can move along the chain, lifting and transferring the chain laterally for a distance of one lane width or up to 18 ft. The cross-section of the barrier is similar to that of a standard safety-shaped barrier except for its "T"-shaped top. See Figure 10-10. An adjustable conveyor on the transfer vehicle has sets of rollers that engage the undersides of the arms of the "T" to lift the barrier. The rollers can lift the barrier up to 10 inches off the pavement so that it can be moved up on top of a curbed surface. The transfer vehicle itself moves at approximately 5 mph and may be positioned so that it is always in the lee of the barrier rather than being exposed to oncoming traffic.

Refer to Chapter 16 for a discussion of the possible uses of MCBs on construction projects. At permanent installations, the MCB may be used to increase the capacity of a highway without adding additional lanes by making one traffic lane contraflow (opposite direction) in the peak hours. The MCB has been crash tested and the results of the tests are published in *Transportation Research Record 1258* (TRR 1258). In addition to the crash test data in TRR 1258, NYSDOT Research Report 145 - *Movable Concrete Median Barrier: Risk Analysis of Deflection into Opposing Traffic* gives additional information.

The following is a partial list of identified advantages.

- The roll angle of an impacting vehicle is lessened because of the special shape at the top of the barrier.
- The cost of increasing capacity by using this movable barrier may be significantly less than the cost of adding an additional lane or lanes in urban or heavily populated areas.
- The barrier movement from one location to another is relatively fast (up to 5 mph) and may be performed with traffic running adjacent to the barrier.
- After an impact, the barrier may be rapidly realigned by the transfer vehicle without the need to place workers on the ground to manually adjust the barrier.
- The transfer vehicle can readily replace damaged units of the barrier thereby reducing maintenance crew effort and time required to repair the barrier.

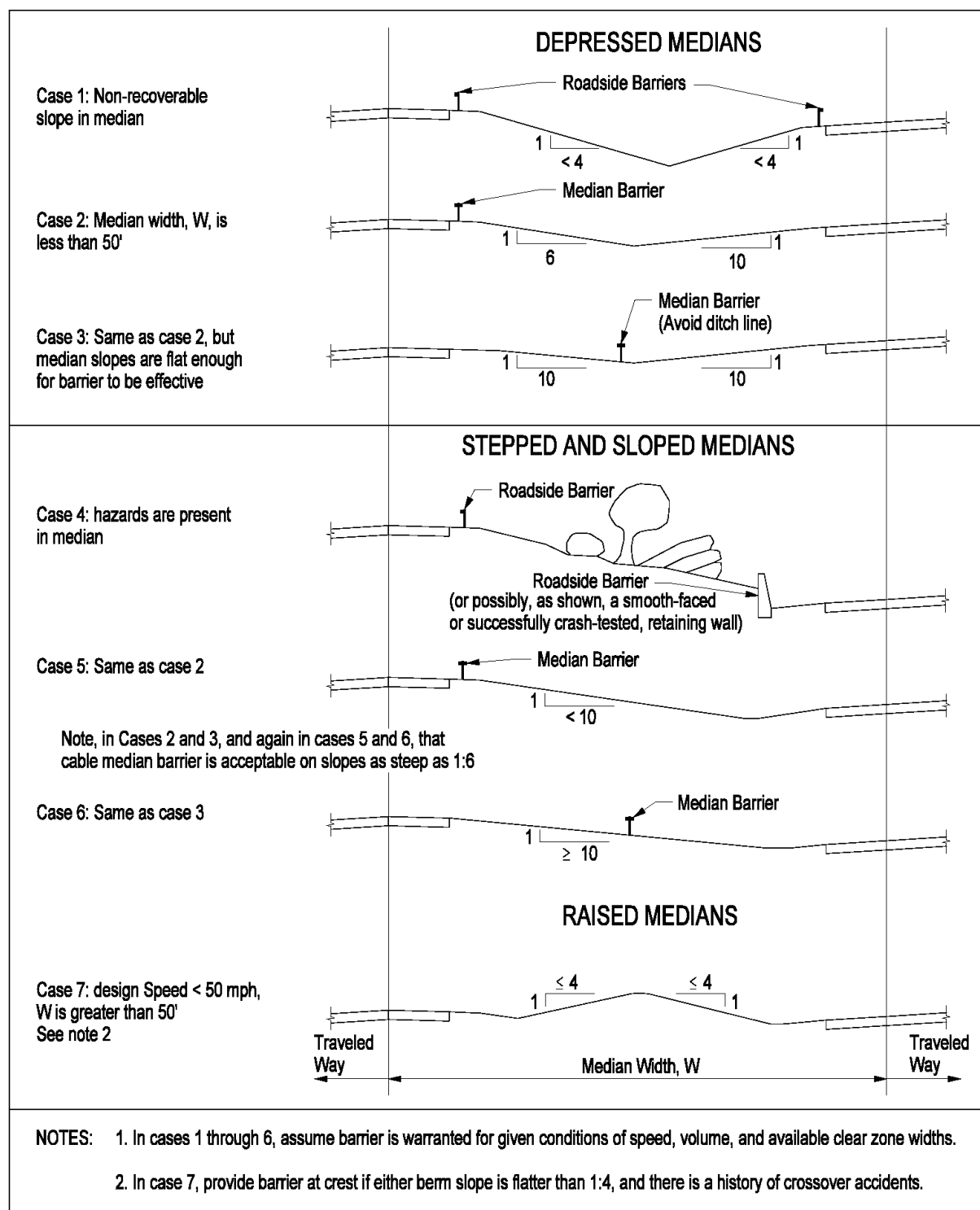
Figure 10-8 Recommended Barrier Locations for Uneven Medians

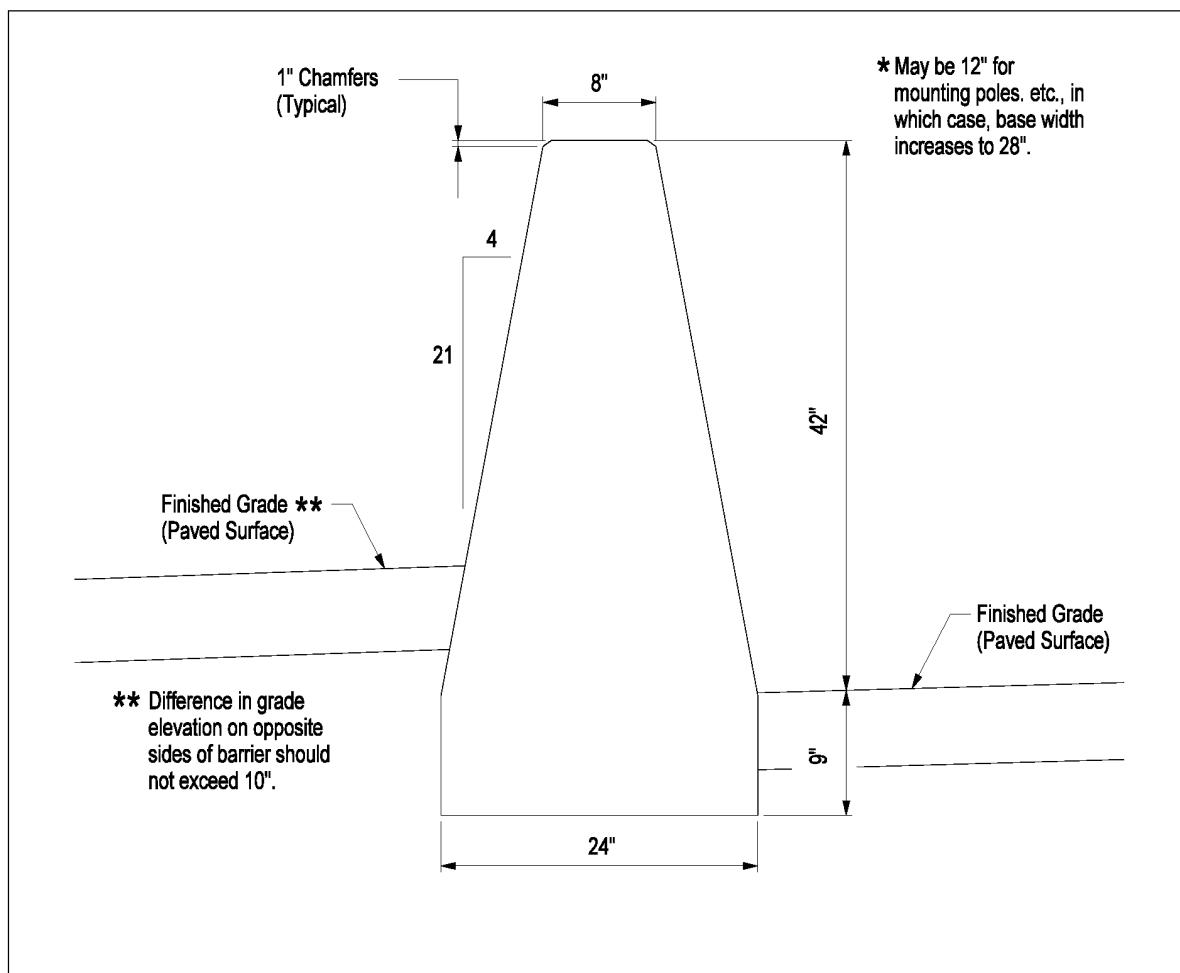
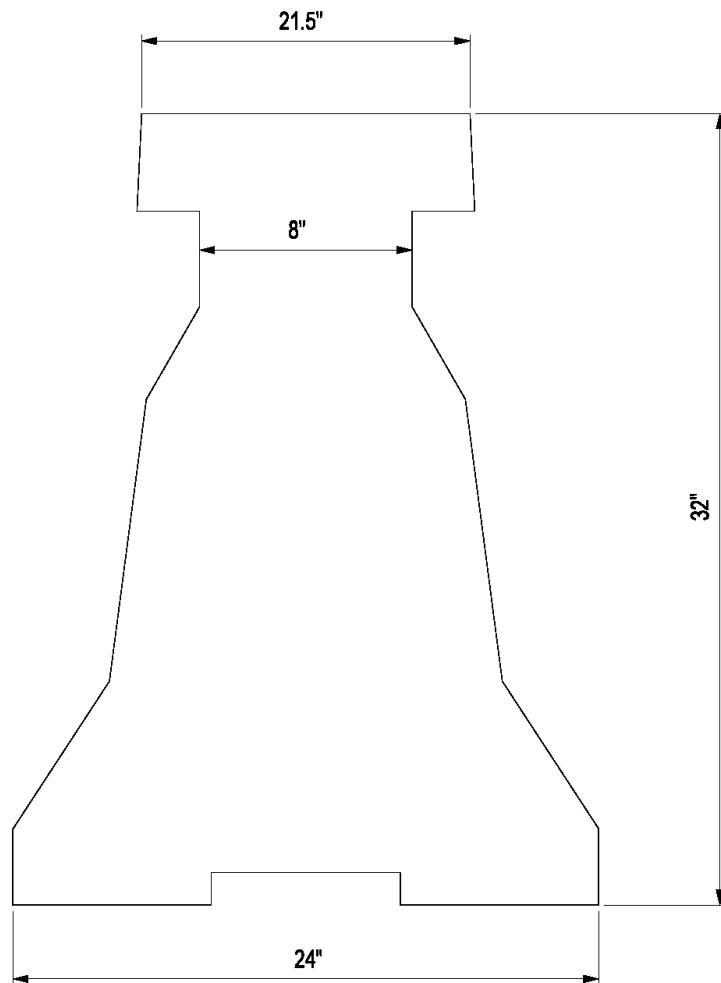
Figure 10-9 Single Slope Concrete Median Barrier

Figure 10-10 Moveable Concrete Barrier

Maximum Dynamic Deflection (Standard Impact) = 40"

Possible **complications** include the following:

- The need for staff to operate the transfer vehicle and a shed or sheds to house it.
- Problematic amounts of snow and ice can be left behind after each move when an MCB is utilized in areas where snow accumulates. Snow and ice accumulations may also prevent movement of the barrier.
- Special compressible hinge arrangements are necessary when the barrier must be used at a location with significant horizontal curvature.
- During research, the barrier translated 4 feet when impacted with a 4400 lb car at 60 mph at a 15° angle.

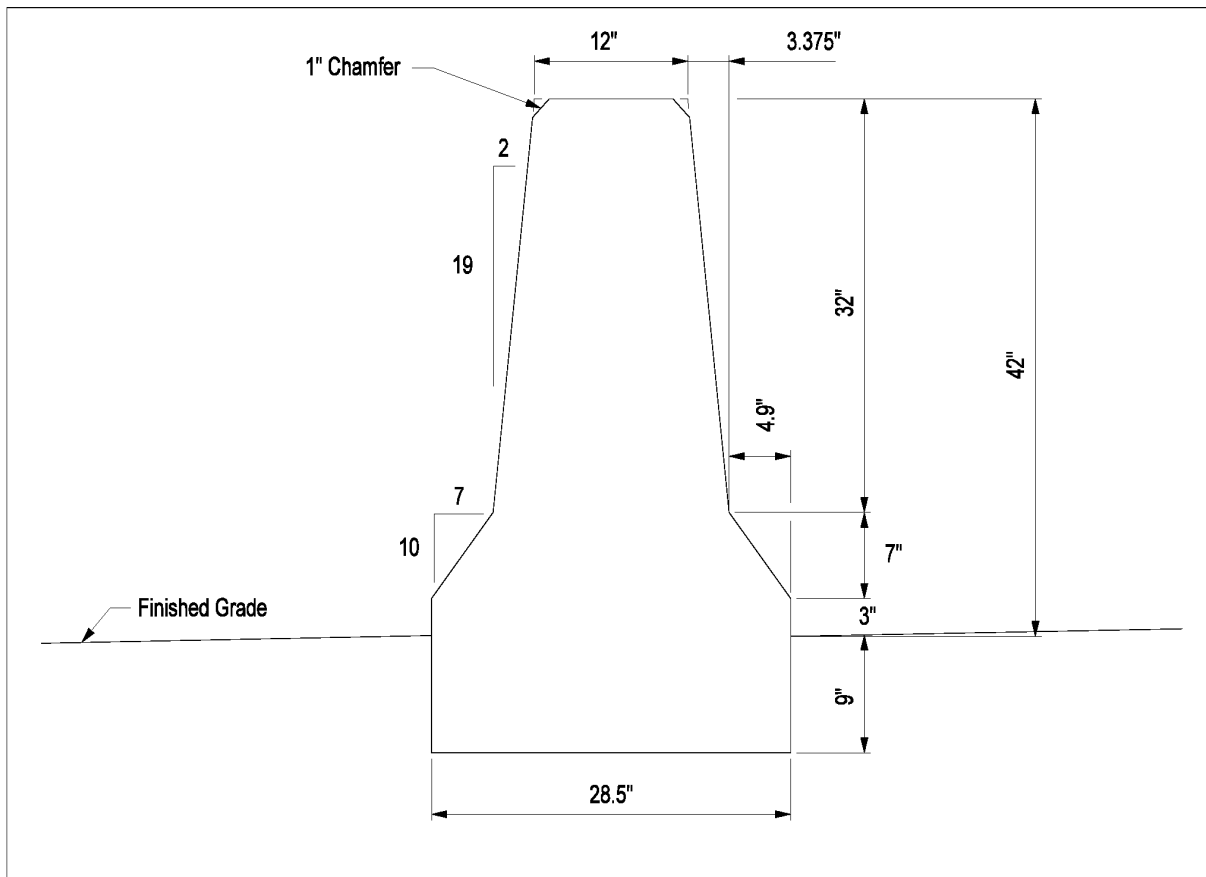
It should be noted that the amount of translation reported in the fourth item is judged to be acceptable for most situations in which an MCB will be used, since conditions will usually limit either speeds or approach angles or both. For this barrier, a small deflection into the opposing traveled way is deemed acceptable. The benefits of using an MCB system should be weighed against the cost of supplying and operating the system, including the cost to house and staff the transfer vehicle. Quantifiable benefits of using the system include reduced delay to the public, the cost of which can be estimated using the Highway User Cost Accounting (HUCA) computer program and available in Lotus or Quattro-Pro formats from the Mobility Management Bureau. Safety and public relations factors are less tangible, but should be considered.

C. Truck Barrier (Extra High)

Truck barrier may be used on divided highways with heavy truck traffic of 3000 or more trucks a day or at locations with a high rate of truck accidents. This concrete median barrier is a "configuration F"-shape barrier that is 42 inches tall with a 12 inch thick stem. (The F shape designated a testing configuration which had a 7" high sloped section near the base as opposed to a 10" high sloped section on the New Jersey shape.) See Figure 10-11. This barrier has been impacted with and contained a 40 ton vehicle in a crash test. The passenger car impacts were within the limits of NCHRP Report 230. The truck barrier has specialized advantages in areas where it can be justified. The following is a list of some of the advantages over the traditional New Jersey barrier.

- The F-shape barrier will impart a lower roll angle to a heavy truck thereby increasing the vehicle's stability after an impact.
- The extra 10 inches of barrier height (above the normal CMB) better contains heavy trucks and helps to keep them from penetrating the line of barrier by rolling over the top of the barrier.
- The extra mass of the truck barrier helps to contain heavy vehicles.
- The extra height reduces headlight glare problems.

A possible disadvantage of truck barrier is that the extra height may reduce the sight distance for operators of lower height vehicles.

Figure 10-11 Truck Barrier (Extra High)**D. Cable Median Barrier**

Cable median barrier is used to prevent crossover accidents on wide traversable medians (over 22 feet). Because of its large deflection distance, cable median barrier must be located well away from traffic, often placing it close to the center of the median. In addition to New York's cable median barrier, several proprietary cable barrier systems are on the market.

Effective in January 2008, NYSDOT radically revised the design of its cable median barrier to conform closely to the recommendations issued with test reports from the Federal Outdoor Impact Laboratory. The barrier has four cables spaced six inches apart vertically, with the lowest cable only 10 inches above grade. Other states that use cable median barrier had experienced problems with vehicles under-riding bottom cables that were more than 16 inches above grade. New York's new cable median barrier is shown on Standard Sheets M606-52, 53, and 54 (metric) and on 606-02 (US Customary). The following list covers the identified advantages of this barrier.

- It uses hardware that is similar to familiar standard cable guide rail hardware.
- The deflection characteristics are the same as the deflection characteristics of cable guide railing.
- In terms of repair costs, the cable median barrier is economical. Even though longer

sections may need to be repaired, the cables are rarely damaged, and the simple design of the system facilitates repairs.

- On projects where aesthetics are a factor, the cable median barrier offers a less obtrusive appearance than other median barriers.
- The cable median barrier may be used with median cross-slopes as steep as 1:6.
- When it comes to capturing large trucks, the cable median barriers are the most effective of the common metal barriers.

Disadvantages are listed below.

- Damage to the barrier, placing it out of service, may be expected even with moderate impacts. However, the number of impacts will be minimized due to the barrier's location near the center of the median.
- Cable barriers are basically "one hit" systems and impacts on damaged barrier may allow penetration. Therefore, cable median barrier will require maintenance after every impact and may require periodic inspections to ascertain if there is any damage from unreported impacts.

E. Self-Restoring Median Barrier or SERB

Though still an approved system, the SERB has not been specified in any recent projects. Maintenance must stock specialized hardware for repair and has had difficulty in getting parts. If the system is proposed for use, it should be discussed with the Maintenance personnel who will be responsible for its maintenance.

F. Modified Thrie-Beam Median Barrier (MB9 Modified)

This barrier is a modification of AASHTO's Thrie-Beam Median Barrier (MB9). This barrier may be used as a median barrier in narrow medians on highways with heavy truck traffic. The system passed NCHRP 350 testing with a steel blockout, but does not appear to offer any significant advantage over the Department's normal median barriers. Furthermore, it is anticipated that its large vertical extent will contribute to snowdrifting problems and be more visually obtrusive. Parties interested in pursuing use of this system may obtain more information from DQAB's Standards and Specifications Section.

10.2.4.10 Median Transitions

Median transitions refer to locations where there are significant geometric, landscape, and safety-related changes to the features separating adjacent streams of traffic. Of specific concern are those situations where traffic will be approaching raised curbed medians containing fixed objects.

As mentioned elsewhere, it is not desirable, from a safety perspective, to introduce features such as vertical faced curb or trees and other fixed objects into medians near medium- or high-speed traffic. However, there will be situations where it is judged appropriate to include trees and other fixed objects in medians, typically on aesthetically sensitive arterials. When a landscaped median with fixed objects will be introduced on a medium- or high-speed highway, a transition should be designed to alert drivers that they are approaching a change in the roadside (median) environment that has safety implications. The design of the physical transition may be complicated by a desire to achieve a simultaneous speed transition, specifically a traffic-calming reduction in speed.

The purpose of this section is to provide guidance on preferred treatments and to describe features that the designer may consider for inclusion in the median transition design. This section is not intended to address how to design the median features on either end of the transition; merely how to design the transition between those conditions. The guidance is intended to apply primarily to medium- to high-speed arterials.

A. Purposes of Median Transitions

The primary purpose of median transitions is to alert drivers to changes in the roadside (median) environment that have safety implications. As a secondary purpose, there may be the simultaneous intent to reduce operating speeds by changing the character of the highway environment. (See also Chapter 25 - Traffic Calming.) Where a traffic calming effect is intended, changes to the median, traveled way, and roadside environment should be coordinated, as practical, to work in harmony towards that end.

B. Locating Median Transitions

At any medium- or high-speed location where a median begins, a transition should be provided along the approach. The transition treatments should, to the extent practical, merge with the median. As discussed later, the transition should begin far enough in advance of the point of concern to provide sufficient advance notification for drivers. This distance will be a function of the approach operating speed and the desired/anticipated speed in the area being transitioned to.

Consideration should be given to the location of the transition with respect to current development and reasonably anticipated (planned) development. For instance, if the transition is intended to contribute to reducing speeds prior to a landscaped median in a village or city, it is desirable that the transition be positioned at the approach to the community so that the speed reduction will be encouraged before the vehicles enter the village or city.

The planned development of the adjoining area should be discussed with municipal planning officials. If it is likely that the desired zone of speed reduction will soon extend further out from the municipality than at present, then a correspondingly longer transition zone should be considered. Consideration should also be given to adjusting the type and the location of the features to facilitate shifting the speed reduction zone in the future.

C. Median Transition Progression

Progression refers to the recommended sequences for the addition of features into a median area. Speed zone and other signing should be provided in accordance with the MUTCD. If the speed limit is being reduced, the signs should precede the features that are intended to encourage the corresponding speed reductions. The following list indicates a typical order in which features could be added to a median.

- Full Barrier (double yellow) lines. (Solid white lines if the lanes to be separated are not in the opposite direction.)
- Split double yellow lines with crosshatching between the pairs. (White lines with chevron pattern if the lanes are in the same direction.)
- Consider the use of Centerline Audible Roadway Delineators (milled-in rumble strips) along, but set back from, the median edge of the approach direction. Also consider the potential for neighborhood objections to the noise that might be generated and balance that against the urgency of warning of the widening of the median area and any accident history that might develop.
- Flush median with color-contrasted and/or textured pavement materials. The Landscape Architecture Bureau should be consulted for information on options.
- Raised paved median with traversable curbs.
- Landscaped median with low plantings (flowers and shrubs, no trees over 4 inches in diameter) and traversable curbs.
- Landscaped median with trees and traversable curbs.
- Landscaped median with trees and curbs as permitted for the operating speed.
- Landscaped medians with pedestrian refuge areas and structural shielding.

A given transition may be between a median that already contains some of the features and a median that contains most of the features listed.

As with the design of the median itself, the design of the transition should be coordinated with and reviewed by the project stakeholders. Of particular importance are the Landscape Architect, Maintenance, Traffic and Safety, and, where takings are involved, Real Estate. Particularly where plantings are involved, maintenance jurisdiction must be resolved.

Additional features that can be considered as means of reducing traffic speeds, or at least alerting drivers to changing conditions, include the following:

- Discourage the use of left-turn lane drops by through traffic by including:
 - appropriate regulatory lane designation signing supplemented by prominent left-turn arrow pavement markings well in advance of the drop,
 - plowable speed humps at the point where turning traffic would slow, and
 - milled-in rumble strips along the dividing line between through and turning traffic lanes, provided they are not near a residential area.
- Use of signs, plantings, and breakaway street hardware along the roadside. Signs

should be included to announce the village or city.

- Where sufficient warranting factors exist, traffic signals may be added at intersecting streets to periodically control traffic.
- Provision of dedicated enforcement sites, if requested by local authorities. The ideal site will include a paved entry point to permit an enforcement vehicle to enter the road with a full view of approaching traffic. Grading and other landscaping features should be provided to prevent easy determination of when the site is not in use.
- Placement of warning signs in advance of periodically active enforcement sites.

D. Lengths of Median Transition Areas

The appropriate lengths for transitions will be a function of their purpose and the speeds involved. If no speed change is involved and the purpose of the transition is merely to make the driver aware that a median will begin soon, then the length of the transition may be shorter than if a speed reduction (traffic calming) is intended. Obviously, the faster traffic is moving, the greater the length that is required for drivers to react to the median features. Similarly, the greater the change in the median conditions, the longer the length of the transition should be. The following transition lengths are recommended minimums. The operating speeds are the free flow (off-peak) 85th percentile operating speeds that are reasonably anticipated after construction of the project (including any adjacent programmed projects). Refer to Chapter 25, Section 25.6.3 for a discussion of reduced operating speeds.

<u>Condition</u>	<u>Recommended Minimum Transition Length</u>
Operating Speed of 35 mph or less. Transition from median turn lane to a treed median with a similar width.	60 feet of curbed area with low plantings.
Consistent Operating Speed of 45 mph. Transition from a median turn lane to a treed median of similar width.	300 feet (150 feet with markings, 150 feet with low plantings.)
Consistent Operating Speed of 45 mph. Transition is from a center line marking to a treed median.	600 feet (300 feet to widen markings to full median width, 150 feet with color contrast or crosshatching, 150 feet with low plantings)
Consistent Operating Speed of 50 mph. Transition is from a median turn lane to a treed median of similar width.	600 feet (300 feet with markings, 300 feet with low plantings.)
Consistent Operating Speed of 50 mph. Transition is from a center line marking to a treed median.	900 feet (300 feet to widen markings to full median width, 300 feet with color contrast or crosshatching, 300 feet with low plantings)
Speed Reduction from Operating Speed of 50 mph to 40 mph. Transition starts from a median turn lane and ends at a treed median with a similar width.	600 feet (300 feet with color contrast or cross-hatching, 150 feet with raised paved median with traversable curbs, 150 feet with low plantings)

Speed Reduction from Operating Speed of 50 mph to 40 mph. Transition is from a center line marking to a treed median.	1050 (450 feet to widen markings to full median width, 150 feet with texture, color contrast, and/or crosshatching, 150 feet with raised paved median with traversable curbs, 300 feet with low plantings)
Speed Reduction from Operating Speed of 55 mph to 40 mph. Transition is from a center line marking to a treed median.	1350 feet (600 feet to widen markings to full median width, 300 feet with texture, color contrast, and/or crosshatching, 150 feet with raised paved median with traversable curbs, 300 feet with low plantings)
Speed Reduction from Operating Speed of 55 mph to 35 mph. Transition is from a center line marking to a treed median.	1500 feet (600 feet to widen markings to full median width, 300 feet with texture, color contrast and/or crosshatching, 300 feet with raised paved median with traversable curbs, 300 feet with low plantings)
Speed Reduction from Operating Speed of 55 mph to 35 mph. Transition is from a grassed median to a treed median.	1200 feet of low plantings. Roadside signs and speed enforcement sites should be considered.

E. Other Median Transition Considerations

Section 10.2.2.7 discusses some options for shielding pedestrians in median refuge islands. While it may be appropriate to use such fixed object measures in medians that contain numerous other fixed objects, bollards or concrete barriers should not be used for pedestrian shielding in the transition areas leading up to those medians.

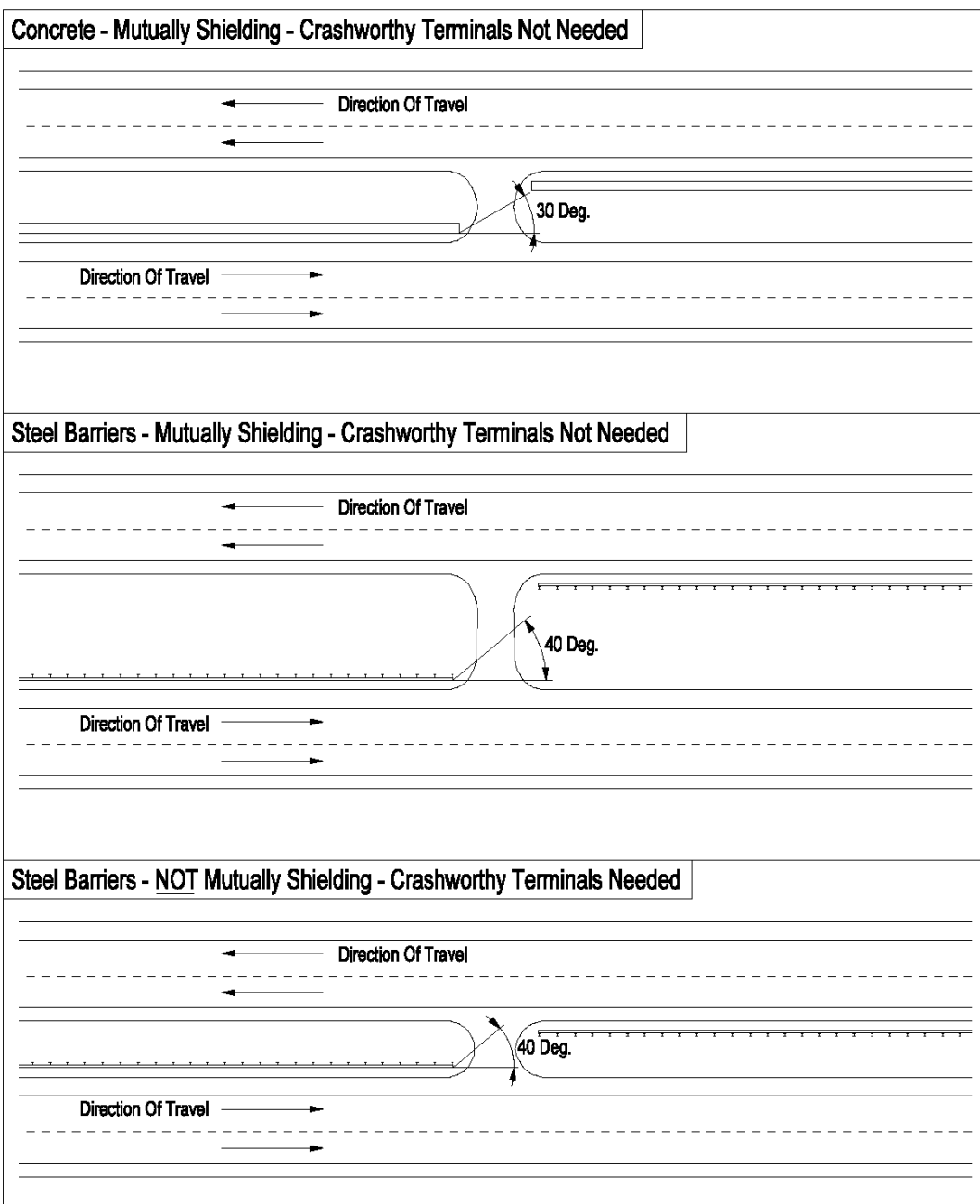
In some treed median settings, typically on high-volume, medium- to high-speed urban arterials, it may be appropriate to provide barriers to shield errant vehicles from the trees. The low profile barrier described in Section 10.2.2.7 has a face configuration that may be used for this purpose. The median could be raised to the height of the barrier and landscaped. The primary points of safety concern would be at leading ends of the barrier, such as the start of the median or where breaks in the median are required for intersections. The recommended leading end treatment is to ramp the barrier up from the pavement level to full height over a length of about 30 feet. In addition to eliminating any vertical faces that could be struck, this ramping would facilitate establishing access for mowing equipment. No nonbreakaway fixed objects (includes trees) should be permitted in the vicinity of the ramp. For operating speeds of 40 mph, there should be a minimum clear area of 60 feet longitudinally from the start of the ramp. For operating speeds of 50 or 55 mph, a clear length of at least 100 feet should be used.

10.2.4.11 Police/Maintenance Crossover Areas

In most instances, these crossover or turn-around areas will constitute a lateral embankment. If the embankment slopes are accessible to vehicles that enter the median, the slopes could act as ramps, launching the vehicles into the air or, if the slope is steep enough, acting as a fixed object which could be impacted. To minimize this possibility, the approach slopes should be flattened to a maximum steepness of 1:6, with a 1:10 or even a 1:12 slope preferred.

Where barriers are used in the medians, their downstream ends should be close to the side of departing traffic. With this positioning, protection of vehicles in the crossover will be maximized. Additionally, the likelihood of errant vehicles passing through the crossover gap will be minimized. Depending on the width of the median, it is possible that the end of one barrier may be able to effectively shield the end of the barrier on the other side. For concrete median barriers, if the angle between the ends of the barrier is 30 degrees or more, the ends may be considered mutually shielding and no crash worthy terminals will be required. For steel barriers, due to the deflections that may occur near the ends, the terminals should only be considered mutually shielding if the angle between them exceeds 40 degrees. At lesser angles, crashworthy terminals should be used.

Figure 10-12 Terminals at Crossover Areas



10.2.5 Barrier Terminals

While a barrier that is impacted on the side will usually redirect a vehicle, the result of running into the end could be much more severe. Some early end sections, or terminals, had exposed rail ends which could penetrate into the passenger compartment. These "spearing" accidents were sometimes fatal. Additional problems occurred with end treatments that were so strong as to be fixed hazards in themselves. Other end treatments tended to lift the vehicle and often produced rollover accidents. Rollovers tend to result in more severe injuries.

The main strategy that NYSDOT traditionally adopted to limit terminal accidents was to move the terminals away from the roadway and ramp the ends down to ground level. This has the effect of limiting terminal impacts to just the vehicles that have traveled a substantial distance off the road and eliminates "spearing" type accidents. Additionally, by aligning the terminal axis away from the road, angled impacts, rather than head-on, become more common, which helps to reduce the number of rollover accidents. The Standard Sheets indicate the amount of flare that should be used for each type of guide rail.

Since the advent of the NCHRP 350 crash testing criteria, there has been a major trend towards the development of proprietary products. (See Section 21.3.4.) In general, newer terminal types may be specified by Regions for research purposes or upon the directions of the Regional Director with the concurrence of the Deputy Chief Engineer, Office of Design. Ideally, selection of a specific system from a set of similarly performing systems should generally be based on the preferences of the maintenance forces in the individual residencies.

However, because specification of specific proprietary products may prove problematic, the Department has strived to develop "optional" items, which are intended to introduce competition by allowing the contractor on a project to choose from among two or more proprietary products that each meet basic needs for the system. In some cases, such as for NCHRP 350-compliant box beam terminals, there are only two such proprietary products available.

Most of the new terminals are sacrificial "gating" type terminals. For high-angle hits near the leading end of the system, these typically allow the impacting vehicle to break the terminal's connections to the ground and push the rail elements aside (gating). For end impacts that are more in line with the guide rail, the terminals tend to function as attenuating structures, cushioning the vehicle's impact by compressing, crushing, bending, folding, breaking, and otherwise mangling their own elements. While this may reduce the peak decelerations and thereby the severity of the crash, the terminals themselves are significantly more expensive than the traditional ones and most are generally prone to greater damage and are more difficult and time-consuming to repair. This last factor is a safety issue due to the repair crew's exposure to, and disruption of, traffic. Moreover, during the period prior to completion of repairs, most of the impacted terminal types will not be capable of providing the desired impact attenuation and, particularly for W-beam, will not provide the anchorage needed by the guide rail. Additionally, as discussed in Section 10.2.2.1 Point Of Need, with flat areas or cut slopes and terminal located relatively close to the shoulder (as most of the new NCHRP 350 terminals are) there is a concern that vehicles may end up traveling close behind the guide rail and risk striking the shielded object. As a result, where clear zones are not wide, the Department's general preference is to avoid using the newer terminals, opting instead to use traditional terminals located well away from traffic, typically close to, at, or beyond the limit of the clear zone or, where back slopes are near, to use a Type 0 terminal for box beam or, for cable and W-beam, to set anchor blocks terminals into the back slopes. These two preferred options will appear regularly throughout the discussion of barrier terminals, so they are explained in detail in the following paragraphs.

Where a barrier terminates near a cut slope, particularly near a normal longitudinal drainage ditch in cut, the barrier should generally be extended to the cut slope, where practical, and terminated with a Type 0 for box beam or anchor blocks if that barrier is corrugated or cable rail. If the end of a guide rail run is carried to a back slope, a sloped terminal section is not required and is generally discouraged. Where a rail system crosses a ditch, attention should be given to the vertical distance from the ditch invert to the rail to reduce the chances of the front of an errant vehicle in the ditch passing under the rail, as that could move the point of impact to the windshield and possibly the passenger compartment. To extend the barrier to the back slope or the limit of the clear zone, the flare rates in Table 10-5 should be used as maximum limits. The horizontal alignments of the rail systems are curved to increase the separation from the road prior to the use of the steep flares. For details, refer to Figures 10-4c and 10-4d. The steep flare rates and wide separations from the traveled way will result in a larger percentage of high-angle impacts. This, combined with the embankment sloping away from the road, will reduce the percentage of impacts that redirect and will increase the need for the guide rail to function as an attenuating structure. For this reason, for back slopes 13 feet or more from the shoulder, the heavy-post blocked-out corrugated rail should be softened by transitioning to a weak-post before going to the steep flare. (Standard Sheet M606-18 covers Transitions between Weak-Post Corrugated beam and Heavy-Post Blocked-Out Corrugated Beam Guide Rail and Median Barrier.) Similarly, box beams are only anchored with weak-posts rather than being fastened to anchor blocks. Type I ends should not be included when “burying” box beam ends. When it is intended that a vehicle should gate through a flared back box beam end, the end of the terminal should be able to release from its anchorage.

The approved end treatments are grouped by barrier type and described in the following sections along with discussion of appropriate conditions for use.

Table 10-5 Recommended Barrier Flare Rate Limits for Permanent Installations

System	Anticipated Operating Speed (mph)	Flare Rates (See Fig 10-4c and 4d)
Cable	All	1:3
Weak-post W-beam	All	1:3
Box Beam	All	1:2.73
Heavy-post W-beam	All	1:8 (or transition to weak post with 1:3 flare rate)
Concrete	70	1:20
Concrete	60	1:18
Concrete	55	1:16
Concrete	50	1:14
Concrete	45	1:12.5
Concrete	40	1:11
Concrete	35	1:9.5
Concrete	30	1:8

The second preferred alternative to using a proprietary NCHRP 350 compliant terminal is to use a conventional terminal carried “close to, at, or beyond” the limit of the clear zone. The logic behind this preference is as follows. The main objection to use of turned-down end sections

was that they are reputed to increase the likelihood that vehicles will destabilize when they ramp up them and will then have a rollover. If a terminal is placed well away from the road, near the limit of the clear zone and, therefore, probably close to a tree or other fixed object, it should make little difference that the vehicle is beginning to destabilize, as it will strike the fixed object before it has a chance to roll over. The fact that the vehicle will not encounter the turned-down terminal until near the limit of the clear zone also means that the driver will have already had nearly the full width of the clear zone, or more, in which to brake and attempt to redirect back towards the road. The interpretation of the terms “close to” or “near” the limit of the clear zone is open to judgment for special conditions. As general guidance, it may be interpreted as 5 feet, but the preference should be to place it farther away whenever reasonable. Conditions that might require terminating “near” as opposed to “beyond” the limit of the clear zone would include the need to provide for mowing equipment access to the area behind the rail and the presence of buried utilities at the limit of the clear zone.

By the same token, the clear zone limit should not be used as an excuse to limit a terminal's offset, if the terminal could readily be set further back. For instance, if the clear zone width for a highway segment had to be set at a low figure of say 13 feet, but, at the station of the terminal, the right of way locally included 26 feet of cleared area and there was not a requirement for mower access behind the rail, the preferred terminal setback should be closer to the 26 foot width, rather than at the limit of the 13 foot clear zone.

In general, it will make more sense to use conventional terminals, set back near, at, or beyond the clear zone, on the lower-volume, secondary roads that have narrow clear zones, than it will to extend guide rail long distances across broad clear zones, such as those typically found on interstates and freeways. Where a highway has broad, high quality clear zones, professional judgment should be used to decide whether it is preferable to use an NCHRP 350 compliant terminal close to the shoulder or to carry the guide rail across a wide clear zone area before terminating it with a conventional terminal. In these situations, the choice between leaving fairly long safe runout areas or placing a barrier that blocks access to potentially hazardous features must be considered.

10.2.5.1 Cable Anchorage

The end of a cable guide rail must be adequately anchored to maintain the tension in the system.

The vast majority of cable systems presently in service have a mildly outmoded traditional anchorage system which uses a single block of concrete with a plan area of approximately 1 yd² either cast or set into a 3'-6" deep hole in the ground. An anchor angle was bolted to the concrete as a bracket with a “U” slot for each cable end assembly. The open slot design permits the cables to release when a snared vehicle runs to the end of the system. A light “keeper rod” prevents the ends from “walking” out prematurely. The first post was set 18 feet away from the anchor block to ensure that any ramping effects were very gentle. Over time, two potential problems with the design were realized.

First, repeated heavy impacts into the run gradually tilted some blocks towards the run. The tilting was greatest if the impact happened during Spring thaws when the soil surrounding the block was saturated and had not yet settled from the frost heave. A few runs on high-speed, high-volume highways received so many hard impacts that the anchor blocks tilted enough that the cable ends could slip up and out of the anchor angles on a subsequent impact. Resetting

those anchor blocks to vertical has required a significantly larger effort than normal guide rail repair tasks, adding to cable's standing as a system requiring significant maintenance attention.

Second, vehicles that deflect cable could be well behind the line of the run when they arrive at the end anchor. In that position, they would be pulling the cable sideways relative to the block, and might have difficulty moving the cable end vertically up and out of the anchor slots. If the ends did not release, larger vehicles could be expected to snap the cable end bolts at the slots, but smaller vehicles might be brought to an abrupt stop.

Because of these concerns, the anchorage was redesigned and the new guidance issued in 1996. To limit block movements caused by impacts to the run, the newer design has a much larger concrete anchor, with a plan area of nearly 2 yd².

The anchor angle on the anchor block was modified to have "V" slots to increase the likelihood of the ends releasing when a snared errant vehicle nears the end of the run and is pulling the cables sideways. To increase the likelihood that such a vehicle will be directed over the release slots, the last post in the run is now mounted directly to the anchor block, but is isolated from rigid embedment by the use of a slip base. The post also serves to apply a vertical component to the tension if a vehicle is pulling the cable laterally when it reaches the end of the run. Another reason for modifying the block was to mount the first post in a manner that would prevent it from being gradually pulled over in the soil. The latest anchorage details are shown on the US Customary Standard Sheets for [606-01](#).

To reduce the potential for snagging the undercarriages of impacting vehicles, the top of the block should not protrude more than 4 inches above grade. A five foot chord with end points on either side of the anchor block is used to define grade. As of this writing, the anchor block comes with either a right-handed or left-handed cross slope to facilitate matching to the ground surface. The right-hand block should be ordered for the situation where the anchor unit is placed at the approach end and, with respect to the oncoming motorist, the ground slopes down to the right. Either option is paid for under the same pay item. (Strong consideration is being given to returning to a single-block system where the block is set to place its top flush with the ground surface.) The initial setting may need to be in a slight depression if significant surface wash may be expected before turf is established.

Note that cable terminals passed the NCHRP350 criteria and may therefore be used within clear zones. Still, there will be situations where it is desirable to run the cable terminal close to the limit of the clear zone to try to prevent errant vehicles from reaching the area behind the rail. Where cable is run through a curve and carried on a flare to the outside of the clear zone or to anchorage in a back slope, it is important that extra posts be used through the curve to prevent the tension in the cable from pulling the posts over. Refer to Figure 10-4d. To provide cable guide rail anchorage in a soil back slope, the standard anchor block arrangement should usually be used, but without a post set in the block, and with the slope across the top selected to match the surface of the back slope as closely as practical. The block-mounted post is not considered necessary in this instance as the anchorage will be set back from traffic and out of the line of the run. The cross slope of the block will need to be towards the road, rather than away from it. Special anchorage arrangements may need to be custom designed for rock back slopes and some problem slopes.

Where existing terminals are not likely to be subjected to these "wrong way hits", existing concrete anchorage units may remain in place. A "wrong way hit" occurs when a vehicle strikes the guide rail at a point between the anchorages and then, while still engaged with the cable,

encounters the anchorage.

10.2.5.2 Terminals for W-Beam Guide Rail

As with cable guide rail, terminals for both weak-post and heavy-post W-beam guide rail must provide anchorage for these guide rails to develop their full capability to redirect errant vehicles. This means that the ends must either be bolted to a competent structure or an anchor block set into the ground. The traditional anchorage units shown on the Standard Sheets for corrugated rail are embedded concrete blocks to which several lengths of corrugated rail are bolted. The rail is mounted at heights varying from near ground level to full height for the system. These units very effectively anchor the guide rail and, because they bring the rail element down to grade, make spearing very unlikely. With heavy-post systems, special triangular mounting brackets make snagging unlikely. Unfortunately, these ramped-down terminals have the potential to contribute to errant vehicles turning over. Because of this, these end terminals are not approved as Test Level II (40 mph) or Test Level III (60 mph) devices. This means that these devices should not be installed within the clear zone close to medium- or high-speed traffic. However, initiation of rollover becomes only a minor concern for a vehicle that has already crossed most or all of the clear zone, so these devices may be installed with the center of the anchor block within two feet of, at, or beyond the limit of the clear zone.

W-beam terminal types can be divided between those for weak-post and those for heavy-post. There are a limited number of options for the weak-post, since the rail system itself initially failed crash testing at Test Level 3, the high-speed criteria. The heavy-post blocked-out system, on the other hand, passed the NCHRP 350 testing. Therefore, private industry developed a variety of HPBO terminal choices that comply with the FHWA mandate that terminals meet NCHRP 350 Level 2 and Level 3 test criteria. The Department approved a number of those new terminals. These new end terminals may be used with strong (heavy)-post blocked-out or weak-post corrugated rail systems. However, if used with the weak-post system, it is generally necessary to have a transition length of approximately 50 feet of the heavy-post blocked-out guide rail to connect to the terminal. If a terminal has been successfully crash tested with a direct connection to weak post W-beam, this 50 foot length of HPBO is not required. As of this writing, the X-Tension terminal is the only proprietary terminal that does not require the 50 feet of HPBO to connect to weak post W-beam.

Most of these new systems absorb impact energy through permanent deformation/destruction of some of their elements. Consequently, these systems tend to be easily damaged and require extensive repairs when solidly impacted and lesser repairs with minor impacts. They have higher initial and maintenance costs than the Department's traditional ramped-down terminals, which can generally still function normally and provide system anchorage after an initial hit. In view of that, and the number of property-damage-only brush hits and generally lower speeds in urban areas, an exception was discussed with and agreed to by the FHWA to permit the use of sloped terminals, such as those shown on Standard Sheet series [M 606-9R2](#) and [M 606-10R2](#) (metric) and [606-07](#) (US Customary), where design speeds on urban highways will be predominantly 40 mph or less. Part of the rationale is that it is preferable to have a fully functional "second best" sloped terminal than an NCHRP 350 terminal that may be damaged and nonfunctional.

In brief, any of the newly approved terminals may be used in low-speed locations (40 mph or less in urban areas, 30 mph or less in rural areas), but, because of cost and repair issues, use of the traditional ramped end sections is preferred where permitted. At higher speeds, the

traditional ramped end sections are generally not to be used **well within** clear zones except where site restrictions prevent satisfactory installation of the new alternative terminals or where the location will not be subject to impact by approaching traffic. Stated another way, where an HPBO terminal is required and (1) design speeds are 35 mph or greater in rural areas or 50 mph or greater in urban areas, (2) the terminal can not be located close to the limit of the clear zone, (3) there are no geometric conditions that would preclude their use, and (4) they are not shielded from approaching traffic, one of the new NCHRP 350 compliant terminals should be used.

NCHRP 350 compliant terminals may be further classified into those “parallel types” that can be installed either parallel to the roadway or with a flare, and those “shedding types” that can only be installed with the terminal flared away from the road. The parallel types are capable of “capturing” a vehicle that impacts the end in a roughly parallel direction and bringing it to a controlled stop. The shedding types are designed to pass an end-impacting vehicle behind the rail system. They must be installed with the ends flared back from the road to avoid in-line hits and facilitate “shedding” vehicles away from the line of the guide rail. Flexibility of installation options favors the former type, which can be installed either parallel or flared. For maintenance purposes, though, the free end of “parallel type” terminals should be offset from the traveled way a minimum of approximately 10 feet, unless conditions require a more parallel alignment. To avoid the risk of an inadvertent installation of a “shedding type” terminal where a “parallel type” is needed, the Department has only approved the use of the parallel-type NCHRP350-compliant terminals.

However, given an unrestricted choice between using (1) an NCHRP 350 or MASH proprietary terminal close to the road or (2) a traditional terminal flared back and either anchored in a back slope, or extended close to, at, or beyond the limit of the clear zone, the latter choice is recommended.

When anchoring in a back slope, the traditional means of attaching the rail to the top of the block will generally prove awkward due to the different direction of approach and the different slope of the ground surface. The Department has not yet standardized a detail for this connection, but one Regional method has been used with success. This method utilizes the traditional anchor block, but mounts a heavy T-section, cut from a WT380 x 128.5, on the top of the block. Holes are provided in the upright leg to allow bolting to the holes in the valley of the W-beam rail. The block is rotated about its vertical axis to align the T to the approach direction of the guide rail. In this manner, the guide rail may be maintained in a vertical plane as it passes into the back slope. While the above system, Special Specification 08606.3402 M, is approved for general use, Regions are not discouraged from attempting alternate anchorage arrangements until a standard detail is accepted. Designers interested in anchorage to rock slopes are referred to Special Specification 08606.3401 M as an example.

A. Weak-Post Turned-Down End Sections

Turned-down end sections may be used on weak-post W-beam guide rail at approach ends inside the clear zone wherever their use is acceptable, typically where the design speed is 40 mph or less in urban areas, or 30 mph in rural areas. As of this writing, the only NCHRP 350 approved end section which may be directly attached to weak-post W-beam is the X-Tension. Therefore, if termination well within the clear zone is necessary on higher speed highways, use one of the other approved NCHRP 350 compliant HPBO end terminals will require a 50 foot transition length of heavy-post blocked-out guide rail between the terminal

and the weak post run.

While the minimum offset for the conventional anchor units is shown on the standard sheets, preference should often be given to extending the anchorage to a back slope or to near or beyond the limit of the clear zone. As detailed in Figure 10-4e, a weak-post, turned-down terminal is one of the preferred methods of terminating a run of HPBO, provided a transition has been made from HPBO to weak-post, away from the shoulder, and the terminal is located close to, at or beyond the clear zone.

The concrete anchor block for the weak-post W-beam guide rail is essentially the same as the formerly approved unit block for the cable system. A line of eight bolts is embedded in the block. Ten holes are provided in the valley of the W-beam to permit adjustment. The first post is spaced approximately 25 ft downstream from the front of the anchor block. The rail is mounted approximately 6 inches lower than normal. The second post is 12.5 ft from the first with the rail mounted 3 inches lower than normal. The anchor position for the typical roadside guide rail approach and terminal section is 4 ft farther from the traveled way than the line of the guide rail. Additional flaring back should be done where practical.

The standard end treatment for openings such as driveways is more abrupt. The intent is to minimize the length of the zone in which the guide rail is not fully functional. The designer should similarly design openings to be as narrow as possible.

For weak-post corrugated median barrier terminals (acceptable for design speeds of 40 mph or less in urban areas and 30 mph or less in rural areas), the anchorage is in line with the barrier. The W-beam end from the terminal side of the barrier is twisted and bolted to nest under the W-beam from the opposite side of the post at a point halfway between the anchorage and the first post. The purpose of this arrangement is to prevent the abrupt vertical acceleration of a vehicle which would be conducive to rollover. The details of the weak-post corrugated beam end treatments are shown on the US Customary [606-08](#) Standard Sheets.

B. Heavy-Post Turned-Down End Sections

The heavy-post blocked-out (HPBO) corrugated beam guide rail end terminals are considered only NCHRP 350 Test Level I (30 mph) devices. Therefore the turned-down terminal is no longer approved for installation within the clear zone of medium- and high-speed highways with design speeds above 30 mph in rural areas and, because of an exception, 40 mph in urban areas. If HPBO guide rail must be terminated within the clear zone, the terminal must (with the exceptions noted herein) be an approved NCHRP 350 compliant terminal (termed 'gating' terminals as a class), qualified at Test Level II or III, as appropriate.

In lieu of these "gating" terminals, the rail may be terminated by using a turned down end placed close to, at, or beyond the limit of the clear zone. To carry the rail across the clear zone, the approach end treatment must either be provided with a gradual flare (due to the unyielding nature of the heavy-post and the consequences of a high-angle impact), or a transition must be made to a weak-post system so that a more abrupt flare can be used, as shown in Figure 10-4e. (As covered in *Research Report 83 - Crash Tests of Sharply Curved Light-Post Guidemile*, the Department conducted research in 1980 which indicated that high-angle impacts into weak-post guide rail systems had acceptable deceleration rates, since

the weak-post rail system essentially functioned as an attenuating structure.) In some restricted situations, use of an NCHRP 350 compliant end terminal may not be appropriate and use of a turned down terminal on the end of a run with significantly more abrupt flare may be required. In general, it is preferable to keep vehicles close to the road and accept the risk of high-angle impacts on HPBO rather than use a gating system that would permit vehicles to strike rigid fixed objects or plunge into bodies of water behind the rail.

C. Parallel Type Gating End Terminals

The ET 2000+, the Sequential Kinking Terminal (SKT SP), and the X-Tension are proprietary parallel type, or controlled stopping, gating end terminals designed to be used on leading ends of runs of heavy-post corrugated beam guide rail. The systems may be installed on either a parallel or flared alignment.

The key component of the ET-2000 and SKT end terminals is a long "shoe" that fits over, and in line with, the end of the rail. When impacted, the shoe is driven along the rail, separating several weak-posts from the rail. As the shoe passes along the rail, the ET 2000+ forces the rail through an opening that flattens the corrugations. The flattened rail is then bent 180° to be extruded back out ahead of the shoe. The SKT 350 resembles the ET-2000 and functions in a similar fashion, except it forms a series of "kinks" in the rail instead of flattening the rail. With either product, the kinetic energy of an impacting vehicle is primarily absorbed in the flattening and bending or kinking of the rail.

The "+" on the ET 2000+ denotes that the impact head was modified to be narrower and deeper than the original square design. This modification should reduce the likelihood of the head being snagged by snowplow blades and should improve the outcomes in accidents involving lateral skids, since having the bottom of the head at a lower height should be better at engaging the frames of vehicles, rather than punching through door elements and into passenger compartments. For these reasons, the "+" configuration should be the preferred selection for Department projects. Unless specifically indicated otherwise, references to the ET 2000 should be taken to mean the "+" configured extruder head.

The systems are manufactured to be supported on either timber or steel breakaway posts. However, the wooden variants have occasionally proven to be a maintenance problem and are no longer accepted by NYSDOT. The steel posts from Trinity, manufacturer of the ET 2000, have an upper and lower (base) post with splice plates lap-welded as vertical extensions on each of the flanges of the base post. Two bolts pass through these splice plates and the flanges of the upper posts. The larger is a ¾ inch bolt which acts as a pivot point. The smaller is a 3/8 inch bolt which acts as a shear bolt when the ET 2000 is impacted head on. The result of this pair of bolts is a hinged breakaway post that is very yielding when bent around the web, but retains strength when the face of the rail is struck. The concept is similar for the SKT, except that the hinge and shear bolts are replaced by a single 1 ¼ inch plug weld through each of the splice plates to the flange of the upper post.

During tests with a 2000 kg automobile impacting at approximately 60 mph, 52 ft of rail passed through the extruder. For this reason, shielded objects should not be permitted in the zone which is within 13 ft behind the rail and within 75 ft of a leading end terminal for design speeds of 60 mph or greater. This length may be reduced to 60 ft for design speeds of 50 or 55 mph, and to 45 ft for design speeds of 45 mph or less.

For shielded objects farther back from the rail, the Point of Redirection for the rail may be

taken as the third post, which is roughly 14 feet downstream from the lead end of the terminal. The Standard Sheets indicate different flare options and the special grading requirements for the systems. For planning purposes, the installed cost may be estimated at \$3000 in the upstate regions and \$4000 downstate. There is an optional pay item which permits the ET 2000, the SKT SP, and the X-Tension to be bid competitively. The pay item series is [606.3402](#).

D. Shedding Type Gating End Terminals

There are a number of proprietary terminals that have passed NCHRP350 crash testing as TL 3 devices but require installation on a flare. These include the Modified Eccentric Loading end Terminal (MELT), the Slotted Rail Terminal (SRT 350), the FLared Energy Absorbing Terminal (FLEAT 350), and the REDirective Gating ENd Terminal (REGENT). Because of the risk that shedding terminals might accidentally be installed in a parallel configuration (where they presumably would not function satisfactorily), the Department has not approved, or has disapproved, their use.

10.2.5.3 Terminals for Heavy-Post Blocked-Out W-beam Median Barrier

As with other W-beam configurations, the terminals must provide anchorage so that the barrier can develop tension when struck by an errant vehicle. In most high- and moderate-speed situations, recent FHWA guidelines essentially preclude reliance on vertical redirection through ramping over the terminal. Terminal arrangements are now supposed to either redirect vehicles laterally or provide crash attenuation. Note that curbs or other vertical separations are not to be placed in proximity to any attenuating systems. Existing mountable or traversable curbs 4 inches or less in height may be retained if required for drainage.

A. Sand Barrel Array Shielding of Conventional Turned-Down Ends

Where median widths are sufficiently wide, it is permissible and economically preferable to use a conventional turned-down end and provide a sand barrel array to shield the approach to it. The layout for the conventional heavy-post median barrier turned-down terminal carries both guide rails to an anchor block. To accommodate the two corrugated beams, the width of the block is increased to approximately 3.5 ft. Refer to the Standard Sheets. The design is intended to provide a gentle ramping effect for direct end impacts. Because the heavy-post median barrier is relatively unyielding and vertical redirection is undesirable due to the possibility of rollover accidents, approach terminals within the clear zone of rural facilities with design speeds greater than 30 mph or urban facilities with design speeds over 40 mph should be shielded with appropriate impact attenuators, one of which is the sand barrel array, or they should be fitted with crash-worthy end terminals. These sand barrel array attenuators should be placed so as to minimize the likelihood of wrong way hits by opposite direction traffic. Where sand barrel arrays are used, they should be capable of decelerating a 2000 kg vehicle to under 22 fps before the end section is contacted. Where space is available in the medians, approach ends should be set back from traffic. For further guidance on design of sand barrel arrays, refer to Section 10.2.6.2.

B. Brakemaster 350 Median Barrier Redirective Gating End Terminal

This end terminal may be used to protect the ends of HPBO corrugated median barriers and, with the appropriate transition, to connect to concrete walls and barriers. The Brakemaster can not be attached directly to concrete barriers or to thrie beam barriers. The Brakemaster consists primarily of steel components, most notably corrugated beams that telescope and flare on impact. Two brakes are attached near the anchored end of a wire rope that extends for the length of the terminal. Energy is absorbed through friction when the brakes are forced to slide along the wire rope. The assemblies typically require extensive repair after a hit. The Brakemaster 350 may be used for speeds up to 70 mph. There is only one model and it has 5 bays. This single model can be assembled so as to protect unidirectional or bidirectional traffic. The terminal conforms to the general behavior mentioned in Section 10.2.2.1, in that it typically will redirect vehicles that impact the third diaphragm or further downstream. The exposed length of the system from the nose to connection to the HPBO is 32.5 ft. An additional 6'-3" is required in front of the nose for the foundation tube anchor assembly that goes below grade. The effective length of the transition piece connecting the Brakemaster to the thrie beam barrier is 6'-3". This piece is the standard corrugated/thrie beam transition piece. The effective length of the thrie beam transition used to connect the Brakemaster to concrete barrier is 16'-8", measured from the nose of the concrete barrier to the Brakemaster. This includes the transition piece and nested 12 gage thrie beam panels mounted onto blocked-out timber posts. The pay item for the Brakemaster includes the required transitions. The last 32 ft of median barrier and the Brakemaster 350 centerlines must be lined up to within 1°. The foundation must be firm soil, compacted subbase, asphalt, or concrete. The area under the unit needs to be flat and cross slopes steeper than 8% are to be corrected by leveling or grading. The width of the unit is 25 inches. However, since elements are likely to flare out 4 ft on both sides when the nose is impacted, installation should normally be limited to locations where the distance between the two traveled way edges is 10.5 ft or greater. Typically, extensive repairs and parts replacements are needed after an impact. This factor should be taken into consideration when considering installation at high-frequency impact sites.

The Brakemaster 350 was specified as Item 15606.31 M Median Barrier Redirective Gating End Terminal. The manufacturer is Energy Absorption Systems, Chicago, Illinois (312) 467-6750. The Brakemaster 350 is vended in New York State by Transpo Industries, Inc., New Rochelle, New York, (914) 636-1000, info@transpo.com. For planning purposes, its material cost may be estimated as \$4000 with an installation cost of \$2000. Add \$500 for the corrugated/thrie beam transition pieces and \$1500 for the transition from the Brakemaster to concrete barriers.

C. REACT 350 for Heavy-Post Blocked-Out W-beam Median Barriers

The Reusable Energy Absorbing Crash Terminal was developed to meet NCHRP 350 criteria. It consists of a line of open plastic cylinders, a pair of cables on each side, a fabricated backup structure, and transition between the backup structure and the protected barrier or wall. The tough plastic has "shape memory" and can be reused. This terminal is intended for narrow hazards. In addition to attachment to HPBO median barriers, it may be used for a variety of other crash attenuation requirements. A more complete description is provided in Section 10.2.6.4, which is within the section on Impact Attenuators.

D. QuadGuard

The QuadGuard is a proprietary crash attenuation system. It was designed as the NCHRP 350 compliant replacement for the GREAT (GuardRail Energy Absorbing Terminal). Like the REACT 350, the QuadGuard may be used for a variety of other crash attenuation requirements. A more complete description is provided in Section 10.2.6.3, which is within the section on Impact Attenuators.

E. Crash Cushion Attenuating Terminal (CAT 350)

The CAT 350 is a Test Level 3 device that has been approved by the Department. An Engineering Instruction on the terminal, EI 01-009 *Crash-Cushion Attenuating Terminal 350 (CAT 350)*, was issued. The CAT 350 (CAT) is intended for HPBO corrugated beam median barriers, but, with a transition (M606-42, M606-43, M606-44, and M606-45), may also be attached to concrete barriers or narrow bridge piers. The CAT has six short breakaway wooden posts and a total length of 43'-9". The CAT is installed in a straight line and requires no concrete footings or foundations, but does need a reasonably flat area under the unit. Cross slopes greater than 8% are to be avoided.

If required for drainage, existing mountable curbs less than 4 inches high may be retained, but all others should be removed, and new ones not installed, in an area between the tail of the unit and a point 50 ft in advance of the nose of the unit.

The CAT (Item 606.46000015) units are anticipated to cost around \$6000 installed upstate, slightly more downstate.

10.2.5.4 Box Beam End Sections

There were four types of end sections for box beam guide rail, designated as Types 0, I, II, and III. The Type II is no longer acceptable for new installations. A new terminal, the Type IIA, has been introduced. For box beam median barrier, there are three terminal options, designated A, B, and C.

A particular concern that needs to be addressed with flared-back box beam terminals, such as the Types 0, I, and IIA, is the height of the rail after it crosses the shoulder break. If the height becomes too great, the front of a small vehicle may be able to get under the rail, allowing the rail to come up over the hood and into the windshield. That occurrence is referred to as "clotheslining" and it could lead to severe accidents, even at relatively low speeds. Four strategies should be considered to minimize this risk.

- Avoid locating the flares where the fore slope drops steeply.
- Adjust the profile of the rail to follow down the slope while maintaining the approximate normal height above grade.
- Adjust local grading so that vehicles will follow the slope smoothly and the rail will be at the appropriate height above the regraded surface.
- For the Type IIA, locate the flare immediately following a driveway so that an errant vehicle crossing the driveway entrance will strike the terminal before it has an opportunity to drop down into the ditch and go under the rail.

A. Type 0 Terminal

The zero designation is appropriate as there are essentially no special elements involved. The terminal consists of running the rail until it touches the back slope and then driving a pair of posts at that point as anchorage. The terminal is also referred to as the “buried in back slope” terminal, but no rail is actually buried. Details of the terminal are shown on US Customary Standard Sheet [606-04](#), Sheet 2 of 2. The plan alignment for Type 0 terminals should be similar to that for a Type I. Use of the Type 0 terminal is acceptable for all speeds, provided a back slope is in reasonably close proximity. A primary concern arises where the rail must cross a ditch. If there is too much space between the rail and the invert of the ditch, a vehicle may be able to get below the rail, allowing the rail to strike the vehicle in the windshield. Where the rail must cross a ditch before reaching the back slope, the ditch cross section should be field checked. The ditch should not be so deep as to carry a car under the guide rail. Deep inverts may be raised with appropriately sized stone filling so that trapped cars will contact the rail at or below normal height.

The piece of rail that makes contact with the back slope is likely to need to have its length shortened. If it is too long, the contact will tend to be too far up the slope and the rail may be too high on the fore slope. Contractors should bid the cost of Type 0 terminals to include any length adjustments, hole drilling, and post relocations necessary to allow the rail to cross the fore slope with a nominal rail height of 27” and without exceeding the maximum rail height of 30 inches. Minor local filling and grading may be needed in order to prevent excessive rail heights.

B. Type I Box Beam End Assembly

In the Type I end assembly, the rail is carried at its normal height until the 7’-4” long Box Beam End Piece is reached. The box beam end piece abruptly turns down on a 1:2 slope. This abrupt end should be considered a potential hazard for vehicles impacting in line with the terminal. The assembly relies on lateral distance from the road to minimize the number of end impact accidents and on flare angle to minimize the potential for end-on or near end-on impacts. In the traditional standard plan arrangement, the rail is flared away from the road, using shop-curved box beam guide rail, until it is approximately 15 ft back from the tangent projection of the main run of the guide rail. When the end is struck from the side, it functions as a gating and attenuating terminal, allowing the vehicle to lose some speed as it rips the rail from the posts and/or extracts posts from the ground.

(Note: Prior to this publication, the Type I Assembly described only the end piece as a separate item. The curved rail was paid for separately. With this publication, one item is being created for the Type I End Assembly and it includes both the curved portion and the end piece.)

Type I terminals may be used on high-speed facilities where their end pieces will be close to (5 feet or less), at, or beyond the limit of the clear zone. Their installation well within the clear zone of medium- and high-speed highways at locations where they would be subject to end-on or near end-on impacts is not approved, although there may be special situations where it is appropriate. NYSDOT experience has been that, if the rail is flared to over 20° and the typical errant vehicle is departing from the road at an angle of 15° or more, the terminal will gate on impact. In medium- and low-speed configurations, the box beam end

piece may be within the clear zone, if it is flared such that typical impacts (assume 15° departure angle) on the end will be at least 35° off-line. Where back slopes are close by, the Type 0 buried end alternative should be considered. The Type I end piece should not be buried in the back slope as it is likely to serve as too much of an anchor, preventing the end of the box beam from yielding.

The designer should avoid arrangements that place the 1:2 turned down ends in the bottom of ditches that are likely to capture errant vehicles.

When box beam guide rail is flared away from the roadway, the top of rail should be maintained approximately 27 inches above ground surface. This may require shaving down the shoulder break where the terminal flares over it and may require minor filling on the fill slope.

In general, Type I End Assemblies should not be carried across ditches as there may be too much potential for vehicles to underride the rail in the ditch. Instead, Type 0 terminals should be carried to the back slope of the ditch.

In some situations with broad, relatively level clear zones, it may be desirable to use a Type I End Assembly, but the normal configuration will not place the end piece within 5 feet of the clear zone. In those circumstances, a new item has been introduced, the Type I End Assembly with Extension Piece. This consists of adding an 18 foot piece of straight box beam between the curved pieces and the End Piece, effectively moving the end piece 6 feet farther from the traveled way.

The box beam guide rail should be assumed to develop full beam strength and redirective capability 60 ft from the turned down end of a Type I Assembly. For convenience, the point of redirection is typically taken as the point of tangency to the run.

C. Type II Box Beam End Assembly

The Type II terminal is no longer approved for new installations, but may be retained in most of its existing locations.

The Type II terminal was originally developed for use in laterally restricted locations and at driveway openings in otherwise continuous runs of box beam guide rail. At various times, its use was also approved to start a run of box beam, particularly at locations where a Type I terminal could not be flared away from the road. The Type II consisted of a two-part gradual ramp intended to minimize the vertical lift imparted to vehicles that run up onto it. The first bend was tack-welded at the lower corners so that it would open when a vehicle rode over it. The typical flare placed the end less than 3 ft from the line of the railing. Full beam strength and redirective capability were developed 22 ft from the anchored end of a Type II assembly, but the point of need was established at 27 ft, where full height is achieved. Unfortunately, high-speed crash testing has shown that small vehicles, even the new heavier small vehicles, may be lifted and rolled over in spite of the mild ramp and yielding hinge.

A new terminal, the Type IIA, should typically be used instead of the Type II. Wherever Type II terminals must be taken down as part of the designed work, the Type IIA terminal should be used as a replacement, provided adequate lateral space is available and the

conditions for installation are met. Where adequate lateral space is not available and the design speed is 45 mph or greater, a Type II should be replaced with a Type III terminal. If the operating speed is less than 45 mph and lateral space is not available to install a Type IIA, an existing Type II may be reset. Trailing end Type IIs may be replaced with mildly flared Type I terminals if lateral space is not available for a Type IIA.

D. Type IIA Box Beam Terminals

The Type IIA is a new terminal that includes the same turned-down Box Beam End Piece used with the Type I assembly, but connected to the run by 18 feet of box beam, shop curved to a 35 foot radius. (As with the Type I End Assembly, the Type IIA End Assembly pay item includes both the curved rail and the end piece.) This flare sets the leading end of the terminal 8'-3" back from the face of the run, as opposed to the 15'-2" for the standard Type I alignment. The Type IIA terminal may therefore be used with narrow clear zones where there is not enough lateral space to install a Type I and there is no back slope reasonably close to permit use of a Type 0. The Type IIA is also intended to be a replacement for the Type II, but requires a greater width for installation. Where the Type IIA can not be flared back, as for instance if there are shallow buried utilities, a Type III terminal should be the alternative to a Type II. If the ROW at the terminal location is not wide enough to accommodate the Type IIA, an easement should be sought for its placement, rather than resorting to a Type III.

The Type IIA terminal was subjected to MASH crash testing designed to evaluate its acceptability for the specific condition of use in narrow clear zones. Two special crash tests, not required for normal testing, were run with a ditch close behind the rail. As a result of the successful crash tests on level ground and the unsuccessful tests with the ditch (not part of the required testing), conditional approval of the terminal as a TL-3 device was sought from FHWA and granted on May 18, 2010, subject to three limitations as follows.

1. The terminal should not be used well within the clear zone. The ramped portion of the end has the potential to destabilize a vehicle. If there is a good width of clear area behind the terminal, the destabilization could contribute to a rollover in an otherwise safe area. However, if there are fixed objects close behind the terminal, then the rollover will not have time to develop before the fixed objects are struck. The leading end of a Type IIA should not be farther than 5 ft from the limit of the clear zone.
2. The longitudinal location of the terminal should not place it where the front of a vehicle would be likely to nose under the flared back portion of the rail and cause a "clotheslining" type of accident. Where the fore slope is relatively gentle, the terminal can generally be made to follow the slope. Where a ditch must be positioned close behind the rail, consideration should be given to extending the longitudinal positioning of the terminal to place it either where the fore slope is gentler or adjacent to a driveway. If the flare closely follows a driveway, the driveway surface should prevent all but a very slow vehicle from dropping its nose below the rail.

If a Type IIA needs to terminate adjacent to a steep-sided ditch, a pipe should be placed in the ditch and fill placed to limit the effective height of the flared back portion of the rail to 30". The leading face of the fill should be no steeper than 1:6, the pipe should be cut to approximate the fill surface, and a grate should be placed over the leading end of the pipe.

3. "The use of these terminals should be supervised to ensure that they are not being placed in inappropriate locations." To meet this requirement, designers should notify DQAB of the proposed locations for Type IIA to obtain confirmation that the locations are appropriate. Photos of the proposed locations will be needed. This should be done for at least the first five projects within a Region to use the Type IIA. In addition to confirming that appropriate locations are being used, the data will facilitate subsequent in-service evaluation of the new terminal assembly.

E. Box Beam End Piece Terminals

Box Beam End Pieces are the same turned-down 7'-3" long pieces found in the Type I and the Type IIA, but installed without any corresponding curved rail. A new item has been created for this specific use of the end piece. The End Pieces may be used without flare, or with minor flare, on the downstream ends of runs on one-way roads where they will not receive an impact from approaching traffic. They may also be installed on two-way roads where the downstream end is close to or beyond the design clear zone width for the opposite direction traffic. They should no longer be installed at driveways or other openings where they can not be flared well back and will be within the clear zone width of approaching traffic. (See possible exception in Section 10.2.7.5 Camp (Seasonal Residence) Areas.)

F. Type III Terminals - NCHRP 350 Compliant End Assemblies for Box Beam

There are two box beam end terminals that have passed the NCHRP 350 testing criteria, the BEAT and the WyBET, both proprietary and available at the contractor's optional choice as a Type III terminal.

The earlier attenuating end assembly was developed by the State of Wyoming (hence, Wy Box End Terminal or WyBET) and the Texas Transportation Institute for installation on the ends of box beam guide rails. There are four working parts to the assembly. The assembly includes three telescoping steel structural tubes; two are 6" x 6", the other is 7" x 7". The fourth part consists of a pair of fiberglass composite pipe sections which are contained in, and crushed by, the other three components when the front of the assembled WYBET is hit. If it is hit on the side, at or beyond the third post, testing indicates that vehicles will normally redirect (establishes the rail's point of redirection). The system passed the NCHRP 350 criteria. The system is marketed by Syro Steel Company, now a subsidiary of Trinity Industries. The Department's approval of the system was announced in EI 98-005.

The more recently approved NCHRP 350 compliant terminal for box beam is the Bursting Energy Attenuating Terminal, or BEAT. This consists of a roughly 3 foot long mandrel that fits into the end of the box beam and has knife-like edges to cut the corners and push apart the sides of the box when the mandrel is driven into the box. The approach end of the mandrel is capped by a reflectorized face plate which distributes the force of impact over a larger area of the front of the car than the mandrel alone would. The foundation requirements are different from those of the WYBET, so the units are not interchangeable.

For planning purposes, the cost of the Type III may be estimated as \$4500 upstate and \$6000 downstate, not including grading. Pay item 606.1203 allows either the BEAT or WyBET option.

G. Median Box Beam End Sections

The Standard Sheets show the two types of traditional end treatments approved for box beam median barriers. Both types, A and B, rely on a ramping effect to avoid snagging. Because the ramped ends are relatively rigid, they could contribute to vehicle launch or rollover and are therefore no longer approved for routine application at locations where they will be exposed to errant vehicles on rural roads with design speed in excess of 30 mph or on urban roads with design speeds in excess of 40 mph. The Type A End Treatment, which is for use in narrow, low-speed medians, includes a concrete anchor block. The lower end of the box beam ramp is embedded and bolted into this block. The Type A concrete anchor is provided due to the higher percentage of end hits that occur in narrow medians. The Type B End Treatment is for use in wide medians and has no anchor block. The end of the box beam is buried flush with the ground surface. Two inverted posts are driven on either side to anchor the rail at the point where it clears the ground. The Type B terminal may be used in high-speed medians, provided either (1) the approach ends are shielded with other barriers or attenuating systems or (2) they are located where they will have a low likelihood of being struck by errant vehicles, such as where they are rendered inaccessible by topography or are in the lee of wooded areas in medians.

The Type C median box beam end terminal was approved in the summer of 1998. It is essentially a Type III box beam terminal with different support post connections (underneath, rather than behind the rail) and an adapter piece to transition the wider median box beam down to the regular box beam size that the terminal can attach to. The Type C is the only approved terminal for box beam median barrier that may be installed within the clear zone at locations where it will be subject to direct impact by medium- and high-speed errant vehicles. The Type C is NCHRP 350 qualified at Test Level III. The Type C (optional) pay item is currently 606.1403.

10.2.5.5 Concrete Barrier End Sections

Because of the hazard they represent, the ends of concrete barriers should always be given special consideration. Where a back slope is close by and the intervening ground is fairly level (1:6 or flatter), the end may be buried in the back slope. Refer to Table 10-5 for recommended flare rates. Where a broad level area is available, the end may be placed beyond the clear zone. When this is done, however, the ramped end section detailed in the Standard Sheets for 606 items should be used to avoid a blunt end. Ramped end sections should not be used in conjunction with attenuators. Ramped end sections are no longer approved for permanent installation within clear zones at operating speeds in excess of 30 mph. If ends can not be moved away from traffic, consideration should be given to either shielding with appropriate guide rail or preceding them with some form of crash cushion. Refer to Section 10.2.6 for a discussion of acceptable impact attenuators. Where guide rail is used to shield the leading end of the concrete (as with the traditional Pier Protection details), consideration should be given to the possibility that an errant vehicle will find its way behind the rail and impact the terminal. If this is considered a likely possibility, particularly where a redirecting back slope is present, the concrete barrier should be provided with a ramped end section and the leading end of the guide rail should be flared away from traffic. Where a back slope is in relatively close proximity, the terminal should be carried to "burial" in the back slope. If a vehicle is likely to "bottom out" and gouge into the redirecting back slope, then approximately 150' of guide rail should precede the beginning of the concrete ramp. If a vehicle can run smoothly up a back slope behind the guide

rail and be redirected back towards the concrete ramp, then a runout length of 250' should be provided on freeways.

10.2.5.6 Transitions

Transitions are defined simply as systems specifically designed to connect two different barrier systems. Two primary concerns must be addressed. First, the systems must be functionally continuous. Second, abrupt reductions in deflection distances between the two systems must be avoided. If a vehicle is moving along a "soft" barrier system at the full limit of its deflection distance and suddenly encounters a "hard" barrier system, it may either stop abruptly on the hard system or break through the soft barrier.

A number of strategies are used to effect satisfactory transitions from "soft" to "hard" barriers. One approach is to increase the rigidity of the "soft" system. This may be done by adding more posts to the system. Table 10-3 lists deflections for the various guide rail systems when reduced post spacings are used. Reduced post spacings must be used for approximately 5 spaces before the reduced deflection is fully effective.

The rail system may also be stiffened by adding elements to the rail. For example, Standard Sheets for 606 series items detail the addition of a nested thrie beam to a transition between concrete barrier and heavy-post blocked-out corrugated beam guide railing. The supplemental thrie beam panel reduces the deflection of the rail so that an errant vehicle may be carried past the end of a concrete barrier without contacting the corner.

A second strategy is to start the "hard" system at a point beyond the deflection distance of the soft system and merge the systems together. Refer to the Standard Sheets for details of the typical cable-box beam transitions. Note that the merging area should be no steeper than 1:6 to minimize the threat of vaulting. Whenever a box beam-cable transition is to be used and the normal embankment is steeper than 1:6, the plans should accurately depict those areas where the embankment will have to be widened and/or flattened to accommodate the transition.

The Standard Sheets detail the guide rail and median barrier transitions from box beam to corrugated beam railing. As with cable systems, it is essential that corrugated beam rails be anchored so the system can develop the tensile component of its capacity. When transitions are made adjacent to a bridge structure, they shall use the details shown on the appropriate Bridge Detail sheet. The transition to bridge rail should not begin before the "point of redirection" for box beam guide rail. It is desirable to have at least one normal box beam post spacing before beginning the reduced spacing for the bridge rail transition. Similar details should be used for transitions to other structures with zero deflections. It is noted that some exceptions may be required where bridges are close to intersecting roads or driveways.

Transitions should not be made directly from weak-post W-beam to any bridge rail system or onto concrete barrier. Direct transitions should not be made because an abrupt reduction in deflection distance between the two systems could lead an errant vehicle to pocket. (Pocketing occurs when a vehicle is brought to an abrupt stop because the rail system ahead of the vehicle forms a "pocket" around the front end of the vehicle rather than directing the vehicle back towards the road.) In addition, transitions should not be made from cable to any other system except box beam.

10.2.5.7 Intersections

Intersections present special problems for barrier design. The main problem is that, rather than the acute angle impacts typical of highway tangents, the impacts may be at any angle, including right angle.

The number of suitable choices becomes limited when guide rail must be carried around a corner, such as at the intersection of an overpass bridge and a ramp. As a special order, corrugated beam guide rail may be bent as tight as a 5 ft radius. Box beam may be fabricated down to a 5'-3" radius. Cable can not be used in these tight radius situations. Such corners are preferred locations for signs, utility and signal poles, traffic control boxes, and manholes. In any intersection, the fixed hazards should be moved as far back from the traffic as practicable. With high-angle impacts, the barrier systems that could be installed to shield these fixed objects may represent as much, or even more, of a hazard than the shielded objects themselves. Where fixed objects will be no closer than 16 ft to the line of the guide rail, corrugated beam should be considered, due to its generally large deflection and correspondingly lower deceleration rates.

Consideration should be given to the protection of the traffic on the road below the overpass. If the volume of traffic on the lower road is great enough that an errant vehicle coming down past the wing wall would be likely to be involved in a secondary accident, then it may be appropriate to provide a strong barrier above the wingwall/slope to minimize this threat. Concrete and box beam barriers are preferred in this situation. With tight bends, the box beam tends to develop arch-action strength which increases its rigidity significantly. The use of box beam is generally recommended instead of concrete barrier due to the more yielding nature of box beam and due to its limited interference with intersection sight distance.

10.2.6 Impact Attenuators

In some situations, a fixed hazard may be present at a location where it is either impossible or impractical to provide a redirecting barrier. The most common examples are the ends of barriers in gore areas between diverging roadways.

Impact attenuators may be categorized as either inertial or compression systems. Inertial systems are designed to transfer the kinetic energy of a vehicle to a series of yielding masses. Sand barrel arrays are a typical example and are discussed in Section 10.2.6.2. Compression systems are designed to absorb the energy of the vehicle by the progressive deformation or crushing of the elements of the system. Compression systems and certain inertial systems require anchorage and/or backup to resist the impact force of the vehicle. Compression systems which are approved for Department use are discussed in Section 10.2.6.3 QuadGuard (formerly the Hex-Foam Sandwich System and Guardrail Energy Absorbing Terminal, or GREAT) and REACT 350. Systems which are considered acceptable but innovative are described in Section 10.2.6.6.

Whatever the system, it is important that the reaction plane of the attenuator system closely match the approach path of the errant vehicle. In particular, curb is not to be used with any of the attenuation systems. Vehicles striking curbs in front of attenuators have shown a tendency to rise, strike the front of the attenuation system, and continue over the top of the system.

Since each of the approved attenuators can be designed to provide satisfactory safety results, the selection criteria are factors such as initial cost, impact frequency, maintenance cost,

downtime, width requirements and redirection capability.

Sand barrels generally have the lowest installation cost. The arrays essentially have no redirection capability and should therefore normally extend a minimum of 2.5 ft (3 ft preferred) beyond either side of the obstacle being shielded. For restricted conditions, the offset may be 2 ft and in special adverse conditions, offsets as low as 1.5 ft may be approved. Sand barrels are essentially one-hit systems requiring complete replacement of any impacted barrels. Their use, therefore, is not recommended for heavily trafficked areas at sites with a high frequency of side impacts. They would be the attenuators of choice for situations where the impact frequency is expected to be low.

The QuadGuard system (Section 10.2.6.3) may usually be repaired by replacing individual crushable cartridges and elements of the nose.

The ADIEM (Advanced Dynamic Impact Extension Modules) is an innovative system (Section 10.2.6.6) that has also been approved by FHWA for use in narrow width conditions.

The Department has previously used proprietary attenuator systems that rely on water-filled canisters. To prevent freezing, these units required that salt or antifreeze be added. The anti-freeze was occasionally stolen and, in accident situations, tended to be quite slippery. The units had to be individually opened to check for leaks. Leaking salt may have contributed to bridge corrosion problems. Finally, the systems were not rated for traffic speeds above 100 km/h. For these reasons, water-filled canister systems are no longer recommended for general use in New York State. As a special exception, refer to Section 10.2.7.3 for use of Hydrocell Clusters on Local Urban Streets.

Truck escape ramps are not widely used in New York and may not be thought of in a discussion of velocity attenuating devices. Still, they should be considered for long, steep downgrades with significant truck traffic. Section 10.2.6.5 discusses truck escape ramps.

Vehicle Arresting Barriers or "Dragnets" have been used in a limited number of permanent locations. They are highly effective at preventing major damage to impacting vehicles and at covering wide areas, which makes them useful for lane or roadway closures as well as some permanent locations. Dragnets are discussed as construction zone devices in Chapter 16.

10.2.6.1 Delineation

Regardless of the system selected, serious consideration should be given to providing delineation to warn motorists away from gore attenuators. This increases the overall safety, allows the attenuators to stay in service longer, and greatly reduces the maintenance costs. Department experience has been that the use of double-light warning beacons produces a distinct reduction in the number of vehicle impacts. Where warning beacons are installed, they should be placed behind the attenuator, on the obstacle, or on the post supporting the appropriate warning signs as indicated in the National Manual on Uniform Traffic Control Devices (MUTCD) and the New York State Supplement.

In high-volume urban areas, a single-light warning beacon may be difficult to distinguish with a background of other city lights. Therefore, and particularly where existing attenuators have a significant accident history, consideration should also be given to providing overhead area lighting to increase the visibility of the system. Refer to the Department's "Policy on Highway Lighting" for detailed criteria and warrants.

Reflective sheeting placed on the front of attenuators tends to lose its reflectivity in a fairly short period of time due to damage from road debris and coverage by dirt, salt, etc. However, if attenuators are experiencing a high number of hits, even a mild reduction in the frequency could justify the cost of reflective sheeting and it should therefore be considered in those situations.

10.2.6.2 Sand Barrels

Sand barrels (Inertial Barrier Modules) are arranged in arrays designed to gradually transfer the momentum of an impacting vehicle to the sand. Lighter barrels are placed near the front of the arrays to gradually slow small vehicles, which are usually considered to be in the 2000 lb category. Heavier barrels are placed farther back in the array to slow the larger passenger vehicles, which are in the 4000 lb category.

The general requirements for the individual barrels are presented in Special Specifications - Items 654.010X M - Inertial Barrier Modules. The standard module weights are 200 lb, 400 lb, 700 lb, 1400 lb and 2100 lb. The specifications require unbagged sand with a 3% to 5% salt (NaCl) content to prevent freezing.

A. Placement Design

Where practical, gore areas should be designed with adequate room to accommodate the recommended array for the design speed. To allow additional stopping space, the desirable distance from the last modules to the fixed object is 2 ft. The minimum is 1 ft. The spacing between adjacent barrels directly affects the occupant deceleration rate; 1 ft is the standard spacing for normal conditions. On existing facilities with space restriction problems, the spacing may be reduced as needed to fit the array into the available space.

Because sand barrels do not provide acceptable redirection, the width of the array should extend beyond both sides of the fixed obstacle. The desirable extension is 3 ft on each side. The normal minimum is 2.5 ft. On existing facilities, 2 ft may be used for restricted conditions and 1.5 ft may be approved in special adverse circumstances. These lateral extension distances should be at least 50% greater than the longitudinal separation between the barrel and the shielded object to minimize the likelihood of striking the last barrel and then the end of the object.

The recommended space for placement of the arrays should permit placement so that none of the barrels encroach on the mainline shoulders. Note that, on new and reconstructed projects, this will normally require that the object to be shielded be at least 3 ft beyond the shoulder. On existing facilities, the minimum space should be such that no barrel is within 1 ft of the traveled way. The minimum conditions should only be applied to existing facilities where the geometry can not be readily modified to provide the recommended space. Figures 10-13 through 10-15 present the recommended minimum arrays for narrow hazards and typical design speeds.

Note that, while some adjustments to lateral placement may be approved upon request, the longitudinal clear spacing between barrels (1 ft, measured at top of barrel) should not be compromised without a good rationale. The longitudinal distribution of masses within the arrays is designed to achieve a controlled deceleration for the speeds indicated. Shorter arrays will cause higher and more dangerous deceleration rates. In some existing situations

with exceptionally adverse geometry, it may be necessary to design arrays that do not achieve the desired decelerations, but are the best arrangement that can be provided. In such situations, the proposed designs should be submitted to DQAB for review as described below.

For situations not covered by the typical examples, the designer should refer to the manufacturer's (see Figure 10-15) literature for more detailed design guidance. The proposed design and supporting details should be submitted for approval to the Specifications and Standards Section of the Design Quality Assurance Bureau. The submission should include the following:

1. A plan of the entire area, preferably 1:2500 scale, with all roadways identified and locations of attenuators indicated.
2. Complete description of the fixed object requiring protection.
3. A 1:100 to 1:250 scale drawing containing all necessary dimensions. In the case of a gore area, the length of the gore should be measured along a line equidistant from the pavement edges, and the width of the gore measured perpendicular to that line at the narrowest point, widest point, and at a point equidistant between the two. Distances between shoulders and pavement edges shall be noted along with any other pertinent information.
4. The highway design speeds and anticipated posted speed limits on all roadways involved.
5. Photographs of existing sites. (Digital images may be e-mailed.)
6. The impact attenuator design speed, which is defined as the greater of highway design, posted, or operating speeds.

B. Installation

The axis of symmetry of the arrays should be directed along the most likely direction of approach for an errant vehicle. For gore areas, this would be back towards the intersection of the edges of pavement. Note, in Figures 10-13 through 10-15, the orientation of the leading barrels in the array with respect to the predominant flow of traffic. For roadside hazards, the angle between the axis of the array and the edge of the traveled way should not exceed 10°. Obstacles in narrow medians should be shielded on both ends and the modules placed on the trailing ends (to shield opposite direction traffic) should be placed flush with the downstream edge of the obstacle to avoid wrong-way hits (by vehicles that have already passed the obstacle). The modules should be placed on a concrete or asphalt surface with a maximum slope of 5% in any direction. Each barrel's location and weight of sand should be carefully spray painted onto the surface, at the position that will be covered by the barrel, to ensure that the array will be correctly reconstructed after an accident. Curbing is to be avoided and should be removed if its height is in excess of 4 in. There have been reports of vandals turning over lighter barrels and rolling them into traffic. In areas where vandalism has been experienced or may be anticipated, local law enforcement agencies should be made aware of the problem. If it persists, consideration should be given to providing the 200 lb and 400 lb modules with a system to fasten them to the pavement to

resist overturning. The fastening system should not interfere with the performance of the barrels and should not present a hazard to the errant vehicle.

C. Advantages and Disadvantages

The main advantages of sand barrel systems are that:

- The systems are relatively inexpensive to install when compared with other impact attenuators.
- No backup wall or plate is required.
- By altering the weight in the barrels and the number of rows, a wide range of design speeds and vehicle weights may be accommodated.
- Wide obstacles can be shielded.

There are several potential disadvantages of the system.

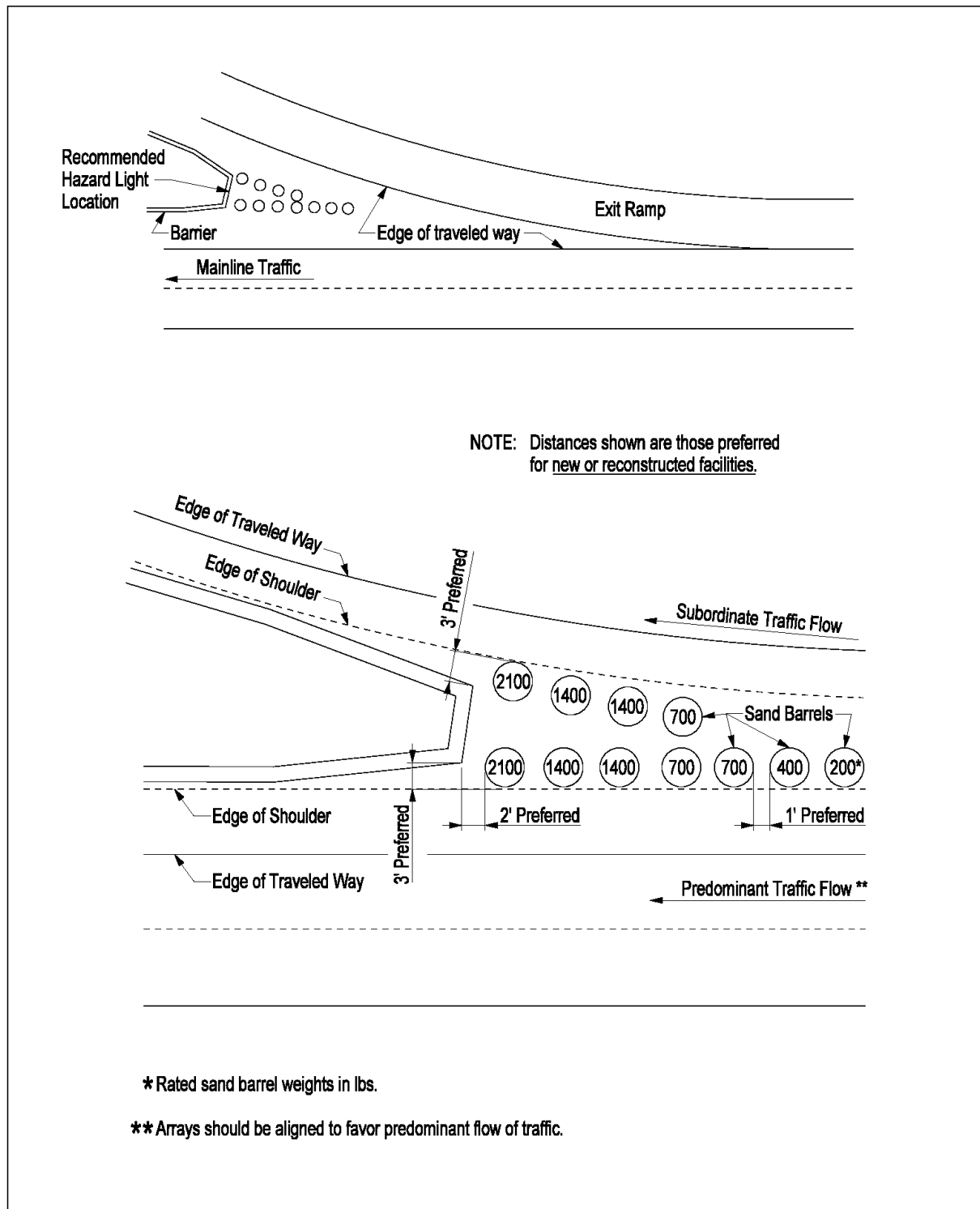
- Barrels will generally require replacement after almost any hit.
- The impact may scatter debris across the roadway.
- The arrays must extend closer to the road than the obstacle does (normally 3 to 2.5 ft).
- The weight of an appropriate array may overload some bridge structures.
- There may not be enough room available for the preferred array.
- The system does not redirect vehicles.
- The heavier barrels in the rear of the array can produce severe decelerations when hit first.
- In some settings, the barrels might be considered visually obtrusive. Note, however, that discrete gray barrels have been used where aesthetic considerations outweighed the safety benefits of the high-visibility yellow. This might be a good option for a parkway where shielding is needed for a fixed object that is not in close proximity to traffic.

D. Sources

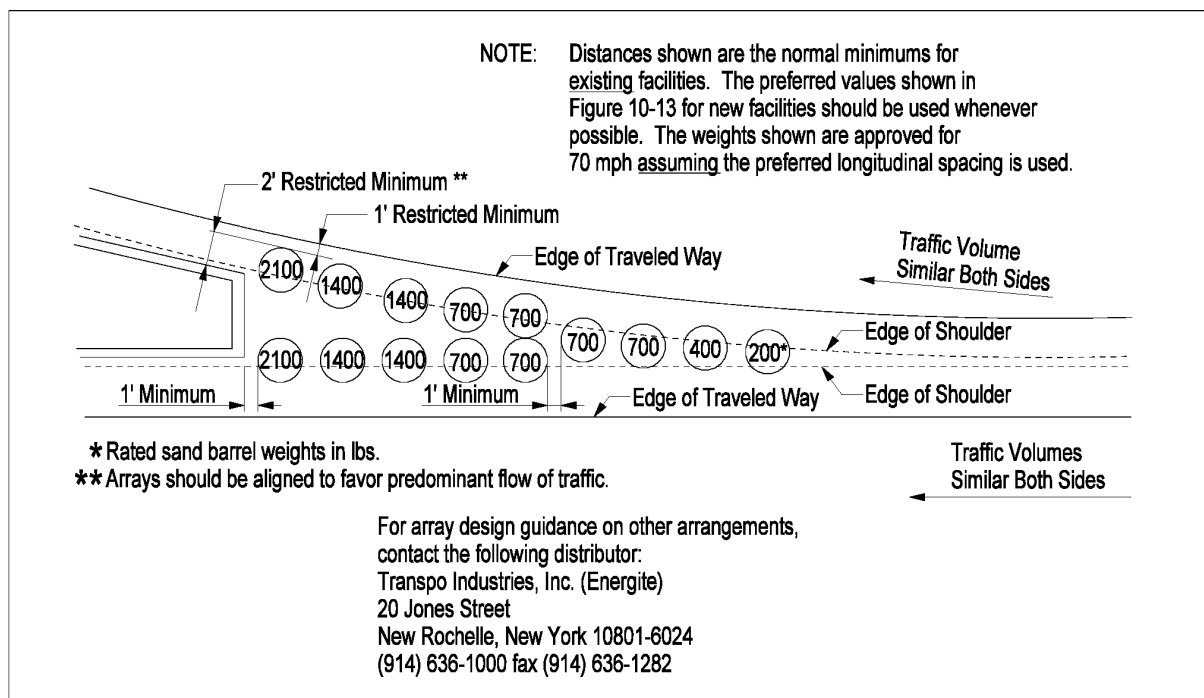
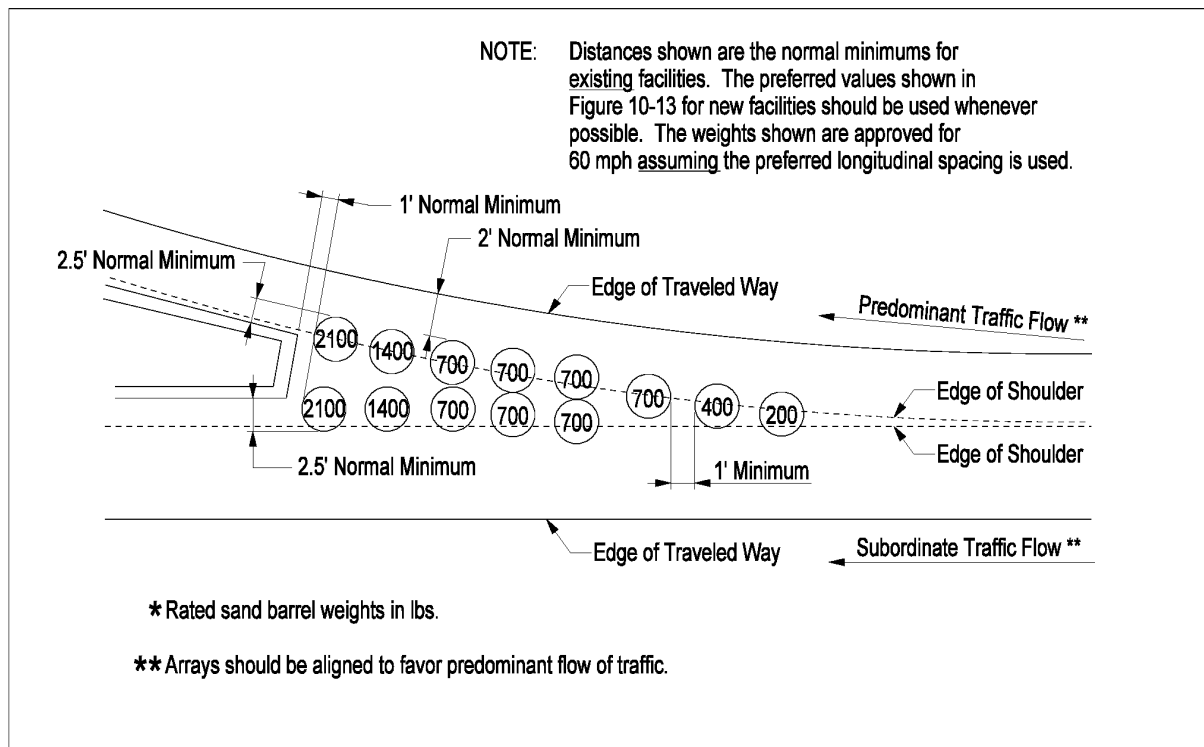
Additional information on design details may be obtained from an approved vendor, such as

- Energy Absorption Systems, Inc., 35 East Wacker Drive, Chicago, Illinois, 60601-2076, (312) 467-6750 or by e-mail at <http://www.quixtrans.com/contact.htm>.
- TrafFix Devices, Inc., 160 Avenida La Pata, San Clemente, CA 92673, (949) 361-5663 or by e-mail at info@traffixdevices.com.
- Plastic Safety Systems, Inc., 2444 Baldwin Rd, Cleveland, OH 44104-2505, (800) 662-6338, or by e-mail at <http://www.plasticsafety.com/contact.asp>.

Figure 10-13 Approved Sand Barrel Array for 90 km/h



Figures 10-14 & 10-15 Approved Sand Barrel Arrays for 100 and 110 km/h



10.2.6.3 Proprietary Attenuating Systems

When impact attenuators are to be included on a project, certain information should be shown on the plans. This includes a plan view showing the unit, its concrete pad (or a note that the existing pavement or foundation at the site is to be used), the locations of any drainage structures, utility information, expansion joints, working cracks, and edges of pavement(s), curbing or islands. The plans should also identify any special transitions required between these units and the shielded object.

A. QuadGuard

Both the Hexfoam Sandwich System and the GREAT attenuators were replaced with the NCHRP350-compliant QuadGuard system. Note that the minimum recommended thickness for the concrete base pad has been increased from 4 in to 6 in and that the reinforcement details are different.

Unlike the sand barrel systems that rely on inertia, the proprietary QuadGuard System absorbs the kinetic energy of an impacting vehicle with a series of crushable blocks. To achieve the crushing, the blocks must be crushed between the vehicle and the anchorage for the system. The blocks consist of a matrix of hexagonal-shaped cardboard tubes filled with polyurethane foam and sealed in ultraviolet-resistant plastic as protection from the elements. To redirect traffic, the flanks of the system are protected with an overlapping array of fender panels. Under mild impacts, side hits may require very little or no repair work and nose hits may simply require (1) that the external walls be pulled back into position and (2) that the crushed hex-foam cartridges be replaced with new blocks.

QuadGuards intended for permanent applications should be installed on reinforced (#5 rebar @ 24" c-c) concrete pads with a minimum thickness of 6 inches, on unreinforced concrete pads with a minimum thickness of 8 inches, or on existing concrete surfaces in good condition and equivalent thickness. Avoid crossing working cracks or joints as special hardware will be required to ensure proper operation during impacts. If they can not be avoided, contact the manufacturer or vendor for assistance with the design of the special hardware.

The QuadGuard is available in five widths and up to twelve different lengths. With six or more bays, the QuadGuard is rated as an NCHRP 350 "Test Level 3" device. This means the units can be used on all facilities, if the right number of "bays" is specified. QuadGuards with widths of 24 in., 30 in., or 36 in. have the same "footprint" as the GREATs of those widths, and may be substituted for those GREATs. (However, note the base pad thickness requirement in the first paragraph of this section.)

The two remaining width options, 69 in. and 96 in., may be substituted for Hexfoam Sandwich systems of those widths. The manufacturer's data were used to generate the selection guidance below. Prices are for units delivered to the site to cover objects 24" wide. As the coverage widths increase up to 90", the prices increase by 20 or 30%. (Contact Transpo Industries as shown on Figure 10-15 for further information.)

ROADSIDE DESIGN

<u>Impact Speed</u> <u>(mph)</u>	<u>Number of Bays</u> <u>Recommended</u>	<u>Effect. Length</u> <u>(ft-in)</u>	<u>Estimated</u> <u>Cost (2008)</u>
43.5	3	11'-8"	\$11000
50	4	14'-8"	\$13500
56	5	17'-8"	\$16000
63	6	20'-8"	\$18500
70	9	29'-8"	\$27000

Pad width should be 4 ft for QuadGuard widths through 3 ft. Pads for wider units should extend a minimum of approximately 6 in outside of the unit components. Cross slopes steeper than 8% and changes in the rate of cross slope (twist) greater than 2% from the front to back of the slab are to be avoided. If the need for a twist is encountered, preference should be given to using a leveling pad.

Certain information should be shown on the plans. This information includes a plan view showing the unit, its concrete pad (or note that the existing foundation is to be used), the location of any drainage structures, utility information, expansion joints, working cracks, edges of pavement, curbing or islands, and identification of any special transitions required between the QuadGuard and the protected object.

If QuadGuards are to be attached to concrete barrier, the concrete barrier should be embedded and reinforced over the first 8 ft from the QuadGuard. Bar reinforcement, consisting of #4 epoxy coated bars at 8 in c-c each way, is required. Twelve typical stirrups (see Standard Sheets) spaced 8 in on centers, will provide the vertical reinforcement in both faces. Six straight bars, 8 ft long, should be spaced at 8 in to provide the horizontal reinforcement and replace the dowels shown on the Standard Sheets.

The advantages of the QuadGuard System are that:

- Its redirection capability provides better protection than a sand barrel system for a small vehicle striking near the rear of the array.
- It may be conveniently repaired after mild side impacts.
- The system is light enough to be placed on bridges.
- The system does not have to be much wider than the hazard.

The disadvantages are that:

- The system is complex to assemble.
- For equivalent protection, the system costs about four times as much as a sand barrel array.
- For severe hits, the repair costs approach the installation cost.
- The system requires more length than sand barrels for equivalent levels of deceleration.

Use of the QuadGuard System may be warranted:

- on high-volume facilities at locations where frequent side impacts may be anticipated,
- at gore locations where the hazard to be shielded is less than 5 ft from either travel lane, and
- on structures where a sand barrel array would be considered too heavy.

B. REACT 350

The REACT 350 (Reusable Energy Absorbing Crash Terminal) consists of a graded series of reusable heavy plastic drums, arranged in single file, open on the top and bottom and connected with cables on the sides. The reusability property is based upon the self-restoring nature of the high molecular weight polyethylene “cans”. The system is to be mounted on a concrete slab with a minimum thickness of 8 in, a minimum width of 4 ft to accommodate the 3 ft wide drums, and a length that is at least 8 in longer than the unit being installed. On top of the slab, a railing system is used to contain and control the movement of the barrels. For full details of the system, see the currently approved Materials Details from the Materials Bureau.

The REACT 350 should be specified using Item 15654.200X for permanent units on a new foundation, 15654.210X for permanent units on an existing foundation, and 15619.420X for temporary units in construction zones. In each item, the “X” ranges from 1 through 3, and indicates the nominal design speed the unit may be used for: 45, 55, or 65(+) mph. The table below indicates the number of bays, length, and estimated costs of the permanent units for each design speed option.

Dimensions and Estimated Costs for Permanent REACT 350 Attenuators				
Design Speed (mph)	Number of Barrels	Overall Length of Unit	Estimated Cost of Unit (2008)	Estimated Cost of Slab
45	4	15 ft	\$14,500	\$1000
55	6	21 ft	\$17,200	\$1250
65	9	30 ft	\$20,800	\$1750

The REACT 350 is a proprietary system vended by Transpo Industries, Inc. (914) 636-1000. The primary advantage of the system is its reusability, although the number of reuses will be dependent on the severity of the impacts. Its primary disadvantage is its relatively high cost.

C. TRACC (Trinity Attenuating Crash Cushion)

The TRACC refers to a pair of redirective impact attenuators manufactured by Trinity Industries, Inc. One is a nine-bay device rated to NCHRP 350 “Test Level 3”, meaning it can be used on all facilities. The other device is a six-bay unit rated as “Test Level 2”, meaning that it may be used on facilities with design speeds of less than 50 mph. The nine-bay unit is 21 ft long. The six-bay unit is 14 ft long.

Either device is 2'-8" wide and may be used to shield objects 24 inches or narrower. It may also be used as an end terminal for NJ-shaped concrete barriers by using manufacturer-supplied W-beam pieces attached to wood or plastic blockouts which are attached directly to the last concrete shape. The TRACC may be used on the end of a run of single slope concrete barrier if the barrier is first transitioned to a NJ shape using our standard transition. Only with the appropriate manufacturer-supplied transition pieces may it be used in two-way traffic situations. These transition pieces can only be attached to a NJ shape. To accommodate the backwards movement of the side panels during a nose impact, it is very

important to leave a clear space with a minimum length of 5 ft behind the ends of fender panels on either side of the shielded object.

TRACCs need to be mounted on and anchored to a rigid foundation. Typically, the anchorage should consist of 7.5 in studs in a reinforced concrete foundation with a minimum thickness of 6 in. Anchorage to asphalt concrete is not permitted in permanent applications because of concerns that the Department would not be able to repair a damaged asphalt foundation quickly enough following impact. Since, however, a Contractor will be at the site during construction, and an EIC will be watching over the work, asphalt anchorage can be a reasonable alternative in the work zone traffic control setting for moderate to moderately severe service conditions. While the above mentioned concrete foundation is preferred, the additional options for temporary (work zone) installations include:

- asphalt concrete with a minimum thickness of 6 in over compacted subbase with a minimum thickness of 6 in using 18 in anchor studs, or
- asphalt concrete with a minimum thickness of 8 in using 18 in anchor studs.

The TRACC is reusable to a limited extent. If the stroke (movement of the front face of the sled assembly due to an impact) is not more than 4'-5", then field repairs can generally be made; otherwise, the system must be replaced. Similarly, if the cross bars are not bent more than $\frac{3}{4}$ in (vertically) by a side impact, then field repairs can generally be made; otherwise, the entire system must be replaced. Upon severe redirecting side impacts, the anchor studs may come loose from a concrete foundation. With a temporary asphalt foundation, the anchor studs may come loose upon a moderate to severe impact. In either case, the foundation must be repaired and the studs reset before replacing the TRACC unit. These units may be installed on existing concrete foundations free of cracking or deterioration that could impair anchorage or the integrity of the foundation. Working cracks or working joints should not be bridged by these units.

Cross slopes over 6% for TRACC foundations are to be avoided. If encountered, they should be corrected by means of leveling or grading. In addition, curbs and islands higher than 4 in should be removed from the area extending from the back of the unit to a point 50 ft upstream from the nose of the unit. Mountable or traversable curbs or islands with a height of 4 in or less may be retained if they are needed to collect and control pavement runoff. However, new curbs, of any height, are not to be installed within the above described limits.

The TRACC crash cushion for permanent locations has a core item number of 654.3X M. The optional temporary attenuator item is 619.18XX M. In temporary (construction) situations, some provision must be made for repairs due to traffic damage. The designer should always include Item 15619.28, TRACC Bays Damaged and Repaired, in construction contracts. Solely to provide a basis for bid comparison, the Estimate should assume that 50% of the bays that need to be installed will require replacement over the life of the project. (If two nine-bay units are needed for shielding on the project, the estimate should reflect that nine bays will be damaged and need repair or replacement.)

The cost of the nine-bay unit may be estimated to be \$10,000; the cost of the six-bay \$6,500. The respective foundation costs may be estimated at \$1200 and \$750. The cost of any metal transition would be another \$175. These estimates do not include a contractor mark-up.

D. TAU II

Barrier Systems Inc. manufactures the proprietary Tau II system, specified as 712-21 Impact Attenuator, Thrie Beam Type with Expendable Modules. Details of the Tau II, including drawings of the crash tested systems and recommended design configurations, are available at http://safety.fhwa.dot.gov/fourthlevel/hardware/term_cush.htm (FHWA letter, codes CC-75, CC-75A and CC-75B). The following are some design considerations:

- These impact attenuators may be used in a parallel configuration to protect objects up to 27 inches wide. Flared transitions may be used to treat wider objects up to 8ft and a 70 mph configuration is available to treat objects up to 8.5 ft wide.
- These attenuators are available in several configurations up to 12 bays. They are considered to meet all pertinent NCHRP 350 evaluation criteria and are federally approved for use on the NHS. The 10-bay unit was successfully tested to a modified NCHRP 350 test 3-31 (head-on impact) at 70 mph. The overall length of the 4-bay, Test Level 2 unit is 15' -5". The length increases by approximately 3 ft for each additional bay (refer to table below). Additional lengths may be needed for transitions or for the concrete backup structure.
- Units may be installed as "stand-alone" or may transition to safety-shape concrete barriers, thrie beam, or the standard corrugated beam (using an intermediate thrie beam transition).
- The following table provides the manufacturer's recommended parallel unit configurations for several design speeds, its corresponding length, and Contractor cost. These costs are based on data provided by the downstate distributor for units connected to a concrete barrier and a coverage width of 30". Steel backup estimates for parallel units are \$2,500 for the 10-bay unit and \$1,500 for the shorter units. Designers need to recognize that this is the distributor's pricing for the units and will need to include additional costs in their estimates to include installation and markup.

	Design Speed, mph					
	44 ¹	50	56	62 ²	68 ³	72 ³
Bays	4	5	7	8	10	12
Length, ft	11.75	14.6	20.25	23.1	28.75	34.5
Contractor Cost	\$9,590	\$10,980	\$12,980	\$17,050	\$19,475	\$22,800

1. Corresponds to NCHRP350 Test Level 2.

2. Corresponds to NCHRP350 Test Level 3.

3. For design speeds over 62 mph, the indicated systems are available, but the 62 mph systems may be used.

- Any curbing from the backup structure to a point 50 ft in front of the unit must either be reduced in height to 4" or less or removed, preferably the latter.
- On the nonapproach traffic side of bidirectional highways, the backup structure must not protrude beyond the article being protected by the impact attenuator. The specifications require transitions on the nonapproach side to avoid snagging of the backup structure.
- The plans should clearly identify the required transition to guide rail, concrete barrier, or concrete backup. The transition and/or concrete backup are included in the item for payment. Note: The lengths above do not include the necessary transition or concrete backup structure lengths.
- Cross slopes of up to 1 on 12 may be tolerated. Differential cross slope (twist) from front to back may not exceed two percent.
- Additional design guidance may be obtained from the manufacturer,

Barrier Systems, Inc
180 River Road
Rio Vista, California, 94571
or local vendor,
Impact Absorption, Inc.
46-04 245th Street
Douglaston, NY 11362

Internet: www.barriersystemsinc.com.

Contact: Ron Keener (888) 800-3691

Internet: www.impactabsorption.com

Contact: Michael Kempen (718-229-0046)

E. SCI

Smart Cushion Innovations Products, Inc. produces the SCI70GM for 45 mph impacts (70 km/h) and the SCI100GM for 62 mph impacts (100 km/h). The system is designed to be highly rugged and reusable. To achieve this, it has extra strong side panels and internals that give it an added weight, and cost, that exceed that for other systems that are not as durable. For the standard NCHRP350 crash tests, the repair parts were only two ¼" shear bolts and the labor was only two workers for less than an hour. The Smart Cushion reported an average of \$39 in repair parts per incident in a documented two-year in-service evaluation posted on the FHWA website. Forty percent of those impacts were tractor/trailer (high mass) impact.

The primary energy absorbing mechanism of the SCI system is a heavy cable and hydraulic piston system where the piston tube has a series of ports that the hydraulic fluid is forced through into the outer casing which retains this excess fluid. This fluid is automatically pulled back into the piston tube during a reset. As the piston is compressed, the number of ports remaining ahead of the piston head decreases, requiring greater pressure to eject the fluid at the same volumetric rate. The resistance of the system is thus a function of the rate at which it is being compressed and the amount it has been compressed.

Transition pieces are available to connect to either Jersey-shaped concrete barrier or single-slope concrete barrier. Because of its unique reverse-tapered design, the attenuator itself is limited to shielding a width up to 2' and a height of 34". Transitions are available for wider hazards, but extra length will be needed to accommodate the flare from the back of the attenuator to the shielded object.

Test Level	System	Length	Weight (lb)	Contractor Cost
TL2	SCI70GM	13'-6"	2470	\$15,700
TL3	SCI100GM	21'-6"	3450	\$20,200

Further information is at www.workareaprotection.com/SCI100GM/Attenuator.pdf. The SCI Products, Inc. contact is Jeff Smith (JSmith@workareaprotection.com), 1-(800)-327-4417.

10.2.6.4 Nonproprietary Impact Attenuators - (Vacant)

10.2.6.5 Truck Escape Ramps

On long, steep declines, heavily loaded trucks may experience brake failure. Gravel escape ramps are one system used to safely stop runaway trucks. The typical ramp leaves the roadway as a flared paved apron. Beyond the apron, the ramp surface is a thick layer of loose, well-rounded gravel. The loose gravel will not support a truck. Instead, the tires plow through the gravel, transferring the truck's momentum to the stones. The preferred ramp profile is a sag vertical curve that starts on the roadway grade and ends on an upward incline. The minimum width should be 25 ft. Drainage must be addressed to make sure the gravel does not become encased in ice or clogged with washed-in silt and sand. The ramp location must be made obvious with advance signs and ramp lighting.

The advantage of the gravel escape ramps is that trucks can be stopped with very little damage.

The disadvantages are that:

- The ramps require a significant amount of right of way.
- To ensure that the gravel remains loose, regular inspection is needed and regular maintenance may be required.

Gravel escape ramps may be warranted for roads with long steep declines and significant truck traffic. Even if present truck volumes are low, the future addition of a ramp should be considered when locating the road and acquiring right of way. For further guidance on gravel escape ramps, refer to Chapter 3 of AASHTO's 2004 *A Policy on Geometric Design of Highways and Streets* and to the Transportation Research Board's May, 1992 NCHRP Synthesis 178 *Truck Escape Ramps*.

The Department has also designed truck escape ramps that rely on Vehicle Arresting Barriers (Dragnets), although these devices are more commonly used in construction zones. Refer to Chapter 16 of this manual for a system description.

10.2.6.6 Innovative Attenuation Systems

Numerous new impact attenuation systems have been and will probably continue to be developed. In the 1990's, the Department permitted use of five of these systems in New York State on a trial basis. In alphabetical order, these systems are known as the ADIEM, the CIAS, the ET-2000, the REACT 350, and the SRT. The ET-2000+ and the REACT 350 have subsequently been approved for general use. The CIAS was dropped by its supplier and was also not being used. The ADIEM had problems and was replaced with the ADIEM (II) which has a more durable "skin". The SRT was dropped as the Department no longer approves proprietary systems that must be flared significantly away from the shoulder.

Other new, properly tested systems may be used on a case-by-case basis subject to approval by the Design Quality Assurance Bureau. This bureau should be involved early in the plans to use any of these systems. Approval to use proprietary systems must be obtained in accordance with Section 21.3.4 of this manual. It should be noted that some of these systems will be significantly more expensive than the Department's traditional end sections. Where guide rails will be terminated close to the limit of the clear area, there will be little safety advantage to providing expensive end treatments. The general guidance is that high-quality rail terminals are

appropriate for high-quality clear zones, while low-quality clear zones (narrow width and/or questionable traversability) only warrant conventional, less expensive terminals.

A. Advanced Dynamic Impact Extension Module (ADIEM)

Unless specifically noted, references to the ADIEM should be taken to mean the newer ADIEM (II). The ADIEM consists of a gently ramped concrete carrier beam on which are mounted ten crushable Perlite concrete modules. The carrier base is composed of reinforced Class A cement concrete. This base is designed to permit it to be strapped to the end of a standard or temporary concrete median barrier. The Perlite concrete modules are cast in three layers of varying strength. The lowest 3" has a compressive strength of about 120 psi, roughly 4% of normal strength concrete. The next 14" has a compressive strength of only 40 psi. The top 7" has a compressive strength of 120 psi. These modules are porous, but coated to prevent water infiltration.

The ADIEM was originally crash tested in accordance with the requirements of NCHRP 230. Five developmental and four compliance tests were conducted. The results of these tests may be found on page 92 of *Transportation Research Record 1367*. The system subsequently passed NCHRP 350.

In service, the ADIEM's safety performance has been good, with only one issue emerging. Along the top, outside edges of the concrete ramp, the design includes a steel tube "bumper" that projects out a bit over two inches from the face of the ramp. There have been two instances of semi-tractor trailers crashing after the lugs on their front tires caught under or in the "bumper" rail as the truck was exiting the system.

The Department has used ADIEMs in both permanent and construction (temporary) applications, at a cost of from \$8,000 to \$15,000 per installation. While experience has been relatively good in temporary situations, there has been a noted deterioration of units placed as permanent installations. The worst problem appears to be caused by snowplow hits that slice through the outer protective covering and permit water to enter and damage the Perlite concrete. Other less severe breaches resulted from unknown causes. The manufacturer subsequently (1999) introduced a more durable outer covering on the modules. Based on current experience, it appears that the individual crushable units should be replaced after three years of service. Note that replacements will also be needed after impacts. The decision to use the ADIEM in a permanent application may still prove to be cost-effective over the long term. However, a firm commitment must be made to repair the covering as needed (repair materials are now provided with the units) and to provide replacement module as needed.

The principal advantage of the ADIEM is its narrow width and ease of module replacement after an impact. The ADIEM is manufactured by Syro Steel, which is now a part of Trinity Highway Products. Detail drawings and specifications are available from their Girard, Ohio office by calling 800-321-2755.

B. Connecticut Impact Attenuation System (CIAS)

The CIAS and NCIAS have been dropped from our list of attenuator options due to lack of use and the manufacturer's decision to cease marketing them.

C. EXTRUDER TERMINAL (ET-2000)

The ET-2000 is now a standard system and is described in Section 10.2.5.2 C.

D. REACT 350

The REACT 350 is now a standard system and is described in Section 10.2.6.3.

E. SRT

The Slotted Rail Terminal was dropped as the Department will not use proprietary terminals that must be significantly flared away from the shoulder.

10.2.7 **Developed Area and Large Volume Exceptions**

Developed environments present more complicated safety design challenges than rural environments. Very often, the roadways that go through these areas are the centers of communities. Increasingly, citizens of these communities have requested that these highways be redesigned using roadside solutions that are not just safe and effective, but that balance the safety and mobility needs of pedestrians, bicyclists, public transit users, and motorists and accommodate community values. Due to these considerations, the Regional Landscape Architect should be consulted for input on many of the design decisions.

The most significant problems in developed areas are the limited right of way and the many differing uses and functions of the urban roadside. The cost of the developed real estate adjoining urban highways frequently makes expansion of the right of way economically prohibitive. The successive expansions of the highway system to meet increasing demand have resulted in many highways where the available right of way can not accommodate the roadway and a clear zone. Because of the restrictions on reasonably available right of way, exceptions to the desired clear zone widths identified in Section 10.2.1 have been established for urban areas. While the clear zone widths selected in developed areas may have to be reduced for both practical and liability reasons, the designer should still strive to provide as much clear area as possible in those situations where vehicles may be expected to need that clear area. The effective clear area can be maximized by clustering the fixed objects (longitudinal placement) and by placing fixed objects as far from traffic as is practical.

Where vertical-faced curbs are provided, the width of the clear zone should provide a minimum of 18 inches from the face of curb to any utility pole, hydrant, or other obstacle. The primary purpose of this offset is to permit passenger doors to be opened when cars stop next to the curb. As such, the 18 inches is primarily for convenience, rather than safety. The preferred minimum offset is 3 ft. At curbed corners where long trucks are more likely to encroach, the minimum clear zone distance from the curb face to obstructions should be 3 ft. For uncurbed streets, the minimum offset from edge of traveled way to obstructions should be 4 ft. (Note that Chapter 2 of this manual requires an 18 inch horizontal clearance, as a safety-related shy distance, from the edge of traveled way to obstructions, including breakaway signs.)

While, in rural areas, attention may be focused primarily on protecting the motorist from the roadside, in populated areas, consideration must sometimes be given to protecting pedestrians and bicyclists from errant vehicles. (Refer to Chapter 17 for guidance on bicycle accommodation and Chapter 18 for pedestrian safety accommodation.) Vertical-faced curbs should generally be provided wherever pedestrians regularly travel along the roadside, provided it is not a high-speed highway. The designer should note that vertical-faced curb has little redirective capacity and is primarily provided to discourage the mingling of vehicular and pedestrian traffic. Barriers should be considered where areas of assembly, particularly playgrounds, schools, and parks, are across "T" intersections, outside of sharp curves, and at locations with a history of run-off-road accidents. Special consideration should be given to urban school zones. Guide rail should be considered both to protect children from errant vehicles and to direct pedestrians to designated crossing zones.

Barriers should also be considered to shield features that, if impacted by an errant vehicle, could produce a catastrophe for the community, such as flammable or noxious gas storage facilities. Conversely, to guard against gas tanker or heavy-truck accidents, extra strength barriers should be considered on the approaches to overpasses that have heavy population concentrations below. Consideration may also be given to installing a barrier to shield structures which have been struck at sites having a history of run-off-road accidents.

On principal arterials, consideration should be given to providing pedestrian overpasses. These overpasses should be enclosed to inhibit or prevent objects from being thrown into traffic. Refer to Chapter 18 of this manual and Chapter IV of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004, for a discussion of pedestrian overpasses and screening.

The roadways to be considered in this section will be broken into five categories for the convenience of discussion. Those categories are: Urban Freeways, Urban Arterials, Local Urban Streets, Suburban Roads, and Camp Areas.

10.2.7.1 Urban Freeways

Urban freeways differ from rural freeways primarily in the volume of traffic handled. In some instances, the urban freeways may also be faced with much tighter right of way constraints. Because the reduced right of way limits the amount of space available for clear zone development, the designer must often resort to an increased use of roadside barriers. Where space permits, preference should still be given to providing the clear zone widths determined in accordance with Section 10.2.1.

Because of the large volume of traffic using the urban freeways, durability of the barrier system is a concern. Preference should be given to systems that will tend to remain in service after being struck. On large volume roads, repair crews are at risk and inadvertently create a hazardous condition for motorists. Because its impact durability is so poor, cable guide rail should generally not be installed on urban freeways with AADTs in excess of 5000 vehicles per lane per day. However, cable guide rail may be used for roads with higher traffic volumes if the correspondingly increased effort can be made to provide timely repair and maintenance and it is believed that repairs can be made safely.

Box beam guide rails are more durable, but may also require frequent remounting. The offset from the traveled way and the anticipated frequency of impacts are factors that should be considered in the selection process. Where frequent impacts are anticipated, the recommended

barriers for large volume urban freeways are the heavy-post blocked-out W-beam and concrete barriers. Furthermore, where truck and large vehicle traffic is permitted, consideration should be given to using extra height concrete barriers in narrow medians. (Refer to Section 10.2.4.9 C.)

10.2.7.2 Urban Arterials

Urban arterials, as indicated in Chapter 2 of this manual, often carry large traffic volumes within and through urban areas. Traffic speeds are generally lower than on freeways and access is only partially limited. Urban arterials tend to have too many signalized intersections and cross-median access points to warrant regular use of barriers. Guide rail should be provided for major drop-off hazards such as approach ramps to overpasses or bridges. Where the operating speeds are 50 mph or greater, median barriers will frequently be warranted to prevent crossover accidents. (See Section 10.2.4.) At lower speeds, curbing may be provided instead of barriers. Because curbing may contribute to loss of control, it should generally be avoided where wide, obstacle-free medians or shoulders are possible. Wherever sidewalks are provided for pedestrian access, however, curbing should be provided.

While landscaped arterials are popular, walled planters and other structures that present hazards should not be permitted within clear zone distances. Flush planting areas should be used instead of raised beds. Most trees will grow beyond a diameter of 4 inches and will become fixed objects. Therefore, they should usually be planted beyond the clear zone. Particularly near intersections and on horizontal curves, the landscaping should not interfere with the recommended sight distance.

On arterials, ditches should be eliminated in favor of a closed drainage system. (Note that, in some situations, there may be a conflict between potential safety benefits of a closed drainage system and the environmental benefits of water infiltration from open systems. The conflict is less relevant where soils have low permeability or ditch grades are steep. The Regional Environmental Contact and the Regional Landscape Architect should be consulted for water quality implications, including SPDES permit compliance.) Utility facilities should also be placed underground or above-ground facilities moved beyond the clear zone. The designer should consult the Regional Utilities Engineer (RUE), and Title 17 of NYCRR, Part 131 of the Highway Law, Accommodation of Utilities within State Highway Right of Way to determine the influence of current utility policy on this aspect of roadside safety.

10.2.7.3 Local Urban Streets

Local urban streets, especially in downtown areas, usually have frequent signalized intersections, typically at the end of each block. Frequently, buildings are close to the road. The roadside usually is curbed and has sidewalks from the curb to the buildings. Many downtown streets permit curbside parking. Where parking is permitted, errant vehicles will usually not reach the roadside. The speed limit is typically in the range of 30 mph. Because of the generally low operating speeds, few roadside design concerns apply to downtown streets.

Large shade trees are popular and seldom present serious fixed hazard problems. On some streets, however, large tree trunks may impair sight distances. Due to the potential hazard of falling limbs, dead, diseased, and dangerous trees are to be considered for complete or partial removal.

The main needs for barrier design are for drop-offs and for median features, such as bridge piers, traffic control masts, and pedestrian islands. In addition to the impact attenuators discussed previously in Section 10.2.6, Hydrocell Clusters may be considered as a special application. The Hydrocell Cluster is appropriate for locations where there is inadequate space ahead of the hazard to permit placement of a larger attenuator system. Use of Hydrocell Clusters should be reviewed by DQAB.

10.2.7.4 Suburban Roads

Some of the most significant roadside safety challenges are presented by suburban roadsides. This category of exceptions recognizes an important type of roadside condition not well covered by AASHTO's Functional Classification of Highways. The suburban environment represents a transition between urban and rural conditions. Often there is no clear demarcation between rural and suburban or between urban and suburban conditions. Safety treatments should consider, and be based on, the operating characteristics in the area, rather than routinely using urban guidelines. The designer should maintain standard lane and shoulder widths and full clear zone widths (including traversability of ditches) as far into the suburban area as is reasonable. The suburban roadside environment is typically well established and less flexible than a rural environment, limiting the practically available space for clear zones and forcing the designer to regularly make safety concessions to the many preexisting constraints. These roads are bordered by numerous residences, other abutting property access points and intersections. In a typical situation, the residences are separated from the road by a ditch which is crossed by driveways. The ditch drainage is carried under the driveways by a pipe which may have a headwall constructed around it. Vehicles which leave the roadway are likely to be directed along the ditch to an abrupt stop at the pipe.

Many of the residences are landscaped with large trees close to the road. The landscaping may include large raised planters, decorative rock walls and rail fences. Mail boxes may have been encased in masonry to resist vandalism. Businesses are likely to have signs close to the road, sometimes in large planters. Utility poles are commonly present close to the roadway.

On many of the suburban roads, the operating speeds exceed 40 mph. In addition to relatively high traffic volumes, pedestrians, bicyclists, and often delivery and mass transit vehicles, may have unrestricted access. As noted in Section 10.2.7 above, protection for pedestrians from possible errant vehicles may be prudent. As stated in Section 10.2.2.4, curbing has limited redirective capacity. Consequently, rather than providing only an 18 in clear area behind the curb, a broader clear area, more reflective of the off-peak operating speed, should be strived for. In higher speed suburban areas, serious consideration should be given to providing a shoulder, rather than just a curb offset. In general, curbs should only be introduced where warranted, such as for drainage or access control, delineation, or where there are sidewalks. Refer to Chapter 3, Section 3.2.9 of this manual.

A. Longitudinal Drainage Features and Transverse Embankments

Research has shown that vehicle control is much easier to maintain if the slopes on transverse embankments do not exceed 1:6. Several commercially available drain pipe end sections have been developed to match this slope. Various bar or pipe grate systems are available to allow vehicles to ride up over the end sections. On reconstruction projects where errant vehicles have a high probability of being directed into a limited number of end

sections, consideration should be given to installation of graded 1:6 end sections.

Where possible, the ditch cross-section should be smoothed to permit vehicles to recover sufficiently to avoid end sections.

If space is available, the drain pipe may be set back from the ditch line beyond the path of vehicles trapped in the ditch and the portion of the embankment crossing the ditch line may be graded to 1:6 slopes.

Rather than providing two separate pipes for driveways in close proximity, a single pipe could be used to eliminate two end sections.

The safest treatment, however, is to eliminate all of the end sections and transverse embankments by installing a closed storm drainage system. The high cost of this measure may warrant a benefit-cost analysis. Note also the potential SPDES conflict discussed in Section 10.2.7.2.

B. Landscaping Features

Some roadside “landscaping” done by property owners may unintentionally produce potential hazards that may be difficult to deal with due to people’s personal association with them. Shade trees, walls, and decorative stones or boulders in front or side lawns may carry personal attachments that involved considerable forethought, time, money, and personal effort on the part of the property owner. Mail boxes, particularly those with special landscaping or atypical support and decoration, may become potential hazards. Mail box placement is subject to both Department and U.S. Postal Service regulations. (The latter may be obtained at most local Post Offices.) Refer to Section 10.5.1 for a discussion of mail boxes.

Potentially hazardous features on private property can only be moved or removed with the consent of the property owner or the purchase of the necessary piece of property with the feature on it. The latter action requires a significant effort, time, money, and, usually, an actual accident history. (Dead, dying, or otherwise impaired trees that have a potential for falling on the road can, of course, be removed without consent or purchase of property. Refer to Section 45 of the Highway Law.)

Potentially hazardous private features within the Department's right of way are usually less difficult to move or remove. Notice must be given to the property owner that an encroachment exists and must be removed from the Department's property. A business sign or small hedge may be fairly easy to relocate; a large tree or a part of a structure is not. The more difficult it is to remove or relocate a feature, the more resistant a property owner may be. Refer to Section 10.5.6 for a discussion of public relations issues regarding hazardous feature removal on Department right of way.

C. Utility Poles

Because of the long lead times required for utility relocations, the need for relocations should be addressed during the scoping process.

The Department's official policy on utilities and their impact on roadside design is found in

Title 17 of NYCRR, Part 131, *Accommodation of Utilities within State Highway Right of Way*. The following information is subordinate to Part 131 and Chapter 13 of this manual.

The Department's policy is that utility poles are not allowed to be located within the guide rail deflection distance or within a Department-designated clear zone. Relocation of utility poles from those locations will contribute to significantly improved roadside safety.

Utility pole accident histories, including, but not limited to, the periodically issued "Bad Actor" list (poles that have been involved in several crashes), should be reviewed and used in connection with the determination of the clear zone.

Relocating utility poles should not be required if numerous other similar hazards, such as trees, are to be left at similar or smaller offsets from the roadway. Utility poles located within the clear zone should be treated the same as other potential roadside hazards and evaluated according to the hierarchy of treatment options discussed in Section 10.2.1.2. and Chapter 13 of this manual.

If relocations are planned, the designer should consult with the Regional Utility Engineer (RUE) to determine the current rules for the accommodation of utilities within State highway right of way and should start liaison with the Utility. The RUE, or the designer with the RUE's oversight, should negotiate the details of a form HC 140-Utility Work Agreement along with any other required agreements. All Agreements should be submitted as early as possible to facilitate proper coordination with DOT's final design. Refer to Chapter 13 of this manual for additional details of the utility relocation procedures.

With regard to clear zone documentation, if, in their final location, utility poles are the closest hazards to the traveled way, they will generally set the clear zone width. In some situations, however, an isolated pole may be documented as an exception to an otherwise wider clear zone. Note that as much additional clear area as is practical should be provided behind a line of utility poles, provided there is no conflict with the Department's landscaping objectives. (While the defined clear zone may end at the poles, an errant vehicle may miss the poles and should be provided with as much additional deceleration distance as is practical.)

10.2.7.5 Camp (Seasonal Residence) Areas

Camp areas, such as those alongside many lakes, are a small part of the overall roadside environment, but they have generated a sufficient number of queries to warrant special coverage. While this section will refer to camp areas, the guidance should also be considered as applying to other areas with similar conditions.

Camp-type areas present significant challenges for barrier design. Access breaks are required at short intervals for driveway openings and walkways. Right of way is usually very tight. Fixed objects are numerous and close to the traveled way. The adjoining terrain is often steep. Water hazards are often accessible. Alignments are often quite curved to follow terrain. Seasonal traffic volumes may be relatively high and operating speeds are often within the high-speed category. Typically, cable is not used because of its large deflection distance and the length needed to develop its lateral strength. Both cable and W-beam would be expensive due to the many anchor blocks that would be required for the frequent openings. W-beam also takes a significant length to be effective and is considered a poor aesthetic choice for camp areas. By default, box beam is generally the preferred barrier choice.

When it is decided to provide shielding by installing box beam guide rail, none of the terminal options are without performance limitations. The following information addresses the issues with each of the terminals in turn and then offers suggestions as to when it might be appropriate to select a given system.

Type 0 Terminals: The Type 0 ("Buried" in Back Slope Terminal) requires the presence of a back slope in relatively close proximity to the road. When there is such a relatively steep back slope in close proximity to the line of the rail, the Type 0 should be the preferred end treatment. In camp situations, the Type 0 terminals would be appropriate on the high side of the road at locations where box beam was needed to shield features such as incised watercourses cutting down the hillside.

Type I Terminals: With its abrupt 1 on 2 turned down end, the Type I end piece should not be installed on lead ends parallel to high-speed traffic. An essentially end-on impact would have four possible outcomes, which might occur in combination. One outcome would be unfavorable. The other three would, most likely, be quite unfavorable. Although unlikely, the vehicle might ride up on to the rail and then roll sideways off of it. The vehicle could be launched into the air, resulting in a subsequent impact with a fixed object or a rollover. The vehicle could fail the weld at the turndown, causing the box beam to spear into the passenger compartment. The vehicle might stop abruptly on impacting the terminal. Because of the above, Type I end pieces should only be installed where the end can be flared away from the road. For special circumstances, exceptions may be necessary in low-speed areas or in medium-speed areas where the run is very short.

Type I terminal assemblies are designed to be installed so that all normal impacts will be side impacts. Vehicles that hit the end at a high angle will cause the terminal and adjoining rail to yield laterally as a cantilever, thereby minimizing the severity of the impact. If the errant vehicle bends the rail aside and passes beyond, any subsequent impact will be less severe due to the energy that was absorbed in bending the rail. Provided the ends are flared away, short runs of guide rail (less than the normally recommended minimum of 125 ft) may be used if it is judged appropriate. In this instance, redirection is not assumed, only some amount of attenuation.

In rare instances, where a Type I end can not be flared away from the road and the associated run is quite short, supported at no more than 7 post locations, it may be acceptable to install the

terminals without flare. In this case, it is assumed that the run and its terminals will separate from the posts, allowing them to act like an attenuator, rather than a fixed, ramping, or spearing object.

Type II Terminals: As stated in Section 10.2.5.4 C, the Type II terminal has been disapproved. While the terminal itself is not judged to be a hazard for low speed contacts, the camp environment typically has steep topography and hazards close to the road, making it preferable to use a terminal that absorbs impact energy rather than passing the vehicle over the terminal.

Type IIA Terminals: In 2007, development began on a terminal that could essentially replace the Type II and function acceptably in high-speed locations. FHWA provided conditional approval for the new terminal on May 18, 2010. The Type IIA is basically a Type I end piece connected to the run by a tightly curved length of box beam (18 foot length, shop curved to a 35 foot radius). The ramped end piece could destabilize an impacting vehicle, so the Type IIA should generally only be used where the end will be close to the limit of any clear area.

Type III Terminals: The Type III terminal is actually an optional item that allows the contractor to select one of two proprietary terminals. Both are designed to be energy-absorbing. Both have a face plate on the leading end of a normal-height guide rail. The WyBET includes a section of a larger-than-normal box beam that telescopes around the regular box beam. When the end is struck longitudinally, the telescoping action causes the crushing of a pair of sacrificial fiberglass pipes inside the box beams. The crushing action produces the energy absorption. One of the limitations of the WyBET is that it must have a completely straight alignment for the first 50 ft to permit the telescoping to take place. The BEAT absorbs energy by slicing open the box when a mandrel behind the impact face is driven inside the box.

If Type III terminals were applied on each end of a run, their length alone, absent any other rail, would require minimum runs of 100 feet. Also, the extensive grading required (often around 60 cy) does not lend itself to this terrain or type of development.

The Type III terminals are a relatively expensive option with typical installed costs of \$4000. The large face plate and breakaway hardware make it the most visually obtrusive of the three box beam terminals. The large face plate should be flared away from the roadway by at least 2 ft to avoid the significant problems that would result if it were struck by a snow plow.

The standards for installation of Type III terminals are intended to maximize safety for roadside conditions that are normally associated with interstate highways. They presume that the prevailing clear zone is broad and readily traversable. FHWA therefore recommended that any installation have a clear area behind the rail that runs for 75 ft along the rail and 20 ft back from the rail. These requirements are unrealistic in most camp areas and, if held to, would provide a spot treatment significantly safer than what would normally be found in adjoining unshielded areas. While designers should always strive to provide clear areas adjacent to highways, failure to provide that recommended clear area behind a Type III will not cause the Type III to malfunction. Any inability to provide the recommended clear area behind a Type III terminal should not be seen as preventing its use in camp-type situations. The objective should be to provide a terminal that is not a hazard in itself. While vehicles that strike the end of a Type III terminal (includes the rail back to the third post) are likely to pass into the area behind the rail, this is essentially what would happen with a Type I or Type IIA and little better than what would happen with a Type II installation.

A. When to Use Box Beam in Camp Areas

Before deciding what type of end sections to use, the question of whether or not to even use guide rail should be resolved. It should not be an automatic assumption that guide rail should be provided wherever possible, just because there are fixed objects near the road. The following questions should be considered.

1. Is there a history of ROR accidents that is significant enough to warrant the installation of barrier? Unless the number and severity indicate a need, the expense may not be justifiable.
2. Are there specific problem locations where there is either a history or the likelihood of ROR accidents? Suspect areas include the outside of blind or unexpected curves, areas with hidden driveways, curves at the bottom of ice-prone down grades, etc.
3. Are there areas where the consequences of leaving the road are unusually severe? There are many locations where a vehicle that skids off the road would impact a tree. Drivers who survive the initial impact without major trauma would likely survive the accident. On the other hand, if a vehicle rolls over on a steep slope and submerges in water, even a mildly injured rider would likely drown. It would, therefore, be appropriate to provide shielding where errant vehicles would be likely to reach bodies of water.
4. Are there areas where people adjoining the highway will need protection from the errant vehicles? While many camps will have trees between them and the road, some may not. Certainly, if the adjoining property owners wish to have shielding, that should be taken into consideration.
5. Will the installation of guide rail make the roadside significantly safer? If the driveways are relatively closely spaced, the percentage of the roadside length that will actually be effectively shielded will remain quite low. Most of the length will consist of driveway openings and end sections that are not capable of redirecting vehicles. Only a small part of the roadside will be shielded by the redirecting portion of rail between the terminals.

In light of the above considerations, the most likely places to warrant box beam guide rail in camp-type settings will be where lengths of over 125 ft can be installed on the outside of curves, at common accident locations, and where an errant vehicle could be expected to reach a body of water. Additional use is left to the designer's engineering judgment.

B. Terminal Selection for Box Beam Guide Rail in Camp Areas

If it is judged that a run of box beam guide rail should be installed, the following are recommended guidelines for selection of the terminal type.

Type IIA or Type I terminals should be used whenever the terminal can be satisfactorily flared enough so that near-longitudinal impacts on the ends are unlikely. The combination of the flare angle and the vehicle's divergence angle should result in a combined impact angle that is often 45° greater than an in-line hit. The choice between a Type IIA and a Type I would depend on the available ROW and the amount of clear area.

If the available ROW does not permit flaring the terminal enough to use a Type I or a Type IIA, than a Type III should be considered. If the curvature of the road requires use of curved rail at the terminal, a Type III can not be used and a Type IIA should be used and an easement obtained.

The Type III terminal should be used when there is not enough available ROW to flare back a Type I end, but there is at least 20 feet of clear area behind the rail, the slope is 1 on 4 or flatter, and the rail and terminal can be installed along a straight line at least 100 feet long.

The Type 0 should be used when a back slope is in close proximity.

Designers should form their own evaluations of site-specific conditions and use their own engineering judgment to determine the shielding that they judge appropriate for each situation.

10.2.7.6 Driveways and Ramps Adjacent to Bridges and Culverts

Perhaps the most commonly encountered special problem in developed areas occurs where the proximity of a driveway or ramp to a bridge or culvert prevents use of the standard length transitions from bridge rail to highway rail. Guidance on dealing with these situations may be found in numerous places throughout this chapter, but is compiled and repeated here for the designer's convenience. The guidance has been organized in the form of a step by step procedure to determine an appropriate, customized barrier design for the specific conditions at a site where an access point (ramp, driveway, street) is too close to a bridge to permit use of a standard length guide rail transition.

There are three primary areas of concern that should be addressed in the design process.

- Concern 1. The barrier transition should minimize the possibility of a vehicle crashing on the end of a bridge's parapet wall or bridge railing system. This is usually the easiest of the three concerns to address. A range of acceptable details have been developed and are presented on the Bridge Detail drawings and the Standard Sheets. They, and therefore this Concern 1, will not be discussed further in this chapter.
- Concern 2. What would be the likely consequences of a vehicle reaching the feature(s) beyond the proposed location for the barrier?
- Concern 3. What would be the likely consequences of a vehicle striking the barrier or its terminal immediately downstream from the driveway or ramp?

Concerns 2 and 3 help guide the judgments that must be made in the following recommended procedure.

1. Evaluate the risks that would be encountered in the absence of a barrier.
2. Based on the risks, decide what degree of shielding effort is desirable.
3. Evaluate what restrictions there are that would limit installation of the desired shielding.
4. Select barrier type and provide location details.

No process can provide satisfactory solutions for all possible occurrences. There is simply too much variability in the range of possible events. Outcomes will vary widely depending on highly variable factors such as vehicle speed, angle of departure from the highway, pavement surface conditions, side slopes, traffic volumes or depths of water under the bridge, growth or removal of trees from the shielded area, etc. Injury outcomes will also be highly dependent on the type of vehicle being driven. Based on both frequency of the vehicle in the stream of traffic and the ability to provide systems appropriate to the vehicle type, the vehicle type that should be designed for will be mid-sized vehicles, such as passenger cars, pickups, vans and sport utility vehicles, rather than large trucks or motorcycles.

A. Risk Evaluation

In order to analyze the above Concern 2, the features that could be encountered can be classified into four levels of risk.

- Risk Level 1. The errant vehicle would endanger lives beyond those of its occupants. The typical case would be if the feature the bridge is crossing is a high-speed,

- high-volume freeway, where an intruding vehicle could produce a multi-vehicle pileup with multiple fatalities.
- Risk Level 2. The errant vehicle would encounter a feature(s) likely to kill its occupants. The most common example of this would be a deep body of water that could cause drowning deaths. The varying degrees of danger posed by water features are discussed in Section 10.2.1.1. Another example would be a deep gorge where the vehicle could land upside down.
- Risk Level 3. The errant vehicle would encounter features likely to cause a crash severity significantly greater than elsewhere along the roadside. Example would be a dry stream bed that the vehicle would dive into or a steep embankment likely to cause a rollover. Another example would be trees or similar fixed objects in locations that would offer significantly less braking opportunity than is available in the clear zone at other points along the highway.
- Risk Level 4. The errant vehicle would encounter features essentially identical to other features found along the roadside. An example might be found on a low-volume rural highway with very narrow clear areas. A vehicle that went beyond the location proposed for the guide rail would typically crash promptly into trees at the edge of the clear area and would be very unlikely to reach the feature that the bridge crosses over.

B. Selecting the Objective for the Barrier

When addressing Concern 3 (the consequences of striking the barrier), the designer should consider the risk level of the features being shielded. The more important it is to prevent the errant vehicle from passing behind the barrier, the more acceptable it is to use a barrier that yields little and whose rigidity is less forgiving when struck.

For Risk Level 1 cases, where penetration by the vehicle will endanger multiple lives, it is appropriate to provide a barrier that will, with a high degree of reliability, prevent a vehicle from passing the barrier, even if a collision with the barrier is likely to endanger the lives of those in the errant vehicle. As an example, it might be appropriate to provide a concrete barrier to prevent an errant vehicle from crashing down onto a freeway and causing a multi-vehicle pileup. Whether the occupants of an errant vehicle crash into a concrete barrier or down into busy traffic, they are at risk. The freeway users should not also be placed at risk.

For Risk Level 2 features, such as a deep body of water, it is desirable to provide barrier to prevent an errant vehicle from reaching the feature. However, the consequences of striking the barrier must be weighed against the consequences of reaching the feature. Shielding a stream with a concrete barrier would be a poor choice if ending up in the stream is likely to be more survivable than a high-angle crash into a concrete barrier close to the road. It will generally be preferable to provide a guide rail system that will yield when impacted, even if there is an increased chance that the yielding system may permit some vehicles to reach the water. (If trees are left in place that will prevent the errant vehicle from reaching the water, the potential hazard being shielded ceases to be the body of water and becomes the trees themselves; a Risk Level 3 problem.)

A similar strategy can be adopted if the feature the bridge crosses over is a highway with high-speed traffic, but low volumes. In this case, there is some possibility that an errant vehicle which reaches the lower highway, at any speed, will be involved in a collision with a high-speed vehicle, but a large chance that it would not. The guide rail between the ramp or

driveway and the lower highway should be flexible to minimize the consequences of colliding with it, particularly if there is a low probability of disastrous consequences if the vehicle reaches the area beyond the rail.

For a Risk Level 3 condition, one where the area behind the rail has significant hazards but does not include “potentially fatal at any speed” hazards, it is desirable to provide a barrier system that could safely prevent vehicles from reaching the hazards. If that is not reasonable, the next acceptable option is to have the barrier function as an attenuating structure, slowing the vehicle, but not necessarily being able to stop it. If the speed can be significantly reduced before the vehicle strikes a fixed object, the accident severity will also be significantly reduced.

For a Risk Level 4 situation, one where the conditions behind the rail are not significantly different from those of the prevailing clear zone, the primary requirement of the guide rail and terminal system is that the typical collision with the system not result in an accident that would be more severe than if the system had not been present. In other words, the primary goal should be to minimize the hazardousness of the guide rail and terminal. As a secondary goal, it is desirable for the terminal system to provide attenuation.

C. Site Restrictions

Once it has been decided what the desired shielding should be, the site restrictions should be evaluated to determine what can reasonably be accomplished. In some instances, it may be reasonable to consider moving the driveway or street farther away from the bridge to permit placement of a better barrier transition. This would be the case if the relocation was relatively easy to perform and it was judged important to obtain additional space to achieve a reasonable barrier transition.

In addition to longitudinal restrictions, there may be lateral restrictions to guide rail placement, typically due to Right-of-Way limits, but sometimes due to the presence of buried utilities or steep drop-offs. A given site may be categorized as:

- Laterally unrestricted, such as where the intersecting access is an on ramp within state ROW,
- Moderately restricted laterally, such as where there is a 10 ft to 20 ft width of ROW beyond the shoulder, or
- Tightly restricted laterally, such as where there is less than 10 ft beyond the shoulder within which the guide rail and its terminal may be placed.

In some instances, it may be reasonable to consider widening the space available for placing the terminal. This would be the case if it were relatively easy to flatten some side slopes. If it was deemed very important to provide additional width to permit placement of a barrier, it might be appropriate to purchase property or to arrange for a permanent easement.

D. Type Selection and Alignment Details

Once the Risk Level has been judged, the intended function of the barrier system has been decided, and the site restrictions have been determined, the designer should address type selection and placement options.

D.1 Type Selection

There are essentially only three types of highway barrier that are currently approved for use in or immediately after transitions from bridge rail and parapet walls. These are box beam, HPBO corrugated beam, and concrete barriers.

The concrete barrier is a good choice when the objective of the barrier is to prevent an errant vehicle from passing beyond the barrier and this objective over-rides concerns about the severity of the collision with the rigid barrier. A challenge to its use is how to place it on a tight curve. Prefabricated units are usually straight sections and poured concrete barriers are typically slip-formed in relatively straight configurations. To smoothly follow a curve, the barrier needs to be poured into curved forms. Another challenge is selecting an end treatment. Refer to Section 10.2.5.5 and 10.2.6 for discussion of means of terminating concrete barrier.

Box beam and HPBO W-beam both perform satisfactorily at redirecting vehicles when they are aligned parallel to traffic. Different considerations apply when they are curved sharply away from traffic or positioned perpendicular to traffic. On a tangent run, W-beam gets much of its strength from the “bow string” effect of tension that develops between the anchor systems when the rail is deflected. If a tight convex curvature is placed in the run, however, most of the guide rail's resistance to deflection must come from the support provided by the heavy posts. The system can be made stronger, but less forgiving, by adding intermediate posts. With high-energy, right angle impacts, there is an increased likelihood that bolts connecting individual pieces of rail will tear through the ends of the rail. If the pieces separate, the vehicle will be able pass through the rail system

The strength of box beam which has been curved to run down a ramp can vary greatly depending on where it is struck. Since it lacks an end anchor, a lateral impact near the end will encounter fairly low resistance to penetration. The posts used as end anchors simply pull out of the ground or the rail separates from the posts and the rail bends easily as a long cantilever.

A lateral impact in the middle of a long tangent run encounters better resistance. In this case, the relatively strong box beam behaves as a beam supported on both ends. Until the beam deflects past them, the weak posts provide significant, but fleeting, support. The rail itself is much stronger than W-beam and less likely to tear through and separate.

A severe impact is likely to result from a perpendicular impact into a tightly curved section of box beam that is well supported by tangent sections in line with the ends. In this case, the rail functions as an arch with solid axial support. (If a terminal end is close to the tightly curved section, the arch is poorly supported and will fail as a bent cantilever.)

D.2 Location and Alignment

In general, the preferred placement option will be to curve the barrier to run it up the side of the intersecting ramp, road, or driveway. The first reason for this preference is that it will generally be preferable to hit the side of a guide rail system rather than its end. The second reason is that the farther back from the main road the barrier can be extended, the more thoroughly the barrier will shield the approaches to the feature the bridge is crossing over. In most laterally unrestricted situations, the preferred option will be to transition from the bridge rail system to the highway rail system and run it down the intersecting ramp or road.

In instances that are tightly restricted laterally, the area behind the terminal should be considered. If there is relatively little lateral distance to obstructions, then a conventional turned down terminal for a W-beam rail or a Type IIA terminal for a box beam rail will be acceptable. (Type I terminals should not be used if they can not be flared away through at least 20 degrees.) While a turned-down terminals might contribute to rollovers if there was more open space, that risk is not significant if there is very little space. Use of the comparatively expensive proprietary NCHRP350 compliant terminals does not make economic or safety sense as they are also likely to gate vehicles through to the shielded objects.

If the area behind the rail appears to provide good recovery opportunities, but the barrier can not be flared back, serious consideration should be given to using an NCHRP350 compliant terminal. The choice between that and a conventional turned down terminal should take into account the traffic speed, volume and any significant accident history or adverse geometry that would be likely to contribute to future accidents.

If the clear area behind the rail allows access to an area that should be shielded, consideration should be given to providing a supplemental run of guide rail upstream from the intersecting road or driveway as illustrated in bottom panel of Figure 10.4c.

The sites that are moderately restricted laterally tend to have the most straight-forward solutions. Usually, the rail should simply be flared back as far as the restriction will permit. This places the terminal as far from traffic as possible and does as much as possible to shield access to the features the bridge is crossing over. As mentioned earlier, the loosely anchored end of a box beam guide rail does not have a high resistance to vehicle penetration to the area beyond the terminal. If it is considered important to prevent access to the feature the bridge is crossing, consideration can be given to placing a separate “run” of rail beyond the terminal to act as a backup. This short section of barrier could consist of a single length of rail supported on heavy posts and located close to the shielded feature. Its intended function would be as an attenuating structure to capture vehicles that passed the primary run of guide rail connected to the bridge rail or parapet wall.

10.2.7.7 Hydrant Fenders

Hydrant fenders are similar to bollards and are placed beside hydrants with the intent of preventing vehicles from striking the hydrants. They should only be placed in an urban setting behind a parking lane, within or adjacent to parking areas, or in similar settings where they will not be directly accessible to errant high-speed vehicles.

10.3 EXISTING FACILITIES

The roadside design concerns that should be addressed on an existing facility are typically dependent on the roadside conditions and the type of project to be undertaken. There is some interaction between these factors. The roadside conditions can influence what type of project is undertaken. Conversely, the type of project can influence the extent of the roadside improvements to be done, or even if the roadside is to be addressed.

Roadside conditions on existing facilities will be addressed on reconstruction projects and on 3R and 2R (simplified 3R) projects.

On 1R projects, the scoping and/or Road Safety Audit team will note the condition of the roadside and other issues. They will determine whether or not to recommend that specific features (e.g., the length, type, or condition of guide rail; brush removal, clearing and grubbing; or fixed objects), be addressed by the project. As needed, roadside work is to be included in 1R projects to avoid degrading safety or to address existing or potential safety problems. The Regional Director will make the final decision on what features will be addressed.

On guide rail replacement/installation projects, the scoping and/or Road Safety Audit team should consider the relationship between the clear area and the guide rail. If improvements can reasonably be made to the clear area so that a specific run can be removed, significantly shortened, or not installed, then the project should include clearing (and regrading if appropriate) at those locations. If there are areas where the clear area is judged inadequate for the project objectives, then the area should be widened or the potential hazards shielded. In general, a clear zone width does not have to be documented for a guide rail project, but the decision to remove a run should be, along with the rationale.

Roadside conditions will generally not be addressed by maintenance-type activities, such as restriping, sign and signal, bridge cleaning or painting, pavement sealing, etc.

For other types of projects not covered by the above guidance, refer to the guidelines for that project type to determine the extent to which the provisions of this chapter apply.

Broadly, for those projects that involve roadside design, the process will include site evaluation, design, and documentation. For any projects involving roadside design on existing facilities, evaluation should consider the factors covered in Section 10.3.1.2, Site Inspection. For projects that require that roadside design be addressed, an accident analysis should also be performed, as discussed in Section 10.3.1.1. A less rigorous accident analysis may be required for 2R projects (see the current guidance for that project type) and less still for 1R projects, which require “a simple analysis of site-related computerized accident data.”

The roadside design for reconstruction projects and for interstate and freeway 3R and 2R projects should follow the guidance in Section 10.2. For other existing facilities whose projects need to address roadside design, particularly non-freeway 3R and 2R projects, the clear zone guidance should follow Section 10.3, while the design of barrier systems should follow the guidance in Section 10.2 with the modifications permitted in Section 10.3.

Documentation of roadside designs should follow the guidance in Section 10.2 with exceptions noted in Section 10.3.

Table 10-6 Location of HDM Guidance on Roadside Design Process for Existing Facilities

PROCESS STEP		PROJECT TYPE		
		Interstate and Freeway 2R/3R, Reconstruction	NonFreeway 2R/3R	Other
Site Evaluation	Accident Analysis	5.3, 7.2.5 and 10.3.1.1	5.3, 7.3 and 10.3.1.1	5.3 and 10.3.1.1
	Site Inspection	10.3.1.2	10.3.1.2	10.3.1.2
Determination of Detailed Scope of Work		7.2.1.2 and 10.3.2.1	7.3 and 10.3.2.2	See Guidance for Specific Project Type
Remediation of Features Included in Detailed Scope		7.2 and 10.2	10.2 and 10.3.2.2 B	10.2

Projects involving existing facilities present special opportunities and problems. The main opportunity is the ability to assess how the safety systems have actually performed and to evaluate how much of a problem some deficient features have been. The first major problem in working with existing facilities is the number of restrictions placed both on (1) the amount of space that may be used for clear zones and placement of safety features and (2) the construction effort in order to accommodate traffic.

The focus of Section 10.3.1 is on the second major problem with existing facilities, which is how to determine an appropriate scope of work for the selected type of project. Unlike a new facility where everything must be built new and to current standards, an existing facility may contain many components that have aged and possibly deteriorated and systems that are no longer the preferred system. It would be economically prohibitive to upgrade all features on a project to current guidance or standards any time that section of highway is worked on. Judgment must be exercised to decide whether a feature can still function adequately even though it does not conform to current guidance.

10.3.1 Evaluation of Existing Facilities

The proper evaluation of an existing facility includes two primary activities. First, the relevant accident data should be reviewed for indications of features that are not performing well or locations where extra attention to roadside design may be appropriate. Second, a detailed site inspection should be performed to determine possible explanations for recorded accidents and to identify nonconforming features and roadside safety concerns and opportunities.

10.3.1.1 Accident Analysis

Prior to site inspection, the project developer/designer should review computerized accident data, as required for most project types. Refer to Chapter 5, Section 5.3, for a description of the various components, options, and interpretation guidelines for accident analyses. In some instances, it may be possible to perform one analysis to cover both scoping and design needs. On larger projects, it will generally be necessary to perform a preliminary analysis during project scoping, followed by a detailed analysis during design. While not required for some project types, an accident analysis is advisable for any project involving roadside design. (At present, all reconstruction, 3R, and bridge projects (except minor bridge rehabs) require accident analyses. The 2R safety screening may also indicate the need for a detailed analysis.) Any significant accident patterns that show up should be investigated in the field. (Note that, on some low-volume roads, there will be fewer accidents and trends may only become obvious if more than three years of accident data are investigated. Input should be sought from the Regional Traffic Engineer regarding the accident history and the appropriate length of study period.) The project developer/designer should try to determine if any specific highway features contributed to the accidents so that appropriate mitigative measures can be evaluated.

10.3.1.2 Site Inspection

The level of information needed to secure design and PS&E approval is typically more detailed than that required to reach project scoping closure. In some instances, however, it may be convenient to make one detailed inspection to satisfy both functions. Regardless of when it is accomplished, a detailed site inspection shall be performed for any proposed project where significant modifications to the guide rail system or the clear zone are normally included in the project. Where vegetation may obstruct the view of the roadside area, it is desirable for inspections to be scheduled for shortly after mowing. Detailed site inspections should not be scheduled for times when features may be obscured by snow cover.

As noted in Chapter 13, the detailed site inspection should be coordinated with the Regional Utilities Engineer to identify any utilities that may need to be moved or altered to achieve the desired safety improvements. The Regional Landscape Architect or Environmental Contact should also be involved, especially in developed and/or environmentally/culturally sensitive areas.

Section 10.2.1 describes a key issue that should be understood before discussing roadside site inspections. The issue relates to the distinctions between concerns for safety and for liability. The primary concern is to address safety. With respect to roadside design, safety is addressed by the term “clear area”, while the term “clear zone” relates to liability. Clear area is the portion of the roadside environment, starting at the edge of traveled way, from which hazards are

essentially absent. The clear zone is the portion of the roadside environment, starting at the edge of traveled way, which the Department commits to maintaining in a cleared condition for safe use by errant vehicles. "Clear area" refers to a physical reality while "clear zone" refers to an obligation. The clear zone commitment may be conveniently defined as one or several uniform widths. The width of the clear area can not be conveniently defined as it varies continuously along the highway and will change over time. However, it is the actual clear area, not the invisible clear zone, which affects the safety of occupants of errant vehicles. Therefore, when evaluating the safety of a facility, the scoper/designer should first examine the clear area. Only after the safety provided by the clear area has been addressed should attention be given to establishing limits of liability by documenting the clear zone width(s) for a project.

For scoping purposes, the clear area portion of the inspection may be aimed at generalized conditions. Examples of impressions that should be recorded include the following:

- general adequacy of the clear area width
- frequency of locations where the clear area appears too narrow
- ease with which narrow clear areas could be expanded
- ease with which appropriate widening of the wider portions of the clear area could be achieved
- evidence of previously constructed clear areas that need to be reestablished
- presence of trees or other fixed objects in the clear area needed for guide rail deflection
- influence of embankment steepness on the safety effectiveness of the clear area
- need for additional barrier where acceptable widths of clear area can not be reasonably obtained

A roadside inspection performed to support detailed design should be more exacting, but may or may not warrant development of more detailed documentation, as discussed in Section 10.3.3. Ideally, the inspection for detailed design will occur after the scoping team has made their recommendation for the clear zone width(s) and any clear area widening. The detailed roadside inspection should be sufficient to support making decisions on the following issues:

- the limits of any clearing or regrading to be shown on the plans, including clearing for guide rail deflection
- specific limits of any locations where the clear zone will be designed to widths narrower than the target set by the scoping team
- locations of any specific features that may need to be targeted for remediation, such as those described below in subsection B, Identification of Roadside Safety Concerns and Nonconforming Features
- specific locations where potential hazards will remain within the clear zone and either need new barrier to be placed or documentation of the decision not to shield

When in the field, the project developer/designer should look for any evidence of previous impact accidents as indicated by paint marks or damage on objects other than barriers, as these will provide a good indication of where some combination of signage, geometric, or clear area improvements or guide rail placement may be needed. **The project developer/designer should also note locations where moderate improvements to the roadside environment would permit establishment of a satisfactory clear zone and allow the guide rail to be eliminated.** When noting nonconforming features and potential hazards during the site inspection, attention should be focused on the features that are within, or will form, the boundaries of the clear zone. Where expansions are being considered, safety concerns should

be noted to the limits being considered. As noted in Section 10.2.1.1, however, features that may reasonably be expected to be reached by an errant vehicle and that may be hazardous when encountered at any speed should be noted, even if they are beyond the clear zone.

It is desirable for the project developer/designer to make a written record of the site inspection for inclusion in the project documents. The purpose of this effort is to further document that the Department was diligent in its efforts to provide a reasonably safe highway. As a minimum, state in the design approval document what specific clear zone widths have been selected for each side of the road (in both directions of travel on divided highways) and each segment of highway and state that all obstacles and nonconforming features, except the noted exceptions, are to be removed from those zones. However, sufficient detail must be obtained to develop the quantity estimates.

A. Desirable Content of Site Inspection Records

Ideally, the record should list the date of the inspection, the name of the person(s) performing the inspection, their functional responsibilities (i.e. Traffic, Maintenance, Construction, etc.), and descriptions of the points where the inspection began and ended. Each shoulder (or side of the median, when appropriate) should be listed separately. It is desirable for the record to include a list of brief descriptions of observed roadside safety concerns and nonconformities and for the location of each to be identified by reference to readily identifiable landmarks, established stationing, surveyed baseline or reference markers. Where groups of potential hazards are present, such as trees, utility poles, or driveway ramps, the type may be given once, followed by a location list. Offsets from edge of travel lanes should be noted. As an aid to subsequent scoping/design, the project developer/designer may make note, in the field, of possible remedies to observed deficiencies.

B. Identification of Roadside Safety Concerns and Nonconforming Features

Nonconforming features (defined in Section 10.1) that should be noted during detailed site inspection include, but are not limited to, the items presented in the lists below. The lists include barrier-related items, cross-section-related items, fixed objects, and roadside obstacles. These lists are not all-inclusive, nor in priority order. Rather, they serve to illustrate the types of features that should be noticed during inspection. The guidance and/or standards for the type of project selected will determine which features must be remedied. It should be noted that the presence or identification of a safety concern or nonconforming feature within the proposed project area does not necessarily require the remediation of that feature. Remediation of a specific feature may not be required by the project type that is determined to be the best type for the prevailing conditions. As a case in point, 3R projects have a "basic safety package" of features that are to be addressed while other features may not need to be addressed if they do not have an associated accident history.

Barrier-Related Nonconforming Features and Safety Concerns The designer should be cautious about specifying "Reset" or "Replace in kind" when dealing with barriers and attenuators. The adequacy of a barrier's type, placement, anchorage, etc., must be carefully reviewed. Attenuators of any kind should be reviewed to confirm that their design and placement are appropriate for the anticipated speeds. Any new or replacement barriers or

attenuators shall be installed in conformance with current standards, including point of need, or an explanation provided in the design approval document. In general, the following and similar instances of outmoded guide rails shall be upgraded to current standards or the conditions warranting their use shall be eliminated, unless it is prudent and permitted to do otherwise for the type of project being progressed. Some of the items, indicated by asterisks, may be acceptable in certain circumstances.

1. Old "boxing glove" or "spade" terminal sections or no end treatment on the lead end of corrugated beam guide rail.
2. Concrete guide rail posts.
3. Outdated guide rail types.
4. Box beam with external couplings or single-bolt (per side) internal couplings. Box beam guide rail or median barrier installed prior to June 12, 1975, are not to be reset and should be removed and replaced whenever practical. Refer to Section 10.5.7.
5. Unremoved wooden posts on driveway openings in guide rail (old design).
6. Previous generation weathering-steel guide rail posts that have experienced severe rusting at the ground line.
7. Deteriorated or nonfunctioning guide rail.
8. Damaged guide rail.*
9. Guide rail with mounting heights (after resurfacing) above or below the limits specified in Table 10-7.
10. Unanchored cable or W-beam guide rail.
11. Breakaway hinges that have been welded together.
12. Inadequate tension in cable guide rails.
13. Cable guide rail on radii tighter than 440', such as at corner intersections.
14. Rising or tilting of cable guide rail anchor blocks.*
15. Excessive erosion around guide rail post systems.
16. Utility poles, boulders, trees over 4 inches in diameter, or similar fixed objects within the deflection distance or clear runout area of a barrier system.
17. Isolated trees within the clear zone.**
18. Growth of trees (not yet 4 inches diameter) within the deflection distance of guide rail.*
19. Guide rail anchorage not flared back to within 1.5 ft of current guidance.
20. Guide rail that interferes with access for disabled persons or sight distance requirements.
21. Guide rail anchorage not carried fully to adjacent back slope.*
22. Guide rail not meeting point of need requirements.*
23. Lack of durable separation barriers for cliffs or deep bodies of water.*
24. Unshielded ends of bridge railings or parapet walls.
25. Bridge approach guide rail not attached to structure in a crashworthy configuration. (See AASHTO's *Roadside Design Guide*)
26. Unshielded abutments and wing walls.
27. Unshielded bridge or building piers.
28. Unshielded blunt ends of concrete barriers within the clear zone.
29. Curbs that are unwarranted, vertical faced, or higher than 4 inches on high-speed highways.*
30. Curbs over 4 inches high placed 1 to 10 feet in front of barriers on medium- or high-speed highways.*
31. Curbing, other than traversable, within 10 ft in front of flexible guide rail on high-speed highways.*
32. Any type of curbing used in conjunction with concrete barrier.

33. Curbing used in front of crash attenuators.
34. Concrete filled steel posts or railroad rail protecting breakaway fire hydrants.
35. Absence of 200 lb sand barrel at front of array (to accommodate small automobiles).
36. Old Hydrocell impact attenuators no longer meeting manufacturer's criteria.
37. Posts inclined more than 15 degrees from vertical.
38. Type I terminals not flared away from traffic.*
39. Type II terminals on high-speed highways.*

* Items followed by asterisks may or may not require remediation, depending on the degree of unconformity, site restriction, or other conditions. Engineering judgment should be applied in determining whether and to what degree remediation is warranted.

** Items followed by a double asterisk may be determined acceptable in special circumstances, but should have the rationale documented if not remediated.

Cross-Sectional and Drainage Feature Nonconformities and Safety Concerns

1. Protruding headwalls on lateral culverts.
2. Squared ends or headwalls on longitudinal drain pipes with diameters over 12 inches.
3. Where tapered end sections are provided, open, ungrated inlets and outlets on longitudinal drain pipes over 18 inches in diameter.
4. Ungrated, but flush, cross-drainage structures with open widths of more than 32 inches.
5. Nontraversable longitudinal ditches. (See Section 10.2.1.1.)
6. Unrounded edges of ditch bottoms.
7. Unshielded highway embankment fill slopes steeper than 1:3 and higher than 3 feet. (Note that fill slopes steeper than 1:3 but 1:2 or flatter may be retained on all but reconstruction projects as long as their height is 3 feet or less. However, such slopes should be flattened when the scope of the project makes that reasonable.)
8. Unshielded nontraversable lateral ditches and waterways. (See Section 10.2.1.1.)
9. Lateral embankments (driveway ramps, etc.) with slopes of 1:2 or steeper and heights greater than 2 feet.
10. Median crossovers with longitudinal slopes steeper than 1:6 for high-speed roads and steeper than 1:4 for roads with operating speeds of 40 to 50 mph.
11. Unrounded shoulder breaks above slopes steeper than 1:5.
12. Clear zones ending at uneven rock cuts or outcrops with protrusions over 6 inches.
13. Sidewalks, curb ramps, and other pedestrian facilities that do not meet ADA guidelines.

Fixed Objects and Roadside Obstacles. Fixed objects are defined as permanent installations, limited in length, which can be struck by vehicles running off of the road. Because of their limited extent, fixed objects should usually be removed from the clear zones, rather than being shielded with a barrier. During the site inspection, attention may be limited to those objects that are within the existing designed clear zone width, except in areas where it is reasonable to consider expanding the clear zone, in which case objects within the potential clear zone width should be noted. The following items are examples of fixed objects and roadside obstacles.

1. Trees over 4 inches in diameter in the clear zone.
2. "Spearing" fences. (See Section 10.5.2.1.)

3. Large planters.
4. Hazardous mail boxes or landscape features.
5. Nonbreakaway signs.
6. Use of inappropriate slip bases on signs: unidirectional where omnidirectional required or unidirectional with wrong orientation.
7. Metal conduits on outside of breakaway poles or posts.
8. Footings protruding over 4 inches (including those for breakaway signs).
9. Driveway headwalls.
10. Fixed objects in a ditch that is likely to "capture" a vehicle.
11. Utility poles in the clear zone.
12. Walls with snagging features or corners of walls
13. Presence of curbs over 4 inches high on roads with operating speeds of 50 mph or greater. (Also check Section 10.2.2.4 to see whether use of any curbs is appropriate.)
14. "Strong" or "heavy" fences. (Includes Rock Catchment Fences.)
15. Hydrant bases more than 4 inches high.

Note that, while trees less than 4 inches in diameter are not considered to be fixed objects, they should still be removed from the clear zone or deflection area. If not, they can grow into fixed objects between the time of one project and the next time that work will be done in the same area. Note also that a few special tree species will not grow to exceed that size and may have been specifically planted with that consideration in mind.

Roadside Obstacles. These differ from fixed objects in that roadside obstacles are of considerable length and are therefore generally much less practical to remove or relocate. Note that the location within the clear zone may determine whether the obstacle should be considered a safety concern or a nonconforming feature. (See 10.1 for definitions.) The following features are examples of roadside obstacles.

1. Dense woods. (Items 1, 2, and 3 may also be treated as a series of fixed objects.)
2. Rows of large trees
3. Rock outcrops or boulders intermixed with trees.
4. Rock cuts where fallen rock may reach or has reached the roadway. (Consult Regional Geotechnical Engineer.)
5. Rough or uneven rock cuts with protrusions of over 6 in. in the potential impact zone.
6. Cliffs or precipitous drop-offs within the clear zone.
7. Bodies of water, including streams and channels over 2 ft deep, within the clear zone.
8. Unshielded cliffs or bodies of water that are beyond the desired minimum clear zone, but that are likely to be reached by an errant vehicle. (A safety concern.)
9. Retaining walls with protrusions of over 4 inches.
10. Smooth retaining walls. (A safety concern.)

In all cases above, these features should be considered high priority if they are associated with accident clusters or a greater-than-average history of accidents. Note that a smooth retaining wall will generally function like a concrete barrier and should be treated at that low level of concern. As a maintenance issue rather than a safety issue, it may be desirable to shield some panel wall locations to prevent large errant vehicles from damaging the panels.

Table 10-7 Acceptable Barrier Heights When Upgrading Existing Facilities

Barrier Type		Normal Height ¹ (in)	Acceptable Heights ⁵			
			Rail/Barrier Height		Post Height	
			Upper (in)	Lower (in)	Upper (in)	Lower (in)
Roadside Barriers	Cable	29 ²	31 ²	27 ²	34	30
	W-beam ⁶ (weak-post)	32 ³	35 ³	29 ³	35 ³ / ₈	29 ³ / ₈
	W-beam (Heavy-post)	29 ³	30 ³	28 ³	31	29
	Box beam	27 ³	30 ³	24 ³	30	24
	32" Concrete (NJ&F shapes)	32 ⁴	33 ⁴	29 ⁴	-	-
	42" Concrete (F and Single Slope)	42 ⁴	43 ⁴	32	-	-
Median Barriers	Cable	28 ²	30 ²	26 ²	33	29
	W-beam (weak-post)	33 ³	36 ³	30 ³	36 ³ / ₈	30 ³ / ₈
	W-beam (Heavy-post)	29 ³	30 ³	28 ³	31	29
	Box beam	30 ³	33 ³	27 ³	26 ¹ / ₂	21
	32" Concrete (NJ&F shapes)	32 ⁴	33 ⁴	29 ⁴	-	-
	42" Concrete (F and Single Slope)	42 ⁴	43 ⁴	32 ⁴	-	-

Notes:

1. Normally measured from the surface directly below the barrier. Measure from the pavement surface if curb is present within 12 inches of the railing.
2. Center of top cable at mounting point.
3. Top of rail at post.
4. Top of barrier.
5. Measured after resurfacing, when applicable.
6. The W-beam referred to is the Modified G2. Most weak post W-beam currently in service at the time of this publication is the older G2 system. The Modified G2 was developed to address vaulting problems with the G2. Among the changes was a two-inch increase in rail height from 30" to 32". The old height criteria for existing G2 systems previously allowed a minimum height of 27" which is no longer permitted. Whether a weak post W-beam is the G2 or the Modified G2, the allowable height range for existing installations is 29" to 35". (In the G2, the rail splice was fastened to the post. In the Modified G2, the splice is between the mounting posts.).

10.3.2 Detailed Scope of Work Determinations

As used here, determining the detailed scope of work is meant to include detailed decisions about whether or not a given specific feature will be included as part of the work. This should be distinguished from project scoping which is a comprehensive assessment of the nature of the project and what it is to accomplish. Guidance on project scoping is contained in the *Project Development Manual*.

If the project is to be a reconstruction project or an interstate or freeway 3R or 2R project, the clear zone width should be selected in conformance with the guidance in Section 10.2.1. Section 10.3.2.1 contains guidance for establishing the detailed roadside design scope, while the remediation of nonconformities and creation of roadside design safety features should be performed in accordance with the guidance for new and reconstructed facilities contained in Section 10.2.

If the project will be a nonfreeway 3R or 2R project, the detailed scoping for roadside design considerations should be developed in conformance with the guidance in Section 10.3.2.2.

For element-specific project types that may involve roadside design, such as Guide Rail Only, Safety Improvement, etc., the detailed scope of work should be developed in accordance with the guidelines for the specific project type and, as appropriate, taking into consideration the nonconforming features and safety concerns identified in Section 10.3.1.2.

For large or complex projects, different parts of the project may be progressed as different project types, such as portions of a 3R project being done as a reconstruction job, or vice versa. When separate types are used on the same job, the appropriate standards should be used to develop that portion of the project or that alternative. Also, if the project type changes during scoping or design, then the appropriate roadside treatment must be changed to reflect the requirements for the new project type.

Regardless of the project type, it is recommended that the final roadside design detailed scoping decisions be documented as indicated in Section 10.3.3.

10.3.2.1 Reconstruction Projects

It is intended that a reconstruction project bring an existing facility up to current standards. It is occasionally (frequently, in developed areas) not reasonable to do so in all areas of the project because of environmental, economic, or other considerations. Consequently, the width of the clear zone may need to be reduced in these situations from the desired to what may be reasonably achieved and all nonconforming features removed from that clear zone, or, as appropriate, shielded with a suitable barrier. Any of the nonconforming features noted during site inspection should generally be suitably remediated or, where upgrading or removal is judged inappropriate, the rationale should be developed and documented in the Design Approval Document. If nonconforming features are noted after the DAD has been finalized and those features will not be remediated, the rationale should be documented in the project files or, preferably, on the project plans.

10.3.2.2 3R Projects (Resurfacing, Restoration, and Rehabilitation)

(Note: In regard to roadside design, Interstate and other freeway 2R and 3R projects should be treated the same way as reconstruction projects. For further details, refer to Sections 10.2 and 7.2 of this manual.)

The major difference between roadside design for a reconstruction project and for a 2R or 3R project is the amount of effort that should be applied towards obtaining the desired clear zone width. On a reconstruction project, the effort to achieve the desired width should extend to what can be reasonably attained when considering factors such as cost, environmental impacts, timeliness, project scope, etc. On a 3R project, unless there is an accident history related to the roadside or the clear zone width is otherwise judged inadequate, any increase in the existing width may be limited to that which may be conveniently attained. While the widths that are developed for either project may vary, in both cases the quality of the zone (traversability, absence of fixed objects) should be similar.

Subsection A, below, describes the rationale for determining an adequate clear zone width. Subsection B lists some of the items that are part of the "basic safety package" for features within or adjoining the clear zone. Beyond this work, the decision to upgrade a given feature (typically done so that the effective width of the clear area may be increased at that location) may be based on evidence of that upgrade being either (1) part of an appropriate solution to an observed accident problem or (2) economically justifiable based on potential safety benefits. The decision process is discussed below in subsection D.

A. Clear Zone Width Determinations for Nonfreeway 3R and 2R Projects

In general, at least the width of the original clear zone should be restored. In determining the adequacy of the existing clear area, the accident history at an existing facility will be a primary consideration. Efforts should be made to provide as much clear area width as is reasonably convenient, unless the presence of a roadside-related accident history indicates that greater efforts should be made.

If the number and severity of run-off-road accidents is at or below average for similar facilities statewide and there are no accident clusters, the greater of either the prevailing or the originally constructed clear area widths may be considered adequate for highways that do not have designed clear zone widths. As a minimum for highways that were constructed with designed clear zone widths in accordance with guidance (such as the Highway Design Manual, AASHTO's *Roadside Design Guide* or *Guide for Selecting, Locating and Designing Traffic Barriers*, 1977 [or its 1980 supplement], or the Highway Research Board's NCHRP Report 54 *Location, Selection and Maintenance of Highway Guardrails and Median Barriers* [1968] or Report 118 *Location, Selection, and Maintenance of Highway Traffic Barriers* [1971]), the existing clear area width is to be maintained or the width of the originally designed clear zone restored, whichever is greater. (Previously constructed clear areas usually represent a significant tax investment in ROW, clearing, and grading that should be maintained as clear area, unless there is very little potential public safety benefit to be obtained from the effort.)

See Section 10.3.2.3 for guidance on highways where tightly restricted conditions prevented the construction of designed clear zones.

If the accident analysis indicates a run-off-road problem, efforts should be made to determine how to treat the cause. If it is indicated that the clear zone width may be a significant factor in the accident experience, the guidance for determining clear zone widths for new facilities (presented in Section 10.2.1) should be used to evaluate the clear zone adequacy in the problem area. In some instances, the accident history may justify using clear zone widths that are wider than the desired clear zone widths obtained using the procedure outlined in Section 10.2.1.

Additionally, where the project scope includes significant changes to existing conditions, the project developer and scope team should review factors that would affect whether the width will still be adequate for anticipated conditions. Factors that should be reviewed include: anticipated increases in operating speed, traffic volume, embankment slopes, highway grades, and roadside development. The designer should decide whether the anticipated changed conditions warrant changes to the prevailing clear zone widths and, if so, should estimate what widths will be adequate. Such determinations rely heavily on professional engineering judgment.

Wherever reconstruction or realignment work is included within a 3R project, that portion of the project should follow clear zone requirements for a reconstruction project.

B1. "Basic Safety Package" for Roadside Work on Nonfreeway 2R and 3R Segments with Design Speeds over 40 mph (60 km/h)

1. Clear Zone –
 - a. Fixed objects should be removed from the clear zone widths or suitably modified.
 - b. Where a reasonable clear zone width can not be obtained, appropriate guide rail or other barriers are to be installed or an explanation provided.
2. Cross Culverts –
 - a. Protruding headwalls on cross culverts within the clear zone should be removed and the end treatments replaced or modified to be flush with the embankment surface.
 - b. Unshielded cross culverts or their end sections which are
 - i. within the clear zone
 - ii. at embankments 1 on 3 or flatter, and
 - iii. CMP 18" (450 mm) or larger, or Concrete 20" (525 mm) or larger in diametershould be provided with grating for traversability. The clear span for grating should usually not exceed 8 ft, so end sections wider than 8 ft at a point where their depth is at least 1 ft should typically be shielded with barrier if they are within the clear zone. (To permit traversal by mowing machines, consideration should be given to providing all 1 foot or greater pipe openings in the clear area with grating.) Alternatively, cross culverts may be extended beyond the clear zone or suitably shielded.
3. Ditches –
 - a. Lateral ditches within the clear zone should be made traversable. (Refer to Chapter 3 of AASHTO's *Roadside Design Guide*.)
 - b. Fixed objects, including driveway headwalls, should be removed from ditch lines within, or forming the borders of, clear zones.

- c. Distinctly hazardous ditches within the clear zone should be remediated or shielded. For details, see the following subsection, "C. Treatment of Roadside Ditches on 2R and 3R Projects."
4. Longitudinal Pipes –
- a. If their diameter exceeds 12" (300 mm), approach ends of longitudinal pipes within clear zones and in bordering ditches should be provided with end sections and, if the surrounding transverse embankment is steeper than 1:3, the pipe should be extended and the embankment regraded to a 1:4 slope or flatter, preferably 1:6.
 - b. If the height of the above longitudinal pipe exceeds 18" (450 mm), the opening should be provided with grating to enhance traversability. The minimum grating in such instances should consist of a mat of #8 reinforcing bars welded together on one foot centers. The mat should extend down to within 4 inches of the invert.
 - c. If the accident analysis indicates that any of the piped driveway embankments have been involved in run-off-road accidents, the critical side of the embankment should be flattened to 1:6 and the pipe should be provided with a 1:6 safety end section with built-in pipe grating. (Refer to series 603.1716XX items. Friction fit sleeves are needed when attaching to SICPP pipes.) These end sections and embankment flattening should also be used if, in the designer's professional judgment, a location has a significant likelihood of having an accident.
5. Guide Rail -
- a. All guide rail is to be of a type currently approved to be in service, meet the required standard details prevailing at the time of its installation, set to currently approved heights, and acceptably anchored and flared as necessary.
 - b. Where the related project work requires relocation or resetting of guide rail or placement of new guide rail, it shall be placed in accordance with the requirements for new facilities. Where existing guide rail is not to be relocated or reset, minor discrepancies in placement location are tolerable. Such discrepancies include terminal flare offsets that are within 1.5 feet of standard practice, point of redirection coverage of the point of need short of current guidance by 10 feet or less, and, in instances where a reasonable runout length is provided, anchorage not carried fully to adjoining back slopes.
 - c. The area behind the guide rail is to be free of objects that will interfere with its desired performance and of a width compatible with its deflection distance.
 - d. On curb-guide rail combinations, relocations or curb removals should be made to eliminate the combination placements not permitted in Section 10.2.2.4.
 - e. Any impact attenuation system is to be installed in conformance with current guidance.

B2. "Basic Safety Package" for Roadside Work on Nonfreeway 2R and 3R Segments with Design Speeds of 40 mph (60 km/h) or Less

1. Clear Zone –
- a. Where a reasonable clear zone width (at least equal to the horizontal clearance) can not be obtained in rural areas, appropriate guide rail or other barriers are to be installed or an explanation provided.
 - b. Where a reasonable clear zone width (at least equal to the horizontal clearance) can not be obtained in urban areas, appropriate delineation is to be installed or an explanation provided.

- c. Fixed objects should be removed from the clear zone widths or suitably modified.
2. Cross Culverts –
- a. Protruding headwalls on cross culverts within the clear zone should be removed and the end treatments replaced or modified to be flush with the embankment surface.
 - b. Unshielded cross culverts or their end sections which are
 - i. within the clear zone
 - ii. at embankments 1 on 3 or flatter, and
 - iii. CMP 18 " (450 mm) or larger, or Concrete 20" (525 mm) or larger in diametershould be provided with grating for traversability. The clear span for grating should usually not exceed 8 ft, so end sections wider than 8 ft at a point where their depth is at least 1 ft should typically be shielded with barrier if they are within the clear zone. (To permit traversal by mowing machines, consideration should be given to providing all 1 foot or greater pipe openings in the clear area with grating.) Alternatively, cross culverts may be extended beyond the clear zone or suitably shielded.
3. Ditches –
- a. Lateral and longitudinal ditches within the clear zone should have side slopes effectively 1:2 or flatter.
 - b. Where driveways are reconstructed, headwalls should not be placed within clear zones.
4. Longitudinal Pipes –
- a. If their diameter exceeds 12" (300 mm), approach ends of longitudinal pipes within clear zones and in bordering ditches should be provided with end sections and, if the surrounding transverse embankment is steeper than 1:2, the pipe should be extended and the embankment regraded to a 1:2 slope or flatter.
 - b. If the height of the above longitudinal pipe exceeds 18" (450 mm), the slope should be flattened to 1:3 or flatter, and the opening should be provided with grating to enhance traversability. The minimum grating in such instances should consist of a mat of #8 reinforcing bars welded together on one foot centers. The mat should extend down to within 4" (100 mm) of the invert.
5. Guide Rail -
- a. All guide rail is to be of NCHRP 230 or more recently approved type, meet the required standard details, set to approved heights, and acceptably anchored and flared as necessary.
 - b. Where new guide rail is to be placed, it shall conform to current standards and shall be located in conformance with current guidance.
 - c. Where existing guide rail is not to be relocated, minor discrepancies in placement location are tolerable. Such discrepancies include terminal flare offsets that are within 1.5' (0.5 m) of standard practice, point of need short of current guidance by 10' (3 m) or less, and, in instances where a reasonable runout length is provided, anchorage not carried fully to adjoining back slopes.
 - d. The area behind the guide rail is to be free of objects that will interfere with its desired performance and of a width compatible with the deflection distance anticipated for the design speed.

When, in the designer's professional judgment, any of the above basic safety treatments can not be reasonably achieved, the rationale for the decision should be documented in the Design Approval Document or, if the DAD has already been finalized, in the project files or, preferably, on the project plans. In general, the degree of explanation for retention of nonconforming features should be commensurate with the degree of potential hazard presented by the feature.

C. Treatment of Roadside Ditches on Non-freeway 2R and 3R Projects

Refer to the guidance in Section 10.2.1.1 C.

If it is the designer's judgment that a potentially hazardous ditch can not be reasonably modified to acceptable conditions and can not reasonably be shielded, then an explanation of the decision to retain the ditch as a nonconforming feature should be provided in the Design Approval Document.

D. Inclusion of Additional Optional Work Items on Nonfreeway 2R and 3R Projects

When it is convenient to do so, efforts should be made to include within the project scope the remediation of features that are needed, but not required, on 2R and 3R projects. This section addresses roadside considerations.

On a given project, several factors affect the relative cost of upgrading. For instance, if a system has several minor deficiencies, the cumulative effect could justify upgrading. Similarly, if work on an adjacent system will require temporary modifications to a second system, the cost of upgrading the second system to preferred practice may be reduced. As an example, if portions of a guide rail run are removed for ditch or slope maintenance work, the cost of changing the offset or anchorage of the rail system will be reduced. Some of the features may have to be taken care of due to related work. For instance, widening or re-alignment of the roadway may require removal of a guide rail and curb and permit reconstruction to current preferred practice.

The potential benefits to safety also vary with project conditions. Removal of an individual fixed object, such as a tree, will yield very little safety benefit if there are numerous other fixed objects in the immediate vicinity at similar offsets from the roadway. Also, if projected traffic volumes are low, the potential benefits of remediating a hazard will be lower since the probability of an accident occurring at a given location are significantly less than on a high-volume road. AASHTO's *Roadside Design Guide* contains guidance on this type of analysis.

Beyond the "basic safety package" items, it is a difficult process determining which nonconforming features and safety concerns are appropriate to include for remediation in a 3R project. The designer should prioritize the features to determine the most appropriate use of the funds available for improving roadside safety. Generally, high priority features will be included while low priority will not. Features that do not fit clearly into either one of these categories may be considered as marginal features: features that should be upgraded if funding is available.

When it is appropriate to prioritize the marginal features, the designer should first make a rough estimate of the cost to upgrade each of the unaddressed safety concerns and nonconforming features noted during the site inspection. The designer should then use his/her professional judgment to rank the potential safety benefits of upgrading the particular feature. A suggested ranking system assigns a value of 1 to the most beneficial and 5 to the least beneficial. The designer may then compare the estimated costs with the estimated benefits to rank the cost effectiveness of upgrading each deficient feature. (In rare instances, it may be appropriate to use AASHTO's *Roadside* computer program to aid in the benefit-cost analysis.) The accident analysis should be reviewed with the Regional Traffic Engineer to see if it is appropriate to make any adjustments to the cost effectiveness rankings. Guided by these rankings and, in some instances, the available funding, the project developer and scoping team should determine which features to include for remediation in the project. The Regional Design Engineer or a designee should review and approve the determinations when Design Approval is requested.

10.3.2.3 Clear Zone and Shielding Determinations in Tightly Restricted Areas

There will frequently be conditions along existing highways that make it difficult or unreasonable to try to provide a significant clear zone width. In hilly or mountainous terrain, such conditions could include steep drop-offs adjacent to the road or rock cuts or steep soil slopes rising just beyond the ditch line. Other conditions include limited ROW, adjacent developments and protected wetlands. On high-volume highways and on interstates and freeways, the features should be shielded.

For other existing highways, particularly those with low volumes, the accident history should be considered. Unless a demonstrated crash history warrants use of barrier or overcoming the difficulties to provide a reasonable clear zone width, an accepted practice is to define a clear zone width that fits within the available space. Since narrow clear area widths will not provide a significant opportunity for errant vehicles to stop or slow before striking fixed objects, some use of barrier may be appropriate, even though the fixed objects are beyond the defined clear zone. The designer needs to decide if, or how much, barrier should be used and where it should be used. Accident history, traffic volume, and operating speed are key considerations. Particularly if the accident rate and severity are high, barriers should be liberally used, if practical. (This may not be appropriate in heavily built-up areas with frequent access points.) Conversely, if there have been few run-off-road accidents and speeds are lower, there is little justification for the use of barrier, even if the clear area widths are minimal. In considering where barriers might be appropriate, priority should be given to three conditions.

1. Features that could be hazardous at any speed, particularly deep bodies of water or high cliffs.
2. On the outside of abrupt or sharp curves.
3. At drop-offs where a vehicle that ran off the road could be hidden from traffic and trapped or injured occupants would remain unnoticed.

The utilization of guide rail in tightly restricted areas is left to the designer's engineering judgment. See Sections 10.2.2.3 and 10.2.3 for guidance on barrier type selection.

10.3.3 **Documentation of Roadside Design Process for Upgrading of Existing Facilities**

Documentation of actions, judgments, desired products, and maintenance objectives can be very useful in proving that the State's duty to adequately design, construct and maintain its roadways, clear zones, and guide rails in a reasonably safe condition has been met. Since this documentation is frequently needed years after the construction work is completed, retrievability is an important issue. With respect to roadside design issues, documentation may be recorded in the Design Approval Document (DAD) or project files (especially for those projects without DADs), as notes or graphical representations on the plans, or in tables in the project plans. The specific documentation that should be provided and the importance of producing that documentation vary with the type of project and the importance of the subject.

10.3.3.1 Required Documentation of Roadside Design Process and Product

A. Interstate, Freeway, and Reconstruction Projects

The *Project Development Manual* requires that the basis for the selected clear zone widths be discussed in the DAD. The selected clear zone widths may be a restatement of the widths defined from previous work at that location, or may be redefined widths, if appropriate. If clearing must be done to obtain the stated clear zone widths, then the clear zones' widths shall be shown in Clear Zone Tables or elsewhere on the plans. Though only as a rare exception, it may be determined necessary to leave a potentially hazardous feature or fixed object unshielded within the clear zone. When this occurs, the decision shall be documented in the DAD (if timing permits) or in the project plans and an explanation shall be provided. Clearing to be done beyond the defined clear zone does not need to be formally documented, but should be recorded as necessary to facilitate the deliberations of the scoping body and transfer of the intent to the designer and of the specific task to the EIC and the contractor. Any changes to barrier location or composition should be clearly indicated on the project plans, most notably as Guide Rail Tables. If it is decided not to place guide railing where it is normally warranted (Section 10.2.2), or not to the normal installation practice, an explanation must be provided.

B. Non-freeway 2R and 3R projects

At a minimum, the DAD is to indicate that the adequacy of the clear area for the facility was evaluated. If it was judged that additional clearing is needed to provide an appropriate clear zone for the facility, the width of the target clear zone(s) for the facility should be recorded in the DAD. If the clear zone widths selected during detailed design are less than the target widths identified in the DAD, the design clear zone widths are to be indicated in the contract documents, preferably as a table of clear zone widths in the plans. If the detail design process indicates that the target clear zone widths in the DAD can be used without alteration for the project, then it will not be necessary to indicate the target clear zone widths in the project documents, but plans/documents must contain sufficient information to ensure that clearing to satisfy the clear zone widths is specified or that barrier shields locations where the width of clear zone will not be satisfied.

If it was judged that additional clearing is not required for the project, either that evaluation is to be noted in the DAD or the clear zone(s) for the project is to be defined. If the need for additional guide rail or replacement of guide rail or barrier is determined during the scoping

process, that need is to be noted in the DAD. If the need for additional guide rail or replacement of guide rail or barrier is confirmed or determined during the detailed design process, the specific barrier needs are to be indicated in the project documents, typically including detailed listing in the Guide Rail Table.

If any potentially hazardous feature or fixed object is to be left unshielded within the clear zone, that decision shall be documented in the DAD (if timing permits) or in the project plans, and an explanation should be provided.

If it is decided not to place guide railing where it is normally warranted (Section 10.2.2), or not to the normal installation practice, an explanation should be provided.

C. Element-Specific and Maintenance-Type Projects

If the type of project does not involve roadside issues, no documentation related to roadside issues is required. If the type of project is one that would often involve roadside evaluation, but it is determined that roadside issues will not be addressed in this instance, then that decision should be noted in the DAD or other project files if a DAD is not involved.

If it is determined that the project will involve roadside safety work, such as clearing to meet a minimum clear zone width or placement of barrier to shield features within a selected clear zone width, then that clear zone width shall be indicated either in the DAD or in the project documents. If clear zone issues only apply to a small extent of the project, then documentation of the clear zone width may be limited to that portion of the project. If any potentially hazardous feature or fixed object is to be left unshielded within the clear zone, that decision shall be documented in the DAD (if timing permits) or in the project plans.

10.3.3.2 Desirable Documentation of the Process

Establishing a relatively safe roadside requires the rigorous application of sound engineering judgment. The nature of the process does not lend itself easily to thorough documentation. However, the designer is encouraged to do so to the extent practical in order that a record is preserved of the roadside condition, both before and after construction of the project. Although the previous section describes the required documentation, it is desirable that a clearly defined written record be preserved which documents that an appropriate scoping/design decision process was used.

The records summarizing the roadside design decisions should be updated prior to letting and finalized as part of the Post Construction Review (PCR) process defined in the Department's *Procedure for Managing Projects*. It is desirable for the roadside design summary to contain several elements.

1. Documentation of Site Safety Inspection - This may consist of carefully prepared field notes or the list of the hazards and deficiencies and their locations generated during the accident analysis and site inspection (Section 10.3.1.2 A).
2. Evaluation - On projects where there is significant flexibility as to what should be included in the detailed scope of work, it is desirable that the decision process be documented. It is desirable to be able to demonstrate that for each safety concern and

nonconforming feature (that is not otherwise mandated for remediation), the cost of upgrading, the relative safety benefit, and the resulting cost effectiveness were considered in determining the best application of the available funds. Where there are multiple occurrences of similar nonconforming features and they will receive similar treatment, it is not necessary to itemize them individually; they may be discussed as a group.

3. Disposition - Following substantial completion of the construction work, it is desirable for the designer to inspect the site with the Engineer-in-Charge or his designee to assess whether any unanticipated potential safety hazards have been created or whether the design has overlooked any relevant nonconforming features. (The documentation of the Site Safety Inspection and the subsequent evaluation should be used as references during the 'Disposition' inspection. Dispositions of nonconforming features may be indicated in a Roadside Design Summary. There are three categories of disposition. A feature may have been (1) upgraded to current guidance, (2) partially upgraded, or (3) not upgraded. If an item has been upgraded to current standards, it may be sufficient to reference a footnote after the item and provide footnotes at the end of the Summary list. If an item has been either partially upgraded or not upgraded, an explanation should be provided. The explanations should be brief but clear. If appropriate, supporting references should be cited.

Figure 10-16, presented on the following page, is an example illustrating a possible format for a Roadside Design Summary. The title page should clearly identify the project and its location. It is desirable for the designer and Project Manager to review the Summary with the Regional Traffic Engineer.

Figure 10-16 Example Page of Roadside Design Summary

(Presented separately on following page to facilitate photocopying.)

Project Name/Location

PIN

CLEAR ZONE SELECTION TABLE

STA SEGMENT STA			SIDE ® OR L)	DESIGN SPEED	AADT	SLOPE	BASIC RECOVERY WIDTH, BRW	K _{oc} R FACTOR		CURVE CORRECTED RECOVERY WIDTH, CCRW	...RECOVERABLE WIDTH	TRAVERSABLE WIDTH	CLEAR RUNOUT WIDTH	DESIRED MINIMUM CLEAR ZONE WIDTH	DESIGN CLEAR ZONE WIDTH, CZ _o
	A														
	B														
	C														
	D														
	E														
	F														
	G														
	H														
	I														
	J														
	K														
	L														
	M														
	N														
	O														

Explanations for differences between Desired and Design widths:

10.4 CONSTRUCTION ZONE GUIDANCE

One of the most challenging roadside design problems is the design of appropriate safety features for construction work zones. The system must be designed to provide for the safety of the workers as well as the motorists, bicyclists, and pedestrians. Most of the barriers and many of the other system components need to be designed as temporary features. Where traffic is maintained through the work zone, conditions are usually quite constricted. The traffic control problem may be complicated by the need to complete the project as a staged construction effort. Safety in the work zone is addressed separately in Chapter 16 - Work Zone Traffic Control. Signage, channelization, and a few typical configurations are covered in the National Manual on Uniform Traffic Control Devices (MUTCD) and the New York State Supplement. The information that was formerly included in the following sections is being/has been moved to Chapter 16. Until that move has occurred, readers may refer to the previous version of Chapter 10 for information.

10.4.1 **Temporary Concrete Barriers (TCB)** Moving/moved to Chapter 16.

10.4.2 **Temporary Timber Safety Curb and Median Barriers**

As explained in EI 03-001, designers should no longer specify timber items 15619.1401 or 15619.1402 in project proposals.

10.4.3 **Dragnets** Moved to Chapter 16

10.4.4 **Moveable Concrete Barriers** Moved to Chapter 16

10.4.5 **Warrants for Work Zone Barriers** Refer to Chapter 16

10.5 SPECIAL TOPICS

10.5.1 Mailboxes

Mailboxes may pose safety problems as a result of either their placement or their construction. Placement problems may arise from several factors.

- There may be inadequate sight distance due to proximity to crest vertical curves or right horizontal curves.
- Due to proximity to intersections, vehicles at the mailbox could distract other motorists or interfere with sight distances. Stopped vehicles might also obstruct stop signs.
- Offset from the road might not be sufficient to allow vehicles to stop far enough out of the traveled way.
- Placement in or near the sidewalk may reduce the usable sidewalk width below standards.

Construction problems would include three categories.

- A mailbox attached to or surrounded by a structure that will function as a fixed object may be capable of producing a serious impact for an errant vehicle.
- A mailbox assembly containing elements that can separate upon impact and may produce injury if these elements enter the passenger compartment. A serious and not uncommon example of this is the arrangement where one horizontal plank supports several mailboxes at about the height of a motorist's head.
- The arrangement of mailboxes could produce ramping and overturning of an errant vehicle. The problem arrangements would typically consist of several closely spaced mailbox posts or a small number of yielding metal posts.

The designer should refer to AASHTO's 1994 publication *A Guide for Erecting Mailboxes on Highways* (Mailbox Guide) or subsequent publications for further guidance on identifying mailbox problems and for designs which address these concerns.

10.5.1.1 Inspections

Inspections for problem mailboxes should be performed as part of a project's site inspection. The location and condition of suspected problem mailboxes should be documented and addressed during the design process.

10.5.1.2 Location Details

In most cases, mailboxes will already have been located along the highways and will remain in their approximate locations, offset as needed to accommodate highway and shoulder widenings. Nonetheless, some relocations will be necessary or possible. When making relocations, the information given below should be considered. The pay item Mailboxes in §619 of the Standard Specifications may be used whenever it is necessary to provide, remove, set back, or relocate a mailbox or to replace a noncrashworthy support. (Note: "Crashworthy", as

used herein, means that the feature has been judged to perform in an acceptable manner when impacted by an errant vehicle.) It is not necessary to use item "Mailboxes" for an existing mailbox if the construction does not require its removal, set back, or relocation.

The following information is taken from the previously mentioned AASHTO Mailbox Guide and represents good practice with respect to locating mailboxes. In general, mailboxes should be located on the right-hand side of the roadway in the direction of the delivery route except on one-way roadways where they may be located left or right. When feasible, they should be located on the far side of intersections and at locations where there is sufficient clearance for vehicles to be able to pull entirely off the pavement. An 8 foot, or preferably wider, shoulder or turnout will enable this.

The placement of mailboxes along high-speed highways should be avoided if possible. If this is not possible and traffic is heavy and speeds are high, consideration should be given to installing mailboxes on both sides of the road so that postal patrons do not have to cross the road to receive their mail. Discuss this with the local postmaster. In no case should mailboxes be located where access to the box must be made from the lanes of an expressway or where access, stopping, or parking is prohibited. In areas where there is guide rail, the mailboxes should be located behind the railing.

10.5.1.3 Structural Details

Mailboxes and their supports shall be in conformance with U.S. Postal Service requirements. They may be made of a variety of materials including steel, aluminum, or plastic. Mailboxes are most frequently mounted on individual supports, the most common of these made from pressure treated or rot-resistant dimension lumber nominally 4"x4", round treated posts 4½" in diameter, or 2" or less steel or aluminum pipes. All these are typically crashworthy. Railroad rails, milk cans filled with concrete, old metal plows and similar supports are not crashworthy. Noncrashworthy mailboxes and those which do not conform to Postal regulations should not be permitted to be used or remain on projects.

Mailboxes gang-mounted on horizontal planks can present an especially hazardous condition and should be remounted on crashworthy individual posts having not more than two mailboxes per post. Individual posts should be installed with a 2.5 ft separation between posts since posts more closely spaced may cause ramping. In the unusual circumstance where there are so many mailboxes being relocated that there will not be room for all while still maintaining the above mentioned post spacing, "cluster boxes" may be a solution. Contact the local postmaster to discuss. "Cluster boxes" are not crashworthy and so may not be located where they could easily be hit.

It is acceptable for newspaper boxes to be mounted on the supports, if constructed of plastic or light gage sheet metal.

For additional guidance, refer to Section 10.5.6, Public Relations.

10.5.2 **Fencing**

It is the general policy of the Department that fences which constitute a hazard, whether privately or State-owned, are to be removed from the clear zone.

Fences within the right of way may have been erected either by the Department or by the adjoining property owner. In either case, the designer should be aware that the fences may be a hazard. The next section provides guidance for private fences. The current guidance for the Department's fences, presented in the subsequent sections, is intended to ensure that fences erected at the Department's direction are warranted and are reasonably safe. Details of fencing used to contain rockfall should be developed in conjunction with the Regional Geotechnical Engineer. Unless designed as breakaway features, such fences should be treated as fixed objects with respect to clear zone determinations.

10.5.2.1 Private Fences

It is DOT policy that fences that constitute a hazard within the clear zone, whether private or state-owned, are to be removed. Private fences may pose serious hazards. While most fences are not substantial enough to wreck an impacting vehicle, they may contain elements that could enter the passenger compartment and cause serious injury or death. The most dangerous elements are long horizontal components, roughly 3 to 6 feet above grade, which can separate on impact and "spear" through windshields. Typical examples include split-rail fences and pipe rails on the top of chain link fences.

A few fences may be strong enough or heavy enough to constitute a significant fixed object hazard. When fences that are considered potentially hazardous are found to be within the State's right of way, the fences are to be removed, treated, or documented as a nonconforming feature. Positions opposite points of entry or on the outside of curves after a long straight section or long hill are more likely to experience accidents. If, in the professional opinion of the engineer, a particular fence represents a significant hazard, the engineer should notify the owner in writing. The letter should request remediation and suggest appropriate alternatives. It is important that documentation of the effort to remediate be retained in Regional files. Refer to Section 10.5.6, Public Relations, for additional guidance.

In addition to the safety aspects of fencing, the designer should be aware of the implications of private fences to land use patterns. While the Department may tolerate casual land use within the right of way, the presence of a private fence within the R.O.W should not be allowed to justify construction of substantial encroachments. Although it is very difficult to detect such activity, suspected problems should be brought to the attention of the Regional Real Estate Group. Prompt action at the start of encroaching construction activity may allow adjustment before the problem involves a completed project.

10.5.2.2 Purposes for DOT Barrier Fencing

The primary purpose for installing barrier fencing is to enhance the safety of the motorist and to enhance the safety of those that the fencing is meant to exclude.

In some locations, the fencing additionally serves to delineate the right of way. However, in many instances it is more convenient to erect the fences in continuous lines leaving irregular

right of way corners outside the fence line.

Fencing is intended to exclude pedestrians, bicyclists, unauthorized vehicles, and domesticated animals. Among wild animals, deer are the major hazard in New York State, due to their number, size, and range requirements. Fencing is not warranted or effective for deer control. Deer routinely vault or crawl under most practical types of fencing. Fencing may cause deer to spend more time within the right of way while searching for a way out of the fencing. Where deer hits have been a problem, consideration should be given to (1) clearing vegetation well back from the road to improve visibility and reduce the potential for surprise, (2) placement of warning signs (No Grazing, Beware of Traffic, or other, appropriate signs) and (3) special treatments, such as underpasses at concentrated crossing areas.

The two most common types of fencing used by the Department are chain link and right of way (R.O.W. or cattle) fencing shown on the Standard Sheets for 607 series items.

Because of the potential for "spearing" accidents and the lack of any offsetting cost advantage, the chain link fence with top rail is generally not to be used on State contracts. Exceptions may be made only in special cases where supporting justification is submitted with the PS&E package or the fencing does not border an established roadside clear area. Exceptions may be approved by the Regional Director in cases where there is a compelling reason, such as:

- where top rail fencing with insert slats is required for visual screening,
- where trespassing or vandalism problems are anticipated and top rail fencing would be more durable and/or easier to repair, or
- on structures in accordance with Bridge Detail Sheets.

Unless excepted by the Regional Director, existing top rails are to be replaced with tension wires whenever the fence is in the clear zone or in a location where it could easily be struck by an errant vehicle and either:

- Repair, replacement, or realignment of the fence is required.
- The fence adjoins, or is within, a reconstruction or 3R project.
- A sufficient amount of related work is being done in the immediate vicinity to justify including top rail removal within the scope of work.

Other types of fencing are described in special and Regional specifications. For built-up areas, the Regional Landscape Architect can provide options and should be consulted to recommend fence styles that are reasonably safe and compatible with adjacent land uses.

Selection might include:

- cattle fences in rural areas,
- high, nonclimbable fences (1 inch mesh) on urban freeways,
- black or green vinyl-clad chain link fences in sensitive residential areas, or
- ornamental fencing in historically designated areas.

Changes in the type of fencing should occur at natural break points to minimize the visual impact.

10.5.2.3 Vandalism and Trespassing

In areas of high crime, vandalism, or risk, a higher quality security fence may be warranted. The Regional Landscape Architect should be consulted on different styles of fencing and more vandal-resistant materials, such as picket and rail fencing and nonclimbable meshes. Fencing will not exclude the determined trespasser. In developed areas, vandals may cut holes or pedestrians may enter at required fencing gaps, such as at exit ramps, to take short cuts across limited access highways. In rural areas, snowmobilers and All-Terrain-Vehicle (ATV) operators sometimes cut holes in the fence to gain access to the right of way. The miles of continuous clear zone with mild grades offer ideal conditions for these kinds of unauthorized vehicles.

There are three measures that can be taken to combat the hazards posed by trespassers. The first is to regularly repair the fencing. Where repeated vandalism is a problem, consideration may be given to repositioning fencing where it will be easily observed or where it works in concert with other obstacles.

The second measure is to request increased enforcement efforts from police agencies in the area.

The third measure is to reduce the desirability of entering the right of way. The addition of a sufficient length of continuous fencing in a median may eliminate a pedestrian shortcut. In rural areas, the continuity of the clear zone may be eliminated by using guide rail to extend from roadside barriers to connect to natural barriers. For instance, where roadside guide rail is used to shield a culvert, clear zone continuity may be interrupted by extending the roadside guide rail down to the drainage feature. While corrugated or box beam guide rails are highly resistant to vandalism, their use may be less safe for errant vehicles than the available clear area would be. Guide rail used to discourage illegal use of the clear area should only be installed at locations that are already shielded, require shielding, or contain other hazards.

10.5.2.4 Warrants for Barrier Fencing

The primary guidance for barrier fencing is AASHTO's November 1990 booklet *An Informational Guide on Fencing Controlled Access Highways*. The guide is used by the Federal Highway Administration and many state agencies. The guide is subject to differences of interpretation. One passage states, "All portions of a controlled access highway should be continuously fenced, unless it can be established that a fence is not warranted; such as in areas of precipitous slopes or natural barriers." In a subsequent paragraph, the guide indicates that, "The cost of a continuous fence of this height... (sufficient to deter deer)...would be excessive and the biologic effects on animal life would be undesirable." The Department's interpretation of this guidance is that fencing is not warranted for the control of wildlife (ineffective) or the exclusion of the occasional hunter (not cost effective for small risks involved). Natural barriers are therefore interpreted to mean ones that would generally inhibit or preclude passage by ATVs and snowmobiles. While continuous fencing of limited access highways may not be warranted, it is considered desirable as a legal means of establishing trespass.

The installation of barrier fencing may be warranted for long-term conditions or temporary conditions as described below.

A. Long-Term Conditions

Since a fence may remain in place and be functional for many years, the selection of a type should take into consideration the potential development of the area.

Most long-term condition warrants relate to limited access highways. The remainder relate to hazardous conditions that may be encountered within the right of way of any state highway.

1. The use of continuous 6 foot high chain link fencing is warranted along the right of way line of any portions of limited access highways in urban areas, towns, or population centers where trespassing pedestrians may be anticipated. Where the limited access highway is flanked by a frontage road with access to adjoining properties, the fencing should be installed between the frontage road and the limited access highway.
2. The use of 4 ft high right of way fencing (as shown on the Standard Sheets) may be warranted along limited access highways in agricultural areas where livestock, particularly cows, are present. In all cases, however, the livestock owners have primary responsibility for providing fencing for their livestock. Any fencing provided by the Department is strictly a secondary barrier to protect highway patrons from escaped livestock. Livestock owners should not be permitted to connect their fences to the Department's fences.
3. The use of either chain link or R.O.W. fencing is warranted along limited access highways in open country to restrict access by snowmobilers, hunters, ATV operators, and others who may be casual users of the R.O.W.
4. The use of chain link fencing may be warranted to inhibit access to hazardous features within the right of way, such as steep rock cuts, recharge basins, transmission towers (owner's responsibility), and some hazardous waterways.
5. The use of 8 ft high chain link fencing may be warranted along the right of way line adjacent to any school play grounds where formal access is not provided and where adequate access control has not been furnished by the school.

In areas that would normally exclude motorized vehicles, such as mountainous, densely wooded or swampy areas, the use of fencing is not warranted for the exclusion of snowmobilers or ATV operators. The high cost of fencing is also not warranted for the exclusion of the occasional hunter or others.

While they are not warranting conditions and not DOT responsibilities, the presence of the following facilities adjacent to the right of way may be taken into consideration when fencing decisions are being made: public water supplies, military bases, mental institutions, state prisons, and power plants.

B. Temporary Conditions

Temporary condition warrants will normally be related to construction work. The contractor may elect to use fencing to reduce rates of theft and vandalism from the construction site. Additionally, fencing may be, and in urban areas is, warranted in an attempt to preclude pedestrians from entering the work zone. Where pedestrian access must be permitted through or immediately adjacent to the work zone, the path or sidewalk may warrant being fenced to guide pedestrians and to isolate foot traffic from hazards within the work zone.

The details of the types and specific locations of work zone barrier fencing should be developed with consideration given to the concerns identified in this chapter and in EI 01-019 Maintenance and Protection of Pedestrian and Bicycle Traffic and should be subject to the approval of the EIC. Use of horizontal rails in fences adjacent to traffic should not be permitted. The designer should refer to OSHA's requirements for fencing of additional hazards, such as high visibility plastic fencing around excavations.

10.5.2.5 Visual Screen Fencing

Visual Screen Fencing is defined as fencing whose primary purpose is to serve as a visual barrier. The most common uses are aesthetic; to mask unsightly areas such as junk yards and to screen high-speed or limited access highways from residences. Visual screen fencing can be used in conjunction with, or as an alternative to, planting. Visual screen fencing can be either a fence to which materials have been applied to increase opacity or a separately-constructed fence specifically designed and placed to serve as a screen. Since the need for such fencing often comes about as mitigation in response to a community request, special attention needs to be paid to local context and community preferences in considering materials, color, scale and detailing. Concerns in addition to aesthetics and context include cost, maintenance and inspection of non-standard items, wind loads, vandalism and, especially in urban areas, security concerns due to the increased opacity. Consult the Regional Landscape Architect for guidance on the selection, placement, and design of appropriate visual screen fencing.

In addition, there may be safety concerns. If the fencing is likely to be reached by an errant vehicle, it should either be shielded behind a guide rail and beyond its deflection or designed to be crashworthy. To be crashworthy, the fencing should not include elements that could penetrate into the passenger compartment and should not have structural components that would be likely to snag a vehicle to bring it to a dangerously abrupt stop. Top rails on a chain link fence would be an example of a spearing element.

Various types of **visual screens applied to other fences** have been tested in actual use. One successful treatment has been the insertion of slats into the weave of chain link fencing. Insertion into a chain link fence 6' to 8' high is usually sufficient to provide the needed effect. This means that, in some cases, it could be added to existing or new right of way fencing at relatively low cost. Options for the inserts include wood, plastic and metal, available in various colors and finishes. Heavier posts are often required, to withstand increased wind loads. The Special Specifications list requirements for the heavier posts needed. The visual impact of increased post size must be taken into consideration alongside other aesthetic concerns, to ensure that the screen suits the project need and context. Another treatment has been fabric screens, but these have proven less successful since they are especially vulnerable to vandalism and wind damage. Many plastic fabrics are also susceptible to ultraviolet deterioration.

Separately-constructed visual screen fencing can be of metal, wood, plastic or a combination. There is no single standard – such fences can be as simple as heavy duty yellow pine, 6' to 8' high in 6' to 8' sections, but can be more elaborate and decorative as the need, context, budget and maintenance capabilities allow. Designers should consider the degree of screening needed. It may be possible to minimize the impact of a view without completely blocking it – for instance by using a colored and tighter-than-standard mesh on a chain link fence (1" or less). A view can also be blocked in the key travelling direction while still allowing visibility for security in another through the use of a vertical louvered construction. Separately

constructed visual screen fences raise the same concerns as described above for visual screens applied to other fences.

Visual Screen Fencing and Noise barriers: Noise barriers, described in detail in 10.5.2.6, are by nature visual barriers as well. Though noise wall materials and construction can vary widely, the scale and heavy concrete construction of those most typically used for effective noise control can have large visual and environmental impacts. Recently, on projects on suburban arterials, visual screen fencing has been offered as an option to communities balancing those impacts with the need for noise mitigation. While not designed to mitigate noise, visual screens often can effectively address the psychological effect of exposure to a roadway, if communities accept the trade-offs. Also, since they might be as simple as a wood stockade fence or a chain-link fence with brown wood or plastic slats 6' in height, they can be a "greener" option, both in scale and construction footprint to traditional noise walls.

Glare Fencing: Glare fencing is a type of visual screen introduced specifically to intercept headlight glare. One general type has been found satisfactory for reducing glare between lanes of opposing traffic—a "paddle-type" system designed for mounting on top of concrete barriers but also adaptable to box beam or heavy-post W-beam median barriers or guide rails. The system consists of vertically oriented paddles approximately 8.5 inches in width mounted every 2 feet on 10 foot continuous runners. Paddle heights are available in lengths of 2', 2'-6", 3', and 4'. The paddles face at a 45° angle to the direction of traffic. See Section 10.2.4.7

Glare fencing may be appropriate on curves on high-volume, narrowly divided highways where headlights can shine directly into the eyes of drivers in the outside of the curve. Glare fencing may also be warranted where close frontage roads or railroads carry opposing traffic. In the latter cases, their design and construction might be no different from Visual Screen Fences discussed above, so the Regional Landscape Architect should be consulted for appropriate materials and details. However, since glare fencing is warranted wherever headlight glare is listed as a contributing factor to a significant number of accidents on divided highways, a partnership is needed between the Regional Landscape Architect and Safety Engineers to ensure that the fence achieves its primary purpose which is safety and accident reduction.

10.5.2.6 Noise Barriers

Placement of noise barriers so that they form the border of the clear zone should be avoided. Where it is deemed necessary to place noise barriers so that they border the clear zone, the barriers should be of a crashworthy design. At a minimum, they should not contain elements that would be likely to enter the passenger compartment and, if designed to deflect vehicles, they should not contain projections in excess of 4". If such a design is not acceptable, any noise barriers that border the clear zone width shall be shielded with suitable roadside barriers.

The purpose of noise barriers is to provide some amount of noise control. This may be attempted with a wall, a berm, or a combination of the two. The Environmental Science Bureau should be consulted to help determine the need for a noise barrier. Noise barriers can have a substantial effect on the visual environment of a highway and the surrounding community. Ideally, any wall or fence option should achieve continuity with the design styles in the neighborhood. The Regional Landscape Architect should also be involved early in the process to review the potential need for a noise barrier and to assess the historic, aesthetic, and cultural heritage of the neighborhood and the affected community's consensus on whether or not to build the proposed noise barrier. A variety of textured or decorated concrete walls have been

used. When a timber noise wall is appropriate for either the entire barrier or in conjunction with other materials or earth berms, Noise Barrier Wall, Item 15607.99XX may be specified. These specifications are for wooden noise wall, but allow approved alternates as well. The wooden noise wall is shown on Standard Sheet 607-5 Noise Barrier Wall Details (Horizontal Sheathing) and 607-6 Noise Barrier Wall Details (Vertical Sheathing). Upon request, the Geotechnical Engineering Bureau will design the footing depths and diameters for noise wall installations.

10.5.3 **Cattle Passes**

Cattle passes are tunnels that allow cattle to move from one side of a road to the other without occupying the traveled way. They were historically provided as mitigation when new roads separated significant quantities of pasture land from the remainder of an active dairy farm. Their rate of installation has declined dramatically in recent years due to the reduction in the number of new state roads and the decline in the dairy industry within the state. The situation is complicated by the provisions of the Farmlands Protection Act which strives to minimize direct or indirect (hindered access) loss of farmland.

In general, the use of cattle passes has proven to be problematical and has not produced one of the desired results: preventing subsequent damage claims. As a consequence, their use should only be approved after close examination confirms the justification. The Regional Real Estate Officer should be involved as soon as possible when installation of a cattle pass is given consideration.

10.5.3.1 Conditions Required for Construction

Generally, all of the following criteria must be met for a cattle pass to be warranted.

- The size of the herd should be at least 25.
- The design year AADT should be at least 500 vehicles.
- The separated parcel of pasture should be at least 10 acres in area.
- The owner actually wants one. Cattle passes are not to be forced on farm owners.

The following conditions are contributing factors that could increase the justification for installation of a cattle pass.

- The present cattle crossing is located where the sight distance is close to or less than the minimum allowed for the particular class of highway.
- The present cattle crossing is located on a grade in excess of 5%.
- The topography is favorable to the installation of an underpass.

For new highways in farm country, the designer should evaluate the first three criteria. If they are satisfied, the Regional Real Estate Officer should be notified to determine the farm owner's interest in a cattle pass.

If a farm owner has made a request for the installation of a cattle pass under an existing highway, the designer should evaluate the first three criteria above and notify the Regional Real Estate Officer.

The final determination of the need for a cattle pass should be made by the Regional Real

Estate Officer after all other options have been examined. Before construction of the cattle pass is approved, the Regional Real Estate Officer must obtain the owner's signature on an Agreement of Adjustment that restricts subsequent claims and on a Maintenance Agreement (Section 10.5.3.3).

10.5.3.2 Design Details

The standard cattle pass options are shown on the Standard Sheets for 603 items. Lengths should generally be limited to 50 ft as cows have shown reluctance to enter longer tunnels. The relatively narrow cross-sections are designed to prevent cattle from trying to turn around inside the tunnel. Wider box culvert cattle passes may be designed to permit easier cleaning and the passage of farm equipment. The specific geometry will be the result of negotiations between the owner, the Department of Agriculture and Markets, and the Real Estate Officer, with cost input from the designer. Because of the danger of cattle breaking legs after falling on ice and other problems, cattle passes are not to be designed to serve as a dual purpose cattle pass and drainage culvert. Entry slopes should be 1:4 or flatter. If possible, the inlet end should be placed above existing ground to minimize entry of runoff. The design should preclude standing water. The placement and back filling should provide for a minimum cover of 1 foot between the top of the cattle pass and the subgrade of the roadway.

10.5.3.3 Maintenance

Cattle passes, by their nature, require periodic cleaning. This is not a proper function of the Highway Maintenance Division. It is recommended that, prior to a final decision to include a cattle pass in the contract plans, a signed agreement be obtained, where the recipient of the cattle pass agrees to clean the proposed facility. However, the structural maintenance of the cattle pass must remain with the agency having highway maintenance jurisdiction.

10.5.4 **Guide Posts**

Guide posts are short, unconnected posts whose purpose is to prevent the willful movement of vehicles into restricted areas. Guide posts are not safety features for errant vehicles. In general, the use of guide posts is discouraged. While the use of guide posts may be warranted for special circumstances within low-speed locations, such as rest areas and other parking areas, preference should be given to the use of curbing and parking bumpers. Guide posts should not be used within the clear zone of any roadway.

10.5.5 **Barriers on Dead-End Roads and Streets**

The Department's barriers for use at dead ends consist of three (formerly two) corrugated W-beam rails with centerlines mounted at heights of 14 inches, 34 inches, and 54 inches on heavy-posts. Details are shown on the Standard Sheets for 630 items, "Highway Barrier and Highway-Railroad Barricade".

These barriers are significant hazards whose use must be carefully warranted and for which thorough warning must be provided. Warning sign requirements are specified in the national *Manual on Uniform Traffic Control Devices* (MUTCD) and its New York State Supplement. At a minimum, signage should include an advance "DEAD END" sign (Section 2C.21) and at least one "end of roadway" marker (Section 3C.04) above the barrier. Each rail of the barrier should

be covered by a strip of red and white striped barricade sheeting (Section 3F.01).

The use of barriers should be limited to those situations where a road ends, such as a dead end at a railroad (Highway-Railroad Barricade) or dead ends against limited access highways or where bridges are out (Highway Barriers). Because the barriers are fixed obstacles, they should only be used when a serious accident is likely to result if a vehicle passes beyond the end of the road. Examples would include dead ends at bodies of water, highway cuts, and other drop-offs. Also included would be cases where the errant vehicle would be likely to cause injury to other people, such as by entering onto highways with volumes in excess of 10,000 vehicles per day or areas where people are likely to congregate. In these latter cases, the barriers would not be warranted if other obstacles such as trees, ditches, or guide rail are present to prevent passage into the critical areas. The barriers would also not be warranted where the end-of-road signage will be clearly visible both day and night and the length of approach is short enough to limit approach speeds to less than 30 mph.

Where the end of the road is followed by conditions that do not exceed the hazard of the barrier, only the signage described in the MUTCD should be provided.

10.5.6 **Public Relations**

The New York State Department of Transportation has a duty to construct and maintain its roads so that they are reasonably safe for users. Sometimes, the details of meeting that duty may meet determined opposition from local residents. Typically, these concerns involve historical monuments, large trees, fences, landscaping features, or structures, often fronting private residences, but on State right-of-way. Whenever projects are considered that would involve potentially sensitive features such as these, the Regional Landscape Architect should be consulted, early in the process, to help address the complex aesthetic, cultural, and environmental issues and the concerns that may develop. The Regional Real Estate Office should also be consulted early in any discussions regarding potentially sensitive right-of-way encroachments. It is the Real Estate negotiator's responsibility to be of as much assistance as possible to those affected by the State's acquisitions. They are prepared to explain the rights and responsibilities of the State and adjacent property owners. Any potentially controversial actions should be called to the attention of the Regional Public Information Officer so the Department can be prepared to address any publicity on the issue.

10.5.7 Resetting Guide Rail

Frequently, maintenance or construction work requires that existing guide rail be taken down. On any projects that require the temporary removal of guide rail, the designer and EIC should try to minimize the amount of time that roadside hazards are unshielded. Where the risks are anticipated to be low, at a minimum, the plans should note that,

"Portions of runs should not be removed until it is necessary to remove them. Any portions of a run should be restored to service as soon as it is practical to do so. Leading ends of guide railing should not be left exposed to traffic without any shielding."

Where the risks will be more frequent or significant, the guidance in Section 10.5.7.4 should be followed.

Often, the guide rail is suitable for resetting. This section provides the guidance to be followed for resetting, salvaging, or rejecting existing guide rail. The term "guide rail" is here meant to cover posts, cable, rail elements, anchor assemblies, and splices for both median barriers and guide railing.

As noted previously in Section 10.3.1.2 B, the adequacy of a guide rail's type, placement (including point of need), anchorage, etc. must be carefully reviewed before specifying its resetting to existing conditions.

10.5.7.1 Railing Unsuitable for Resetting

Box beam guide rail or median barrier installed on contracts let before June 12, 1975, shall not be reset and shall not be retained on projects where any significant amount of construction work is to be performed. This rail can be recognized by any one of the following conditions.

- The rail is joined by external couplings.
- The rail is joined by two-bolt internal couplings.
- It lacks an imprinted heat number and manufacturer's symbol to indicate the material met the requirements of ASTM E436 - *Standard Method for Drop-Weight Tear Test of Ferritic Steels*. The imprint is generally opposite the weld at intervals not exceeding 4 feet.

The designer should field inspect all the existing guide rail installations within the project limits and determine which sections are not suitable for resetting. If any rail is severely damaged or rusted, it can not be reset. If any rail (that is otherwise suitable for resetting) has effectively lost its galvanized coating, it should be rejected as unsuitable for resetting. Outmoded corrugated shapes can not be reset. "C" posts were discontinued by EI 82-49 and are not suitable for resetting. "Z" posts, rarely encountered now, are also not to be reused.

10.5.7.2 Rail/Barrier Suitable for Resetting

When the designer has determined that a run (section) of guide rail, including cable guide rail, is not outmoded and that most of the lengths are suitable for resetting, it shall be so designated in a schedule on the plans. In the case of existing cable that will be reused, new splice couplings and wedges are to be used.

After contract award and prior to the dismantling of sections of the installation, the Engineer-in-Charge and the Contractor shall jointly survey those sections to be reset and determine and record the amount of visible damage. Such damage to the installation includes but is not limited to posts, cable, rail elements, anchor assemblies, and splices. When these elements are damaged beyond repair, the cost of replacing this material will be borne by the State. Payment will be made under an appropriate item when included in the contract; otherwise payment will be made by agreed price or force account.

When the damage survey is completed, the installation shall be dismantled and the acceptable material stored for later resetting. The material previously catalogued as damaged, and also that damaged by the Contractor's removal operation, shall be removed by the Contractor from the site. The cost of all additional inventory required to replace material damaged by the Contractor's operation shall be borne by the Contractor. This replacement inventory material shall be equal in kind and quality of that stockpiled for resetting as determined by the Engineer.

10.5.7.3 Salvaging or Removing Railing not Suitable for Resetting

When the designer determines which runs of guide rail are predominantly not suitable for resetting, the Regional Maintenance Engineer should be notified. The Regional Maintenance Engineer should determine whether a given run should be designated as Remove and Dispose, Item 606.71 to 606.80 or as Remove and Store, Items 606.61 to 606.70.

The designer should include a schedule on the plans indicating which runs of guide rail are "Suitable for Resetting", and which are suitable to "Remove and Store", or "Remove and Dispose".

Under the Remove and Store option, the Contractor is to remove the guide rail and neatly store the components in separate piles so that Department forces can salvage usable parts. Prior to project completion, salvage shall be performed and the Contractor shall be notified by the Regional Maintenance Engineer that salvage has been performed, so that the Contractor may begin to dispose of all remaining material as required by the specifications. Salvaged parts may be used for maintenance work on outmoded systems, current systems, or temporary detours as appropriate. However, outmoded (see 10.5.7.1) box beam should only be used for spot repair work. Outmoded box rail elements (lacking imprint of heat number and manufacturer's symbol) which are accepted by the Regional Maintenance Engineer as Remove and Store must be accompanied by written instructions from the EIC that the rail elements must be drop weight tear tested in accordance with ASTM E 436 before being installed in the normal maintenance operation. Where applicable, the designer should note this requirement on the plans. The Materials Bureau, through the Regional Materials Engineer, should be contacted for lot stocking and sampling instructions of box rail elements which are desired to be salvaged.

Contact the Design Quality Assurance Bureau should resetting or salvaging situations be encountered that are not covered by the above instructions.

10.5.7.4 Guide Rail Resetting Time Allowances

Guide rail provides an important safeguard that is lost during the time that it is removed for resetting. To minimize the exposure period when this protective feature is not available, guide rail that will be exposed to traffic should not be taken down earlier than necessary and should be put back in service as soon as possible. The designer should include notes in the contract documents alerting the contractor to the duration requirements for any project where guide rail replacement, resetting, or new installations are required. Recommended durations for a variety of guide rail installation conditions are shown below in Table 10-9.

Table 10-9 Recommended Guide Rail Installation Time Allowances

Work Operation	Allowable Out-of-Service Time Durations	
	AADT > 40,000	AADT < 40,000
Resurfacing/Roadside Safety	14 Calendar Days	21 Calendar Days
Guide Rail Replacement Projects	2 Calendar Days	2 Calendar Days
Reconstruction of Shoulder, Pavement, or Minor Culvert (< 6 ft diam.) Embankment Work	21 Calendar Days	28 Calendar Days
Median Barrier/Rail, Pier Protection, or Bridge Approaches Major Culvert Reconstruction	Same Day, unless temporary protection provisions made.*	Same Day, unless temporary protection provisions made.*
New Guide Rail Locations**	14 Calendar Days	21 Calendar Days

* Must be satisfactory to EIC. Consult with Traffic & Safety for further guidance.

** Not extensions of existing runs.

The designer should identify special situations, such as high accident locations, bodies of water, cliffs, etc., that may warrant shorter time durations or positive protection at all times. These areas should be described separately in the Special Notes, referenced by station or reference marker, and their allowable replacement durations specified.

The designer should include the following notes, as needed, in the proposal as a Special Note.

SPECIAL NOTE

GUIDE RAIL DOWNTIME RESTRICTIONS

This contract contains restrictions on the amount of time that any run of guide rail may be out of service or that installation of new runs may be deferred. The Contractor is advised to be aware of these restrictions when preparing bids and scheduling work for this contract. Failure, as determined by the Engineer, to comply with the time frames specified will result in assessment of nonpayment for Item 619.01 Basic Maintenance & Protections of Traffic (*or the appropriate item for special project types*) for each calendar day during which the cited guide rail installation is not complete. In addition, liquidated damages will also be assessed at rates shown in Table 108-1 of Section 108.03.

Guide rail shall not be removed from any location where traffic is being maintained until the Contractor or Sub-Contractor is prepared to fully install the new section of rail and its terminals. The Contractor shall schedule operations to replace all rail on the same day as removed unless

subsequent construction operations make it impractical to do so. Installation of the new rail shall begin as soon as practical after removal of the existing rail. Installation work on any individual location shall continue until all the railing at that location has been installed. When guide rail can not be replaced on the same day as removed, (1) the work area shall be delineated using the Overnight Shoulder Closure Details shown in the plans and (2) the guide rail shall be replaced within the guide rail replacement time duration for this contract, which is XX calendar days, except as noted below:

- The guide rail replacement duration shall be YY days for the following runs of rail:
Station *aa+bbb* to *cc+ddd*, *Right (or Left)*
- The guide rail duration for installing the following runs of new guide rail shall be
Station *eee+ff* to *ggg+hh*, *Right (or Left)*, ZZ days from *Beginning of mobilization* or *Creation of feature to be shielded*.

The guide rail replacement duration for a given existing run shall be measured from the first day that dismantling of the run begins to the day of complete installation of the rail and its end assemblies.

The designer should note the downtime restrictions below the guide rail tables on project plans that have such tables.

10.6 REFERENCES

1. *A Guide for Erecting Mailboxes on Highways*, 1994, American Association of State Highway and Transportation Officials, Suite 225, 444 North Capitol Street, N.W., Washington, D.C. 20001
2. *An Informational Guide on Fencing Controlled Access Highways*, November 1990, American Association of State Highway and Transportation Officials, Suite 225, 444 North Capitol Street, N.W., Washington, D.C. 20001
3. *A Policy on Design Standards, Interstate System*, January, 2005, American Association of State Highway and Transportation Officials, Suite 225, 444 North Capitol Street, N.W., Washington, D.C. 20001
4. *A Policy on Geometric Design of Highways and Streets*, 2004, American Association of State Highway and Transportation Officials, Suite 225, 444 North Capitol Street, N.W., Washington, D.C. 20001
5. *ASTM E436 - Standard Method for Drop-Weight Tear Tests of Ferritic Steels*, Volume 3.01, 1991, American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania, 19103-1187
6. *Bridge Detail Sheets*, Structures Design and Construction Division, New York State Department of Transportation, State Campus, Albany, New York, 12232
<https://www.nysdot.gov/main/business-center/engineering/cadd-info/drawings/bridge-detail-sheets-usc>
7. *Guidelines for the Adirondack Park*, Third Edition, August 2008, New York State Department of Transportation, <https://www.nysdot.gov/divisions/engineering/environmental-analysis/manuals-and-guidance/greenbook>
8. *NCHRP Report 230 - Recommended Procedures for the Safety Performance Evaluation of Highway Safety Appurtenances*, 1981, Michie, J. D., Transportation Research Board, 2101 Constitution Ave, N.W., Washington, D.C. 20418
9. *NCHRP Report 350 - Recommended Procedures for the Safety Performance Evaluation of Highway Features*, 1993, Ross, H. E., et al., Transportation Research Board, 2101 Constitution Ave, N.W., Washington, D.C. 20418
10. *NCHRP Synthesis 178 - Truck Escape Ramps*, 1992, Witheford, D. K., Transportation Research Board, 2101 Constitution Ave, N.W., Washington, D.C. 20418
11. *NYSDOT Client Report 37, Performance of Cable Median Barrier on the Palisades Interstate Parkway*, January 1989, Tyrell, A. B. & Bryden, J. E., Engineering Research and Development Bureau, New York State Department of Transportation, State Campus, Albany, New York, 12232
12. (MUTCD) *Manual on Uniform Traffic Control Devices*, refers to a combination of two documents: the national MUTCD and the New York State Supplement.
MUTCD 2003 Edition with Revisions Number 1 and 2 Incorporated, dated December 2007,

Federal Highway Administration <http://mutcd.fhwa.dot.gov/>

NYS Supplement to the National Manual on Uniform Traffic Control Devices, Office of Traffic Safety and Mobility, New York State Department of Transportation, 50 Wolf Road, Albany, New York, 12232, Published as *Transportation Title 17B (NYCRR)* by Thomson West (800-344-5009)
<https://www.nysdot.gov/portal/page/portal/divisions/operating/oom/transportation-systems/traffic-operations-section/mutcd>

13. *NYSDOT Research Report 145 - Movable Concrete Median Barrier: Risk Analysis of Deflection into Opposing Traffic*, December 1988, Bryden, J. E. & Bruno, N. J., Engineering Research and Development Bureau, New York State Department of Transportation, State Campus, Albany, New York, 12232

14. *New York State Standard Sheets*, Design Quality Assurance Bureau, New York State Department of Transportation, 50 Wolf Road, Albany, New York, 12232
<https://www.nysdot.gov/portal/page/portal/main/business-center/engineering/cadd-info/drawings/standard-sheets/606-guide-railing>

15. *Policy on Highway Lighting*, December 1979, NYSDOT Traffic and Safety Division, 50 Wolf Road, Albany, New York, 12232
<https://www.nysdot.gov/portal/page/portal/divisions/operating/oom/transportation-systems/repository/policylight.pdf>

16. *Procedure for Managing Projects*, Third Working Draft, September 1991, Program and Project Management Division, New York State Department of Transportation, 50 Wolf Road, Albany, New York, 12232

17. *Research Report 83 - Crash Tests of Sharply Curved Light-Post Guiderail*, July 1980, New York State Department of Transportation in cooperation with FHWA, New York State Department of Transportation, State Campus, Albany, New York, 12232

18. *Roadside Design Guide*, 2006, American Association of State Highway and Transportation Officials, Suite 249, 444 North Capitol Street, N.W., Washington, D.C. 20001

19. *Project Development Manual*, Project Development Section, New York State Department of Transportation, 50 Wolf Road, Albany, New York, 12232
<https://www.nysdot.gov/divisions/engineering/design/dgab/pdm>

20. *Standard Specifications - Construction and Materials*, 2008, Design Quality Assurance Bureau, New York State Department of Transportation, 50 Wolf Road, Albany, New York, 12232
<https://www.nysdot.gov/main/business-center/engineering/specifications/2008-standard-specs-us>

21. *Transportation Research Record 1258 - Roadside Safety 1990, Performance Evaluation of a Movable Concrete Barrier*, 1990, Glauz, D. L., Transportation Research Board, 2101 Constitution Ave, N.W., Washington, D.C. 20418

22. *Transportation Research Record 1302 - Roadside Safety Features 1991, Single-Slope Concrete Median Barrier*, 1991, Beason, W. L. et al., Transportation Research Board, 2101 Constitution Ave, N.W., Washington, D.C. 20418

23. *Transportation Research Record 1367 - Development and Evaluation of Roadside*

Features, ADIEM: Low Cost Terminal for Concrete Barriers, 1992, Ivey, D. L. & Marek, M. A., Transportation Research Board, 2101 Constitution Ave, N.W., Washington, D.C. 20418

24. *Utility Reimbursement*, Highway Design Manual Chapter 13, Appendix G, Design Quality Assurance Bureau, New York State Department of Transportation, 50 Wolf Road, Albany, New York, 12232

https://www.nysdot.gov/portal/page/portal/divisions/engineering/design/dqab/hdm/hdm-repository/hdm13app_g.pdf

25. *Weighted Average Item Price Reports*, Office of Engineering, New York State Department of Transportation, 50 Wolf Road, Albany, New York, 12232

<https://www.nysdot.gov/portal/page/portal/divisions/engineering/design/dqab/waipr>

APPENDICES

- A. SPOT EVALUATION OF DESIRABLE CLEAR ZONE WIDTHS**
- B. SUPPORT OF GUIDE RAIL OVER SHALLOW OBSTRUCTIONS**
- C. BARRIER IMPACT TESTING AND ITS RELATION TO IN-SERVICE PERFORMANCE**

SPOT EVALUATION OF DESIRABLE CLEAR ZONE WIDTHS

10A.1 INTRODUCTION

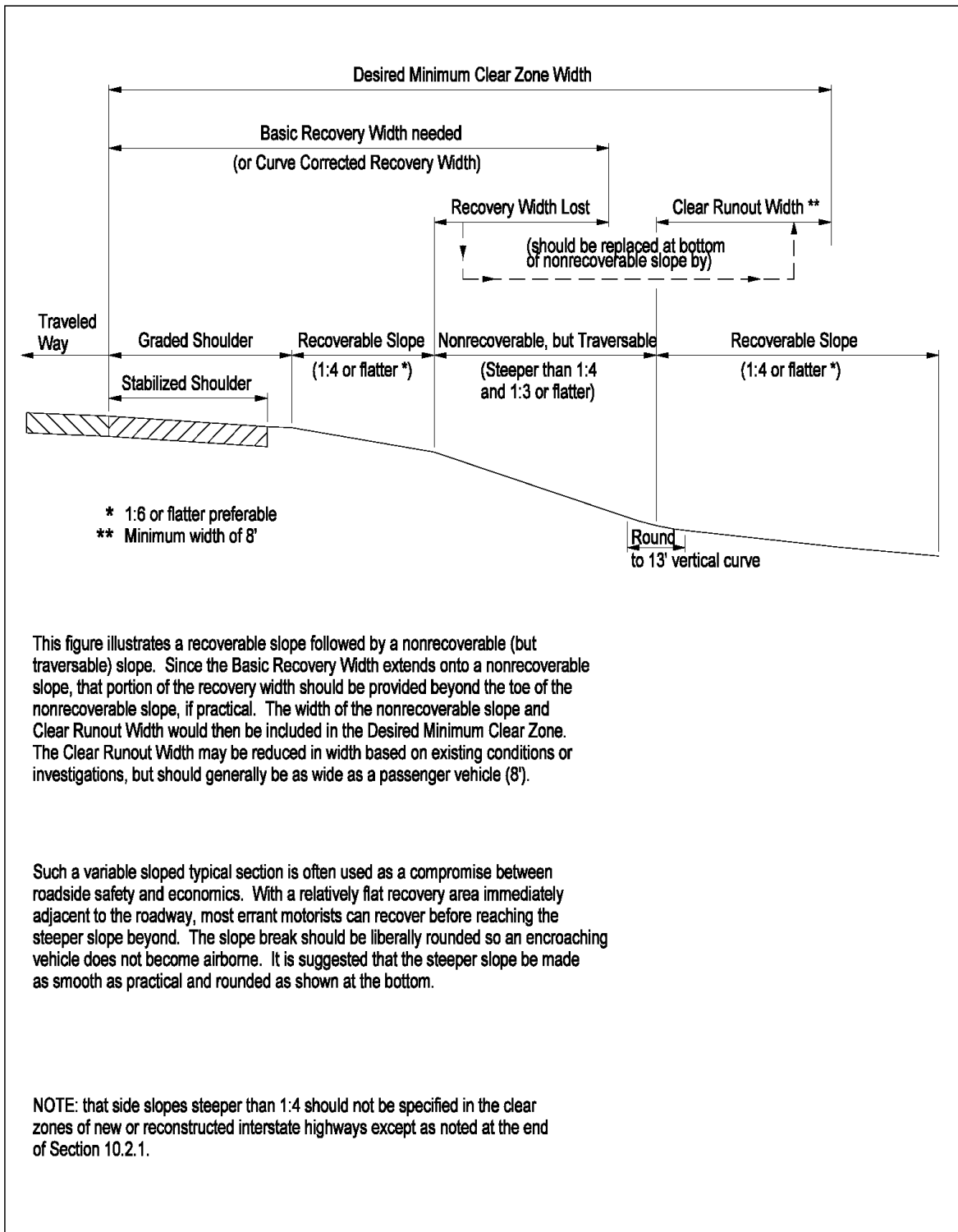
Roadside conditions change almost continuously from station to station along a highway. Factors such as embankment height and slope, ROW widths, development, and context vary rapidly over short distances. It is not reasonable to expend the resources that would be needed to determine the best clear zone width at each change in conditions. Still, there may be some instances where it is appropriate to evaluate the desirable clear zone width at a specific location, such as when various widths can be obtained and a basis is needed to determine what would be appropriate. The following procedure discusses the Spot Evaluation of Desirable Clear Zone Widths.

1. **Basic Recovery Width, BRW.** This is a numeric value (selected from Table 10-1) representing the basic width of recovery area that should be provided for given traffic volumes, design speeds, and slopes ranging from 1:3 cut slopes to 1:4 embankment slopes. Slopes in this range are considered recoverable since a driver may be able to recover control of an errant vehicle and return to the roadway. (Smooth cut slopes steeper than 1:3 may generally be included as part of the clear zone, provided there are smooth slope transitions between the roadway and the slope. This remains an area requiring the use of good judgment.) The BRW does not take into account curvature, nonrecoverable slopes, or accident history. The BRW values will generally, but not always, provide adequate width for recovery of errant vehicles. See Figure 10-2b for an example of a compound slope solution.

2. **Nonrecoverable Slope.** Traversable, but nonrecoverable slopes may be present in the clear zone, but may not be credited towards meeting the Basic Recovery Width needs. See Figure 10-2a.

3. **Curve Corrected Recovery Width, CCRW.** This width takes into account the effects of horizontal curvature. It is obtained by multiplying the Basic Recovery Width by the appropriate horizontal curve correction factor, K_{oc} for the outside of curves. Table 10-2 presents the curve correction factors. It is desirable to apply the curve correction factor where long tangent sections of highway are followed by curves, and particularly when those curves have rated speeds* 10 or more mph less than the prevailing or anticipated operating speed on the tangent. The horizontal curve correction factor, K_{oc} , should also be applied when the curve is at the bottom of a long downgrade or obscured by a crest vertical curve and there is an increased possibility of a driver being "surprised" by the curve. (On existing facilities, refer to the 3R Standards for additional alternatives for dealing with problem curves, such as providing more superelevation or signage.) See Figure 10-2c.

* The rated speed is the maximum speed at which a vehicle can travel a superelevated curve without exerting any side friction. The rated speed, V_r , may be calculated as the square root of $(.15Re)$, where R is the radius of the curve in feet, e is the superelevation in percent (e.g. 6, 8, etc.), and V_r is in miles per hour.

Figure 10A-1 Clear Zone Terminology and Nonrecoverable Slopes

4. **Clear Runout Width, CRW.** This is the width that should be provided at the toe of a traversable, nonrecoverable fill slope. The minimum value of this width should be 8 ft to accommodate the width of a passenger vehicle. Otherwise, the width should be such that, when added to the width of the graded shoulder and any other recoverable width above the nonrecoverable slope, the Basic Recovery Width or, where appropriate, the Curve Corrected Recovery Width is attained. Refer to Fig. 10-1.

5. **Desired Minimum Clear Zone Width, CZ_{DM} .** This is the larger of the following, as appropriate:

- Basic Recovery Width
- Curve Corrected Recovery Width
- The sum of the Clear Runout Width plus the width from the traveled way to the toe of the traversable but nonrecoverable slope

6. **Design Clear Zone Width, CZ_D .** Selection of the Design Clear Zone Width should be made by an engineer experienced in roadside design. The selected value should take into account the Desired Minimum Clear Zone Width, environmental effects and cost considerations. Generally, the spot Design Clear Zone Width on a new project will equal or exceed the Desired Minimum, on reconstruction projects it will range at and below the Desired Minimum, and on 3R projects it will frequently not meet the Desired Minimum.

Spot clear zone width evaluation should involve the following steps.

1. Select the cross section to evaluate and note the parameters that will affect the desirable clear zone width.
2. Use the project design speed and the Average Annual Daily Traffic to obtain the Basic Recovery Width, BRW, from Table 10-1.
3. If the cross section is within a problem or "surprise" curve, as discussed in Section 10.2, and the clear zone being considered is on the outside of the curve, multiply the BRW on the outside of that segment by the appropriate horizontal curve correction factor, K_{oc} , (see Table 10-2) to obtain the Curve Corrected Recovery Width, CCRW.
4. If any traversable but nonrecoverable slopes cut into the recovery width, determine an appropriate Clear Runout Width, CRW, to extend beyond the base of the slope.
5. Using the Desired Minimum Clear Zone Widths (maximum clear width obtained from steps 2, 3, and/or 4) and taking into account environmental effects, topography, adjacent development, right of way availability and other cost considerations, the engineer should select an appropriate Design Clear Zone Width, CZ_D , for that spot.

Figure 10A-2a Sample Clear Zone Calculations-Cases I & II (Nonrecoverable Slopes)

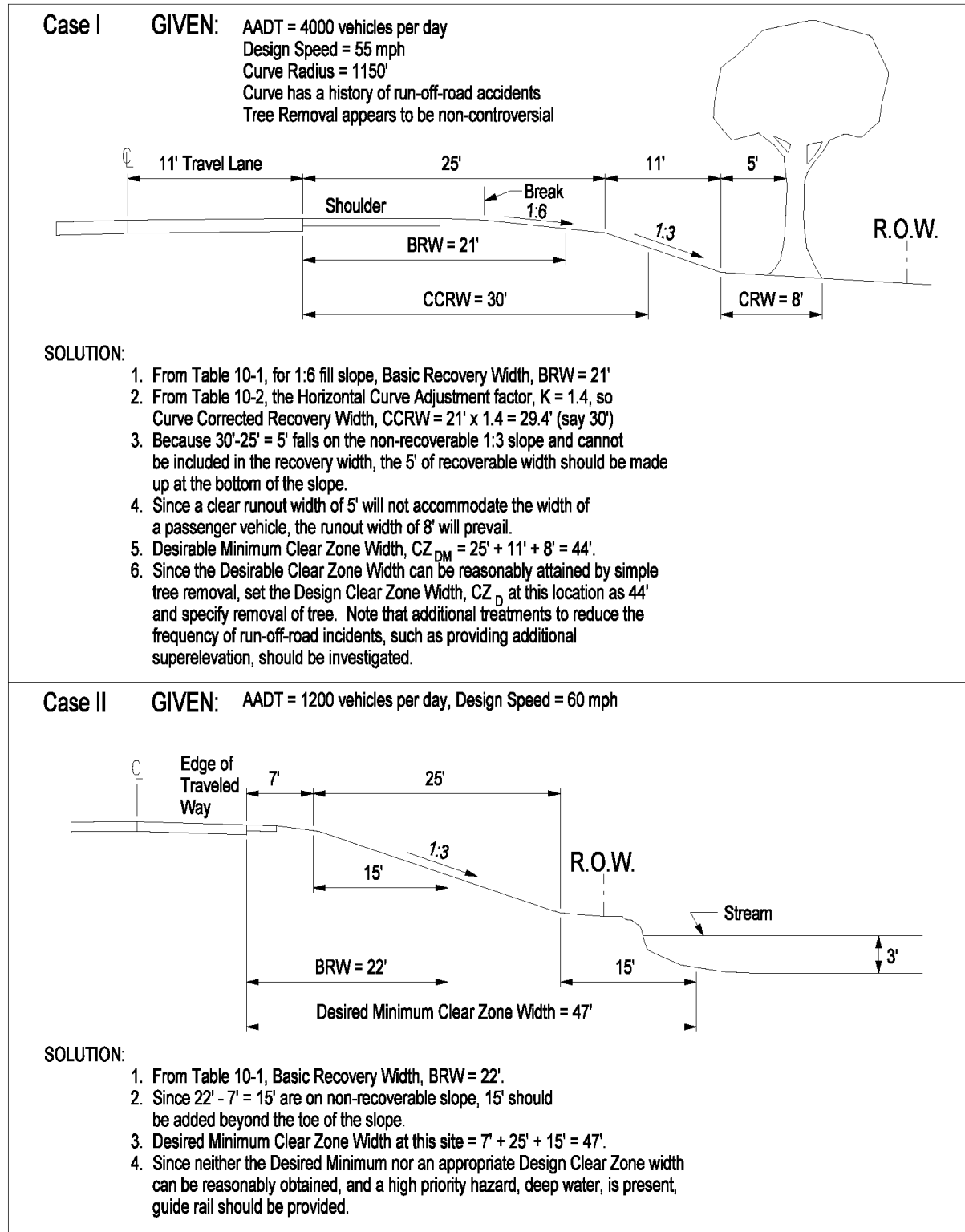


Figure 10A-2b Sample Clear Zone Calculations-Case III (Rock Cut)

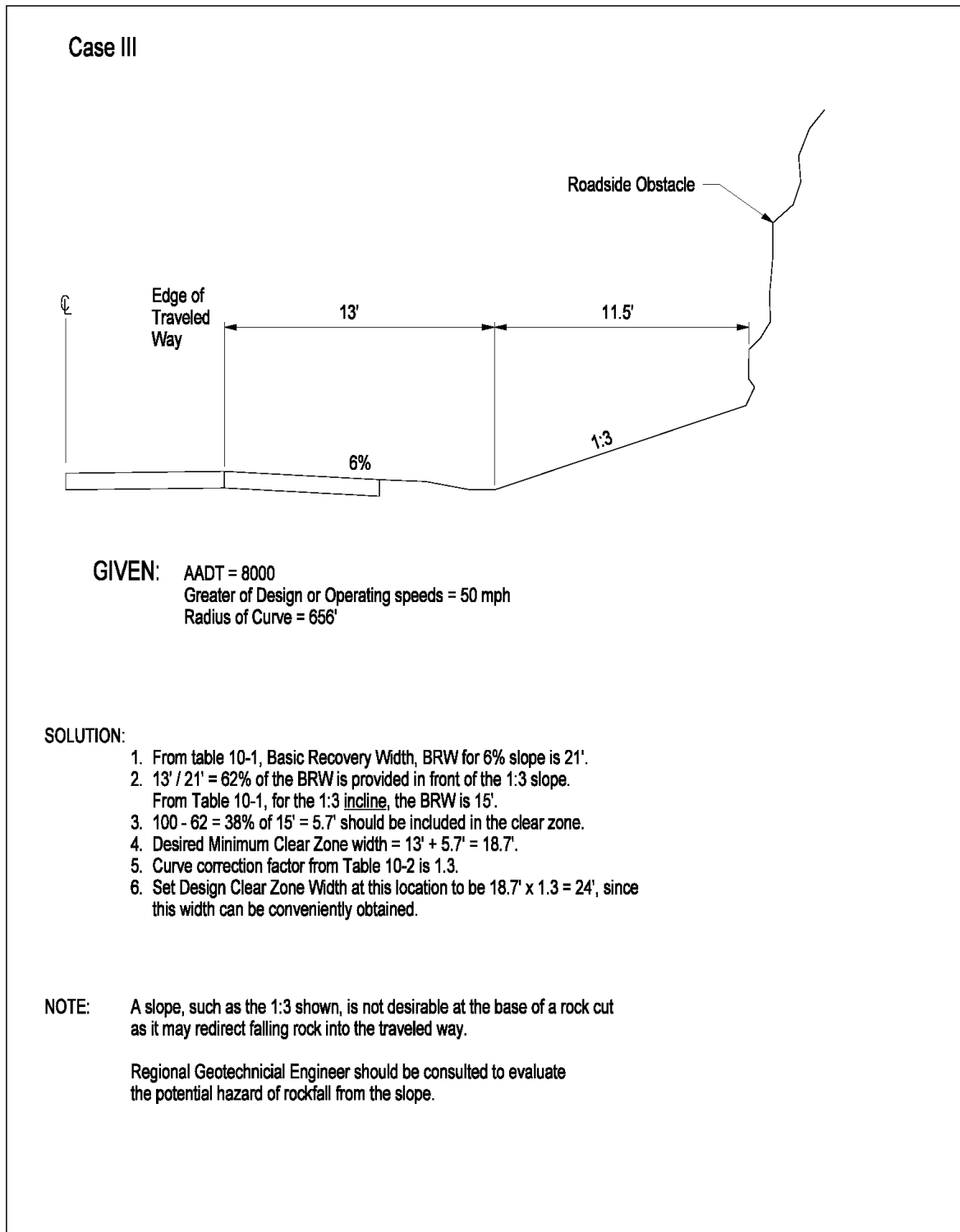
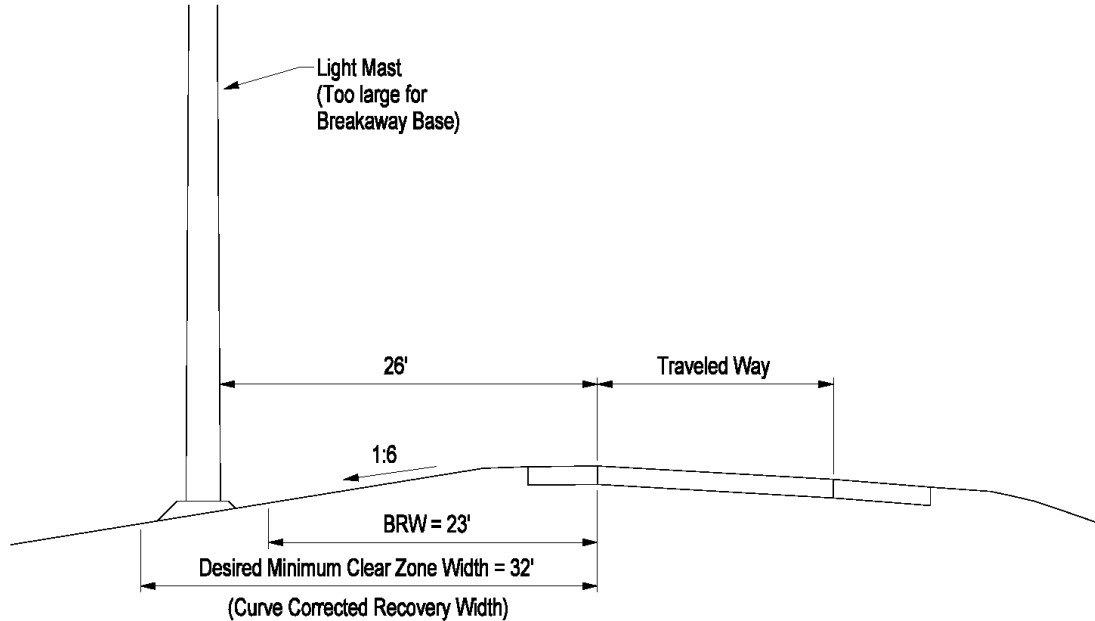


Figure 10A-2c Sample Clear Zone Calculations-Case IV (Ramp Curve)

Case IV

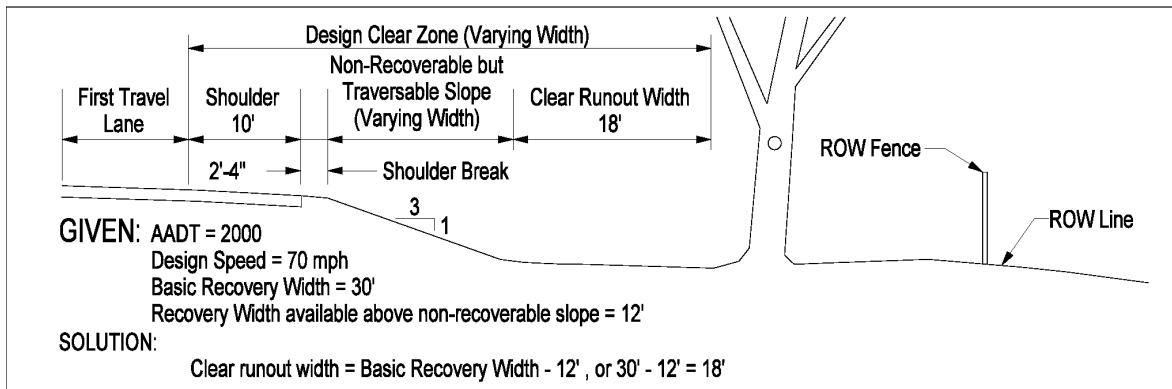
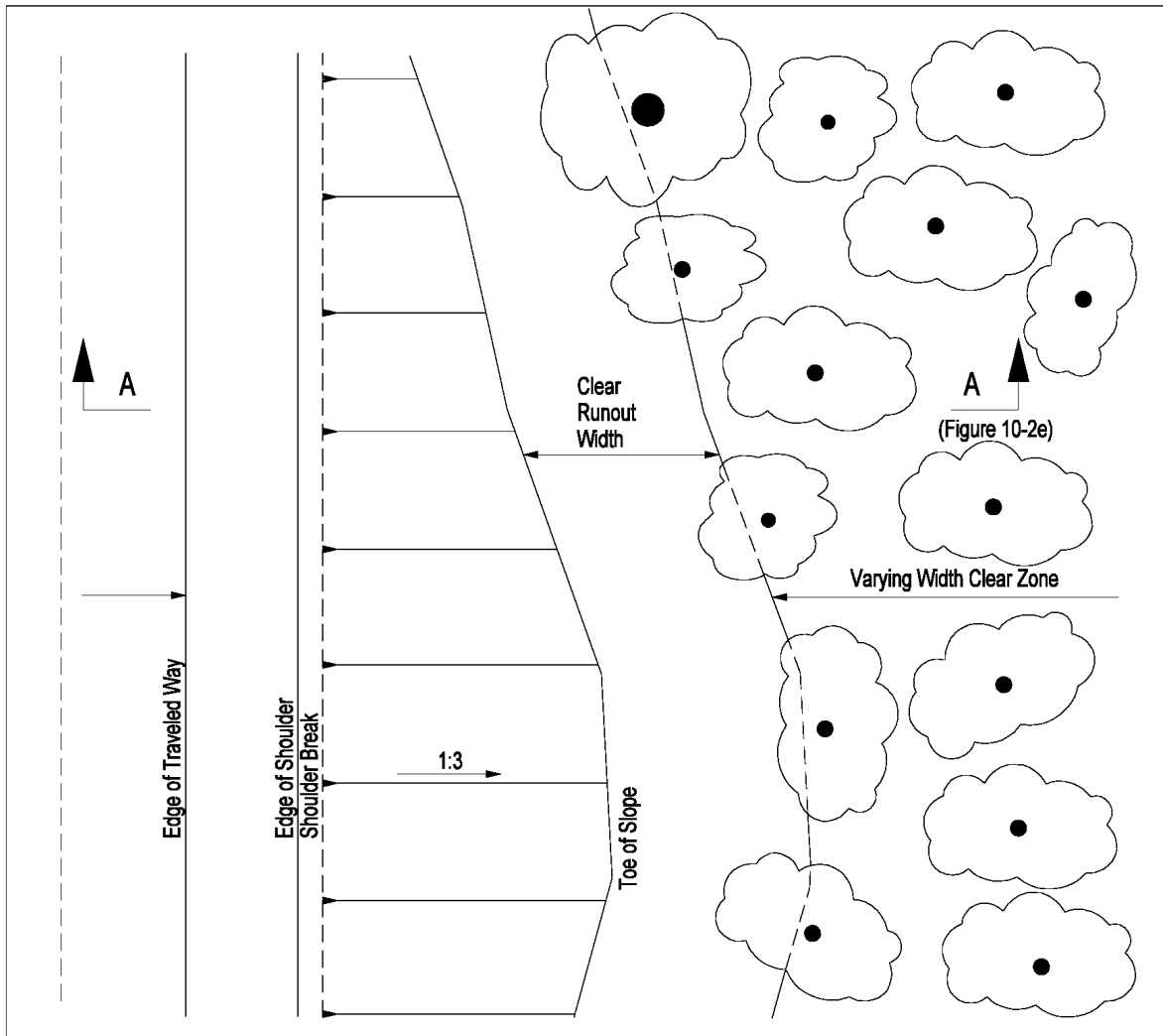
- GIVEN:
1. Exit ramp or curve following a long tangent.
 2. AADT of 25000
 3. Main line operating speed = 70 mph
 4. Curve Radius = 1150'
 5. Rated Curve Speed = 55 mph
 6. Reconstruction with proper superelevation



SOLUTION:

1. From Table 10-1, for a design speed of 55 mph and an AADT of 25,000, the Basic Recovery Width, BRW, for a 1:6 slope is 23'.
2. Since the curve's rated speed is more than 10 mph less than the prevailing operating speed prior to the curve, the Horizontal Curve Adjustment Factor, K_{OC} , should be applied.
3. From Table 10-2, for a design speed of 55 mph and a 1150' radius curve, $K_{OC} = 1.4$. Therefore, the Curve Corrected Recovery Width, CCRW, is the Basic Recovery Width, BRW, times 1.4. $CCRW = 23' \times 1.4 = 32'$.
4. Since there are no non-recoverable slopes in the section, the CCRW becomes the Desired Minimum Clear Zone Width, CZ_{DM} .
5. Since the light mast is inside the Desired Minimum Clear Zone Width, it should be either relocated or shielded. If removal is not possible and the remainder of the clear zone is good, preference should be given to use of an impact attenuator. If there are problems with the rest of the clear zone, preference should be given to the use of guide rail or barrier.

Figure 10A-2d&e Sample Clear Zone Calculations-Plan & Section of Runout Width



Appendix B

Support of Guide Rail Over Shallow Obstructions

**Design Quality Assurance Bureau
Originally Issued January 2004**

(Converted to US Customary Units on 8/28/2008)

Appendix B
Support of Guide Rail
Over Shallow Obstructions

Table of Contents

1. Background	10B-3
2. General	10B-3
3. Use of this Guidance	10B-4
3A. Cable Guide Rail	10B-5
3B. W-Beam on Weak Posts	10B-9
3C. Box Beam	10B-13
3D. W-Beam on Heavy Posts	10B-17
3E. Base Plates for Weak Post Rail Systems	10B-20
3F. Concrete Barrier	10B-22
3G. Lateral Offsets	10B-23
3H. Payment Considerations	10B-24

1.0 Background: For several decades, it has been the Department's general practice to provide barriers where a highway crosses a culvert. These barriers could be guide rail, culvert rail or bridge rail, depending on the size and other geometric details of the culvert involved. Unfortunately, it was not always clear which type of rail should be used in a given circumstance. When the National Cooperative Highway Research Program issued their Report 350 – *Recommended Procedures for the Safety Performance Evaluation of Highway Features* (NCHRP 350), it was endorsed by FHWA. FHWA went one step further to require that all barriers and terminals used on federal-aid highway projects should meet the NCHRP 350 test criteria or be judged capable of passing them. As a result, extensive testing was performed on existing highway barrier systems. Acceptable bridge rail and highway guide rail systems were developed or existing systems were validated. Because the testing process is expensive and our culvert rail was relatively seldom used, it did not appear to make economic sense to perform the expensive testing necessary to confirm its ability to pass the new crash test criteria. Taking into consideration the possibility that it might not have passed, the decision was made to drop culvert rail as a barrier option at culverts. Consequently, any barrier placed at a culvert should now be provided either as highway guide rail or as bridge rail. This present guidance is intended to define the range of circumstances where it is appropriate to provide guide rail. Whenever the culvert size and geometry do not meet the conditions described herein, any barrier needs should be met with a bridge rail option. Guidance on the appropriate bridge rail for a given situation should be obtained from the Structures Division.

Since the use of guide rail at culverts often introduces the problem of the culvert preventing posts from being driven to their normal depths, it made sense to extend the guidance to include other obstructions to driving as well. Therefore, this guidance describes acceptable methods of dealing with situations where the presence of a shallow obstruction, such as a culvert, boulder, or utility line, prevents driving guide rail posts to their normal depths at their normal locations.

2.0 General: If the obstruction is identified early enough and is of limited extent, it may be possible to shift the entire run of rail slightly so that the obstruction is straddled and no other modifications are required. The most common choices for supporting guide rail over a shallow obstruction are to move, shorten, or add posts to support the rail system. However, these options may only be selected if there will be no fixed objects or snagging holes (see the fourth and subsequent paragraphs of this subsection, below) within the deflection distance of the guide rail. For conditions not meeting this requirement, refer to guidance from the Structures Division.

If posts cannot be moved or added to eliminate the conflict with the shallow object, then it may be reasonable to weld a base plate to the bottom of the post and bolt the base plate to a concrete base. This concrete base may be either one constructed for that purpose, or may be the obstruction itself, assuming it is acceptable to bolt to that specific culvert or footing. While providing base plates for multiple posts may be necessary in some cases, the practice should be avoided. Where a base plate and bolting option is used, it may be assumed that the resulting rail deflections will be similar to the standard deflections. The typical base plate details for weak posts are covered in Section E of this document. Base plates for heavy posts are covered on Standard Sheet M606-10R2.

In rare instances, shallow rock may be encountered over broad areas. When this occurs, post hole locations should be drilled to normal depth, posts should be inserted without soil plates, and the holes should be backfilled with gravel or sand. Alternatively, consideration may be

given to using concrete median barrier in place of guide rail, since its embedment depth is only 9 inches. Refer to Section F for safety considerations related to concrete barrier.

Since some of the modifications identified in the following sections should be assumed to increase the deflection distance of the guide rail, that system should be reevaluated to determine if any rigid fixed objects (such as headwall or wingwall projections, utility poles, or trees) would be within its deflection distance. Fixed objects within the deflection distance should be removed or a stiffer barrier system should be substituted, specifically one with a deflection less than the distance to the fixed object. See Highway Design Manual Table 10-3 for the standard highway guide rail deflections.

In addition to fixed objects that project above grade, consideration must be given to “holes” that a vehicle’s wheel might snag in, possibly resulting in a rollover accident. For guiderail systems that have large deflections, there is the potential for high-speed errant vehicles to deflect the rail, slow, and then snag on fairly narrow “holes” in the embankment. For this reason, no openings with widths over 3 feet, such as culvert ends, should be permitted within the deflection distance of rails with standard deflections of 5 feet or more, unless the opening is covered with a grating to prevent a vehicle’s tires from snagging.

For guide rail systems with standard deflection distances less than 5 feet (HPBO and box beam with 3 foot and 3'-1½" post spacings), the potential for vehicles snagging in holes is significantly reduced. If the vehicle is not going fast, the rail deflection is significantly reduced and the consequences of a snag are lowered. If an impacting vehicle is going fast, the vehicle usually loses contact with the ground at impact and it is over an opening for such a brief moment that its tires do not have an opportunity to move down into the “hole” enough to produce a snagging condition. For these reasons, wider openings are permissible within the deflection distances of more rigid rails. Therefore, for guide rail systems with standard deflection distances less than 5 feet, no ungrated openings with widths over 10 feet should be permitted within their deflection distance.

Regardless of the above allowances, unless peak flow and debris indicate otherwise, most culverts exposed to traversal by errant vehicles should be flush with the embankment surface and grated for traversability, if their width is greater than 1.5 feet and less than 5 feet. When these openings are behind guide rail and debris accumulation is judged to be a problem, it may not be necessary to cover the entire height of the opening, but it is desirable for the grating to extend 1.5 feet beyond the deflection distance. For smaller transverse culverts, the minimum grating may consist of #8 reinforcing bars welded together on 12 inch centers. This rebar mat was “crash” tested for transverse culvert configurations and judged satisfactory for covering openings up to 5 feet by 7.5 feet. Note that, by increasing the bar size to #9, satisfactory results were calculated for openings measuring up to 10 feet by 17 feet.

3.0 Use of this Guidance: Sections A through G of this document describe options for supporting rail over shallow obstructions. Section H addresses payment for those measures. To use this guidance, select the best modification to address the shallow obstruction, check the deflection to verify that the barrier system choice is acceptable, and make any modifications to the post design as indicated. If a check of the deflection distance indicates that the barrier selection is not appropriate, a different barrier system should be used. In some instances, the extent of the obstruction and the proximity of openings (particularly at large, shallow box culverts) may require that bridge rail be used. Refer to guidance provided by the Structures Division for those treatments.

3A. Cable Guide Rail Posts at Shallow Obstructions

Cable readily permits the longitudinal repositioning or addition of posts, because a post may easily be fastened to the rail at any point along its length. Slight longitudinal repositioning of individual posts will not have a significant effect on the deflection distance. Therefore, if the obstruction to driving a post is fairly narrow, such as a small culvert or boulder, the post should be moved longitudinally by up to 2.5 feet. See Detail 1-B. Note that aesthetics may be an issue where the guide rail is being used on a tight radius (minimum radius for cable is 450 ft). If the post relocation introduces an objectionable jog in the curve, consideration should be given to using the additional post arrangement shown in Detail 1-C.

If the obstruction requires movement of a post by more than 2.5 feet, an extra post should be added, such that the moved post and the added post straddle the obstruction. Ideally, the posts should be spaced evenly at the third points of the length between the posts on either side. See Detail 1-C.

If the obstruction is wider than two-thirds of the normal post spacing, the span width between the moved and the added post may be increased, but should not be more than 2.5 feet wider than the normal post spacing for the run. Some minor adjustment of the posts outside of the moved and added posts may be needed, but it should be remembered that more support is needed near the wider span. See Detail 1-D.

If the obstruction to post driving is more than 2.5 feet wider than the normal post spacing, then the use of shortened posts should be considered. A maximum of 12 inches of post and soil plate may be cut off the bottom of a single post assembly without significantly affecting the deflection distance. See Details 1-G and 1-H. This amount applies to either standard posts, which have a normal embedment depth of 33 inches, or to extra long posts, which have a normal embedment depth of 54 inches. The amount cut off the bottom of any one post should not significantly exceed the amount needed to permit driving the post so that its top is at the correct height.

To maintain the normal deflection distance in an area where two posts need to be shortened by up to 12 inches, additional posts should be added. Post spacing for shortened posts should not exceed $\frac{2}{3}$ of the typical post spacing and the length of the spanned area should not exceed twice the normal post spacing. See Details 1-E and 1-F for examples.

If a cable run with 8 foot post spacings (standard deflection = 8 feet) has a single post that needs to be shortened by more than 12 inches and all spacings are kept to the normal dimensions, then the deflection in that immediate area between the normal posts should be assumed to be 11 feet. See Detail 1-J.

If the extent of the shallow obstruction(s) prevents the use of any of the above options, consideration should be given to modifying or removing the shielded feature, switching to a different barrier system, or bolting the posts to the obstruction or a constructed foundation as described in Section E. Consultation on selecting an option is available by contacting the Design Quality Assurance Bureau.

10B-1 Cable Guide Rail Adjustments over Narrow Shallow Obstructions to Post Driving

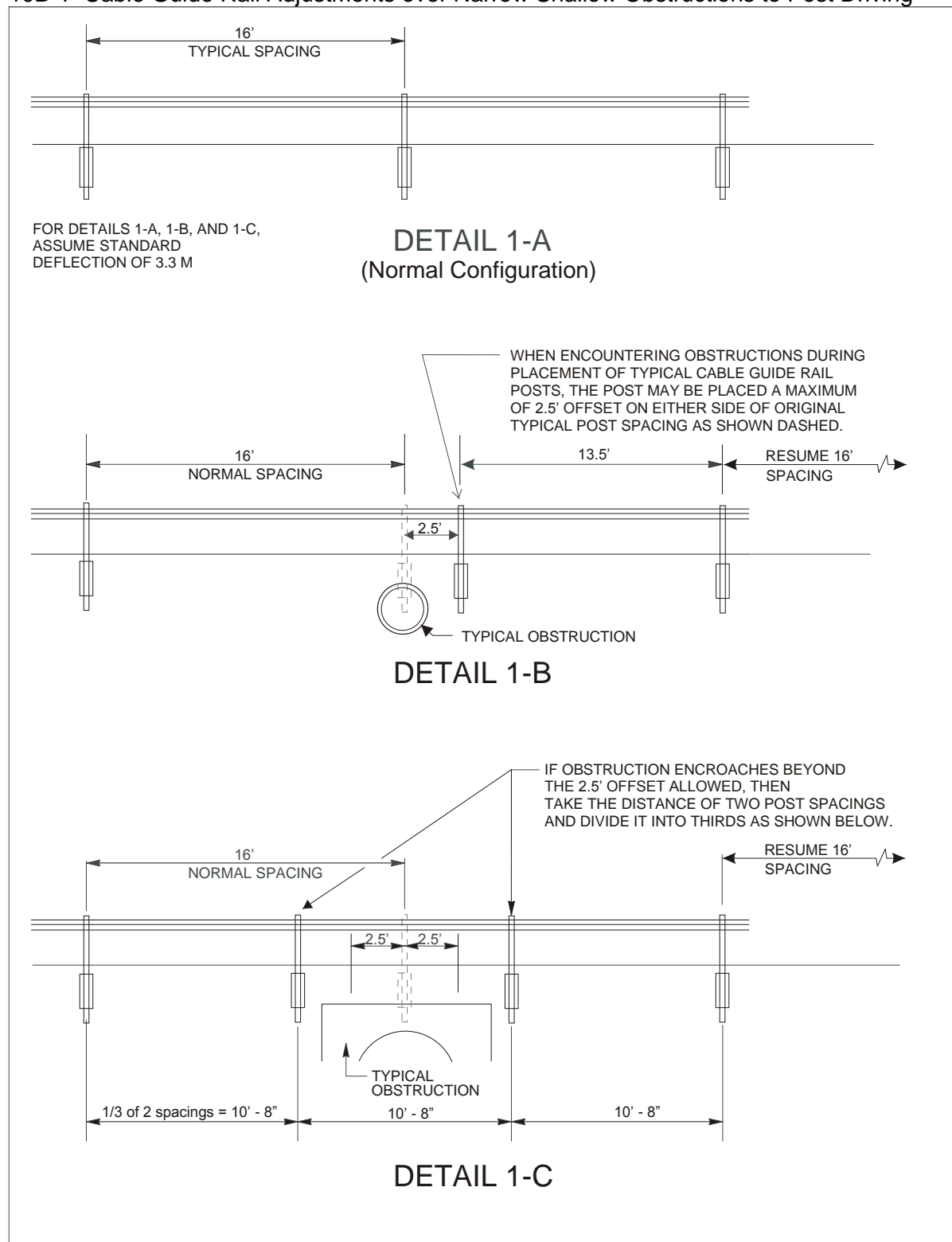


Fig. 10B-2 Cable Guide Rail Adjustments over Wide Shallow Obstructions to Post Driving

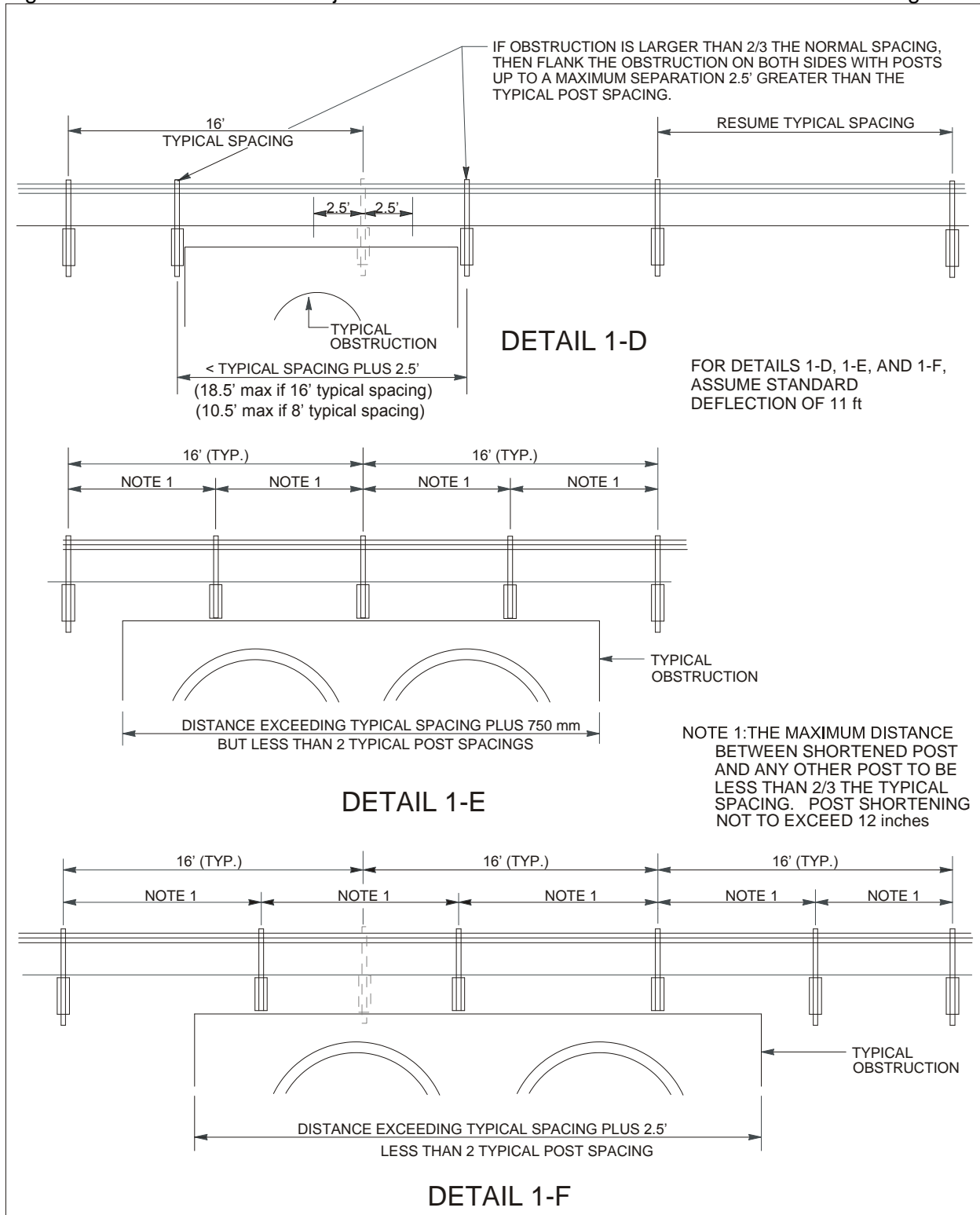
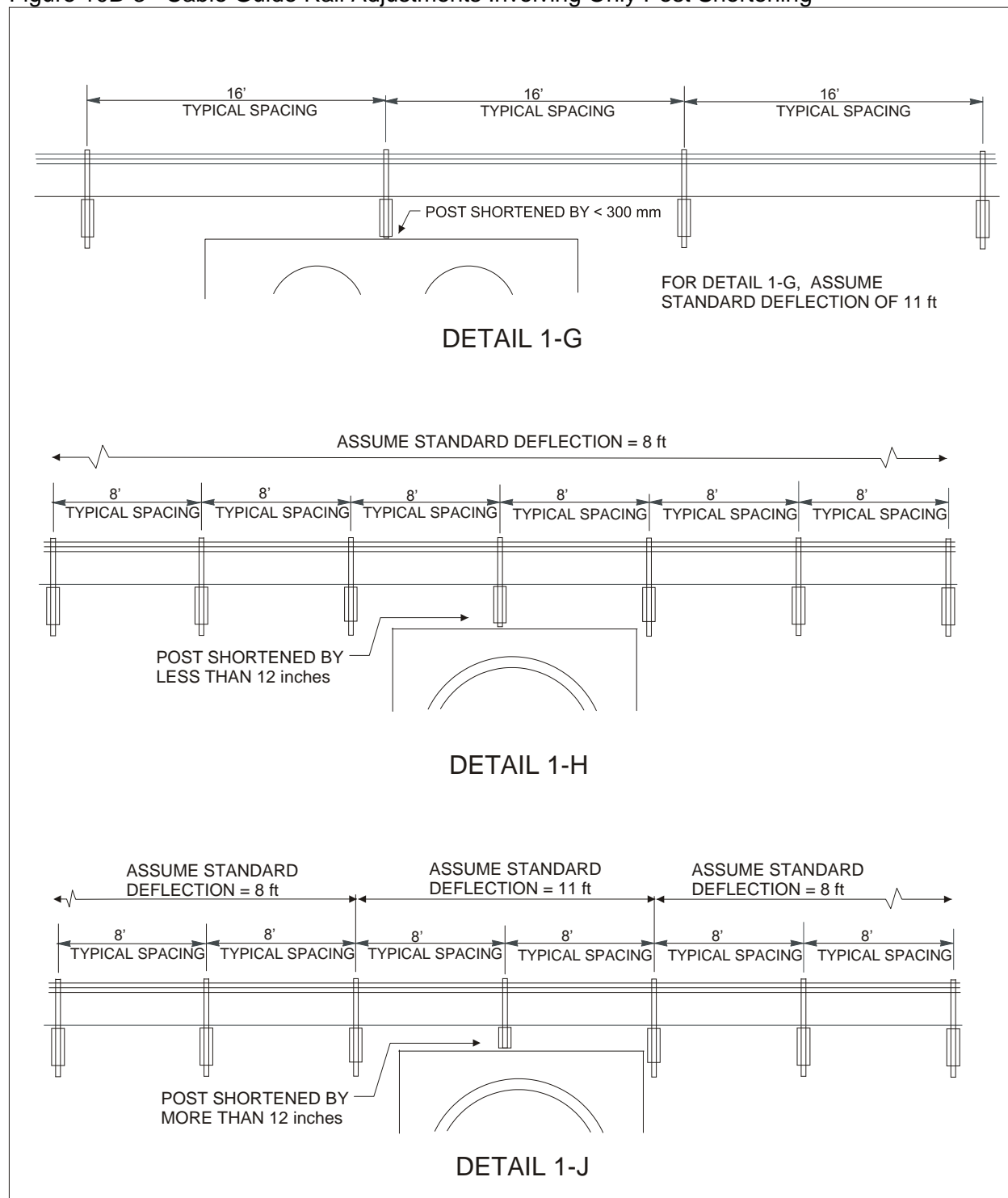


Figure 10B-3 Cable Guide Rail Adjustments Involving Only Post Shortening



3B.W-Beam on Weak Posts at Shallow Obstructions

Unlike cable guide rail, W-Beam is fabricated with bolt holes that only permit fastening to posts at predefined points, 6' - 3½" apart. Posts may be spaced at either 12' - 6" or at 6' - 3½", depending on the deflection distance available behind the rail. In the following paragraphs, options for the 12' - 6" spacings will be described first, followed by those for 6' - 3½" spacings. As indicated on Standard Sheet 606-6, additional posts may be placed for added backup support and they need not, and actually should not, be fastened to the rail. (NOTE: Revisions to the weak post W-beam system placed beam splices between posts that are on 12' - 6" spacings. The details herein show the traditional splice locations.)

Normal Post Spacing of 12' - 6": If a single post encounters a shallow obstruction, that post may be shortened by cutting a maximum of 12 inches of post and soil plate off the bottom of the post assembly. See Detail 2-A.

If a single post encounters a shallow obstruction that would require shortening the post by more than 12 inches, two additional posts should be added, one in each of the adjoining bolt holes on either side of the obstruction. The shortened post should be included for aesthetics. See Detail 2-B.

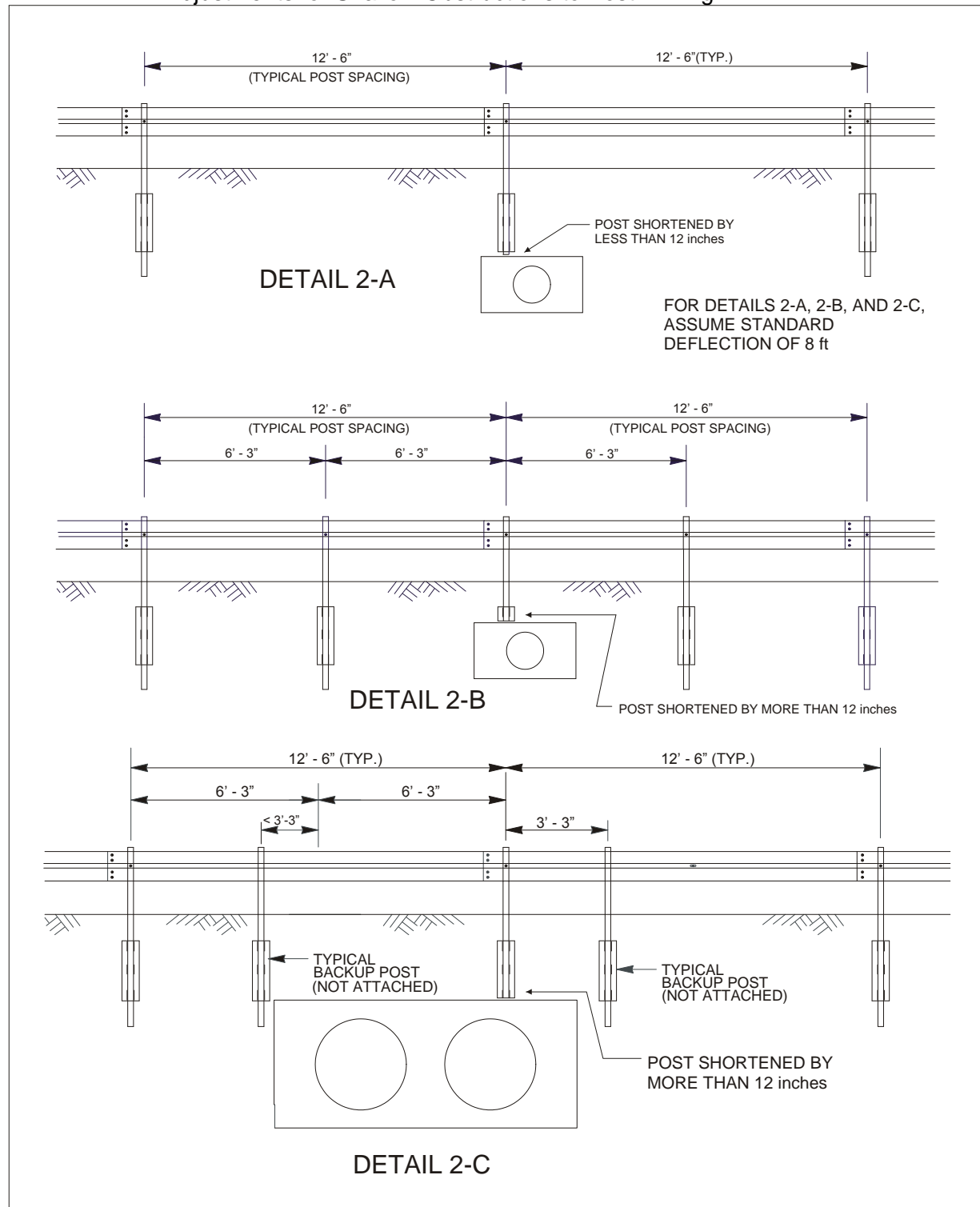
If a shallow obstruction is found that would require shortening a post by more than 12 inches and the obstruction would also require shortening of a post placed at one of the adjoining bolt holes 6' - 3½" away, backup posts should be provided on either side of the obstruction, provided they will not have to be spaced more than 12' - 6" apart. The post location that would require a shortened post should receive that post, as it is needed for vertical support. See Detail 2-C.

Normal Post Spacing of 6' - 3½": If a post encounters a shallow obstruction, a maximum of 12 inches of post and soil plate may be cut off the bottom of the post assembly before it is driven, and an additional piece of W-beam added behind the other rail sections, centered on the shortened post. See Detail 2-D. (If the shortened post occurs at a splice, extra holes will have to be drilled in the backup rail to accommodate the splice bolts. See Detail 2-E.) If the post would have to be shortened by more than 12 inches to drive it to the appropriate height, the clear area required for deflection distance behind the doubled rail, and for 10' on either side of the affected post, should be increased from 6 feet to 8 feet. See Detail 2-F. If the post would have to be shortened by over 18 inches to drive it to the appropriate height, the above conditions would apply, but that post may be eliminated.

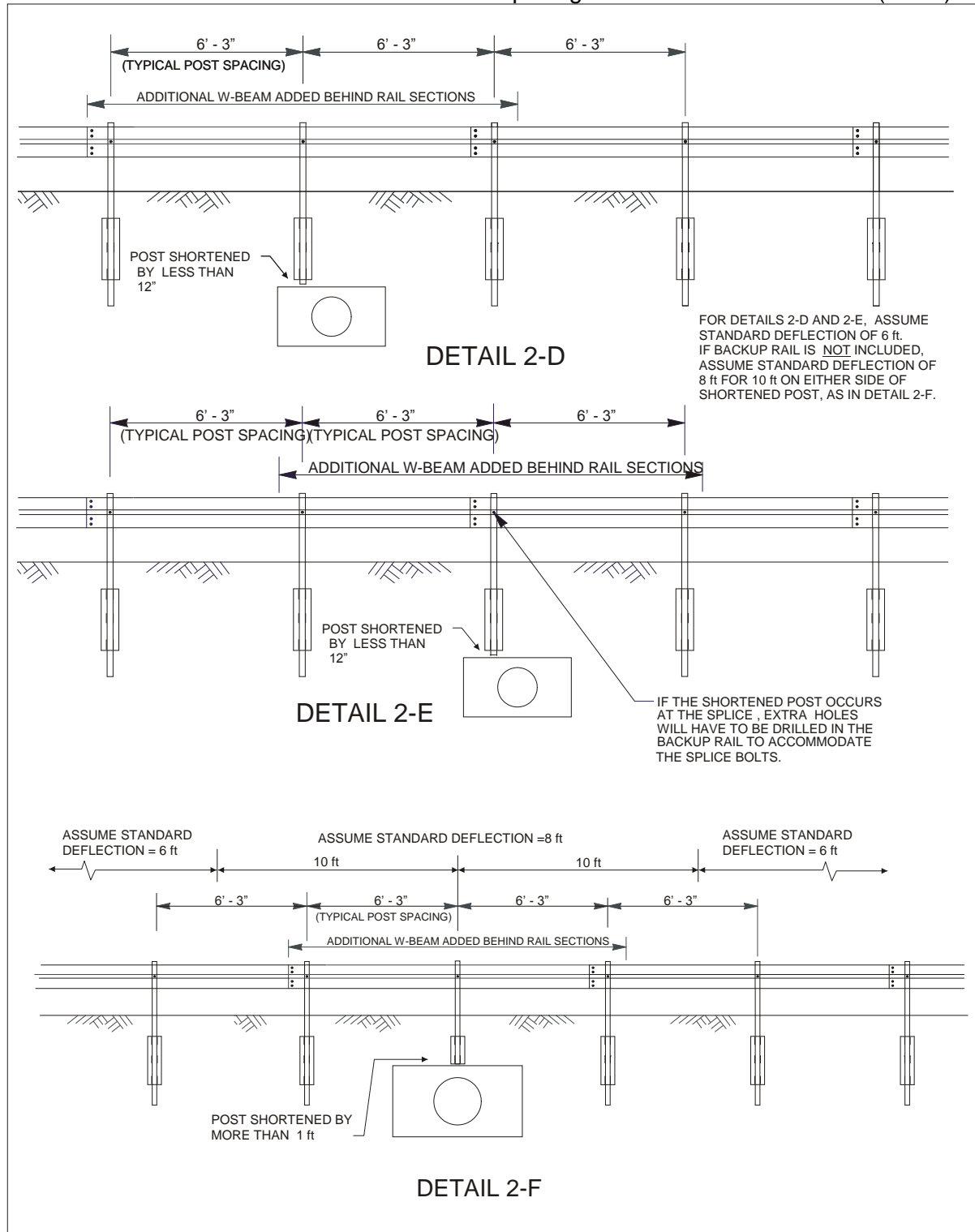
If two consecutive posts encounter an obstruction that requires shortening each by less than 12 inches, the posts may be shortened accordingly, but the deflection distance should be increased from 6 feet to 8 feet over a length of 10' in either direction. See Detail 2-G.

If two adjoining posts encounter an obstruction that requires shortening of either by more than 12 inches, backup posts should be provided on either side of the obstruction, provided they will not have to be spaced more than 12' - 6" apart. Since backup posts are not connected to the rail and therefore can not provide vertical support, any post location that would require shortened posts for vertical support should receive that post. The shortened posts should also be provided if they will be 2 feet away from the adjoining backup post. The deflection distance should be increased from 6 feet to 8 feet over a length of 10' in either direction. See Detail 2-H.

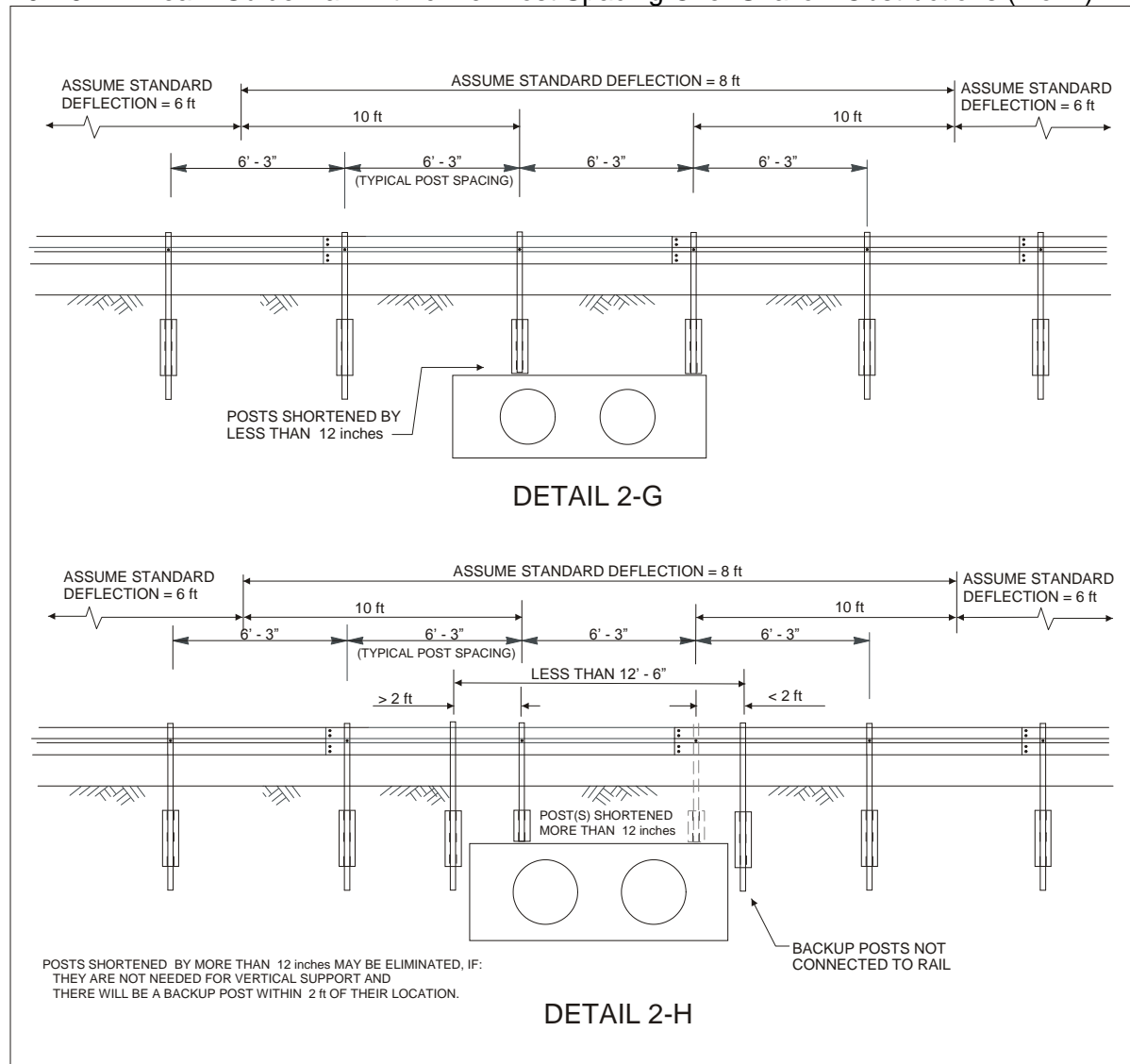
Figure 10B-4 Weak Post W-Beam Guide Rail with 12' - 6" Typical Post Spacing –
Adjustments for Shallow Obstructions to Post Driving



10B-5 W-Beam Guide Rail With 6' - 3½" Post Spacing Over Shallow Obstructions (1 of 2)



10B-6 W-Beam Guide Rail With 6' - 3" Post Spacing Over Shallow Obstructions (2 of 2)



If a continuous obstruction is encountered that would require shortening two or more adjoining posts by over 18 inches, then consideration should be given to welding a base plate to the bottom of the posts and fastening the base plate to a concrete footing. (If the obstruction is a concrete structure that it is acceptable to bolt to, then it will not be necessary to place a separate footing.) If mowing behind the rail will be required, then consideration should be given to constructing the footing so that its surface acts as a vegetation control strip at ground level and extends approximately 20 inches behind the posts. Details of the base plate and footing for weak posts are shown in Details 5-A through 5-D.

3C. Box Beam Posts at Shallow Obstructions

Box beam guide rail is designed to have significantly less deflection than either cable or weak post W-beam guide rail. The rigidity and mass of the beam contributes to the system's stiffness, allowing beam action to span across several posts at the same time. Because of this combined action of the posts, it is acceptable, where necessary, to shorten a single post by as much as 12 inches, as in Details 3-A and 3-G, without assuming any significant increase in deflection distance. (Post shortening should not be done where extra length posts are needed due to the proximity of steep slopes.)

Normal Post Spacing of 6': Where 6' post spacings are being used, posts may be repositioned (but not removed) without increasing the assumed deflection distance, provided the following spacings are not exceeded: 10' when no beam splice is included (Detail 3-B), and 8' when a beam splice is included (Detail 3-C). New holes drilled in the box beam to permit fastening to the posts should be field galvanized (in accordance with the Standard Specifications) soon after drilling and prior to mounting the rail.

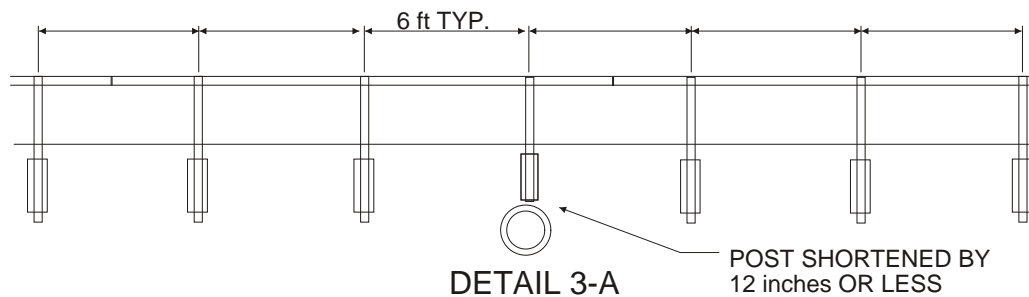
While the rigidity of box beam permits repositioning of its supporting posts up to the limits indicated in Details 3-B and 3-C, longer spans between supporting posts introduce the risk that the rail will bend too much when struck, allowing a vehicle to pocket. To minimize this possibility, it is permissible to stiffen the spanned area by bolting an additional length of box beam rail to the back side of the primary rail. The fastening should be done using four $\frac{3}{4}$ " x 14" hex head bolts, or a continuously threaded bar, with washers. With the rail reinforced in this manner, a span of 13' may be used between supporting posts as indicated in Details 3-D and 3-E. Note that the supporting posts will have to be set back 6 inches to accommodate the width of the backup piece of box beam rail.

If a shallow obstruction extends for up to 20 feet under a run of box beam with 6' post spacings and does not require shortening any of the posts by more than 12 inches, then shortened posts may be used, but with 3' post spacings above the obstruction, and an additional full length post(s) placed on either side of the obstruction as may be needed to ensure that the split spacing extends beyond the sides of the obstruction. See Detail 3-F for an instance where a full-length post is needed to extend the split spacing on the right side.

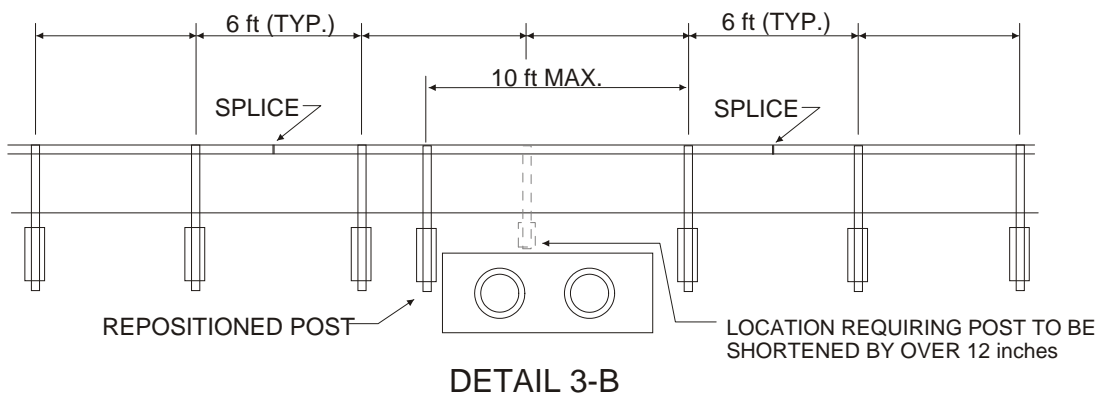
Normal Post Spacing of 3': Where 3' post spacings are being used, it is acceptable to skip a single post, if a shallow obstruction is encountered that would require shortening that post by more than 12 inches, but the deflection for a zone extending out to 10 feet on either side of the removed post should be assumed to increase from 4' to 5'. See Detail 3-H.

If a shallow obstruction extends for up to 20' under a run of box beam with 3' post spacings and does not require shortening any of the posts by more than 12 inches, then shortened posts may be used, but the deflection for a zone extending out to 10' on either side of the outside shortened posts should be assumed to increase from 4' to 5'. See Detail 3-J.

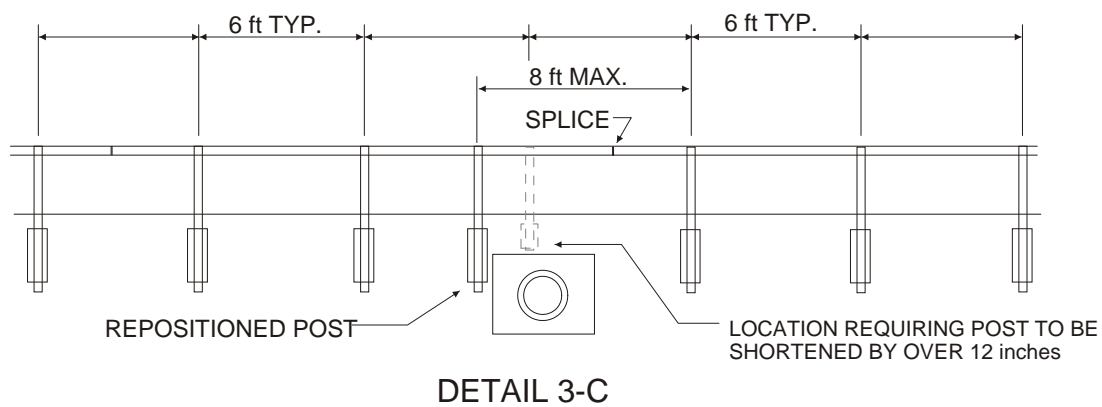
10B-7 Box Beam Guide Rail with 6' Post Spacing over Narrow Obstructions to Post Driving



FOR DETAILS 3-A, 3-B, AND 3-C,
ASSUME STANDARD DEFLECTION = 5 ft



DETAILS 3-B AND 3-C DIFFER IN THE
LOCATION OF THE BEAM SPLICE.



10B-8 Box Beam Guide Rail with 6' Post Spacing over Wide Obstructions to Post Driving

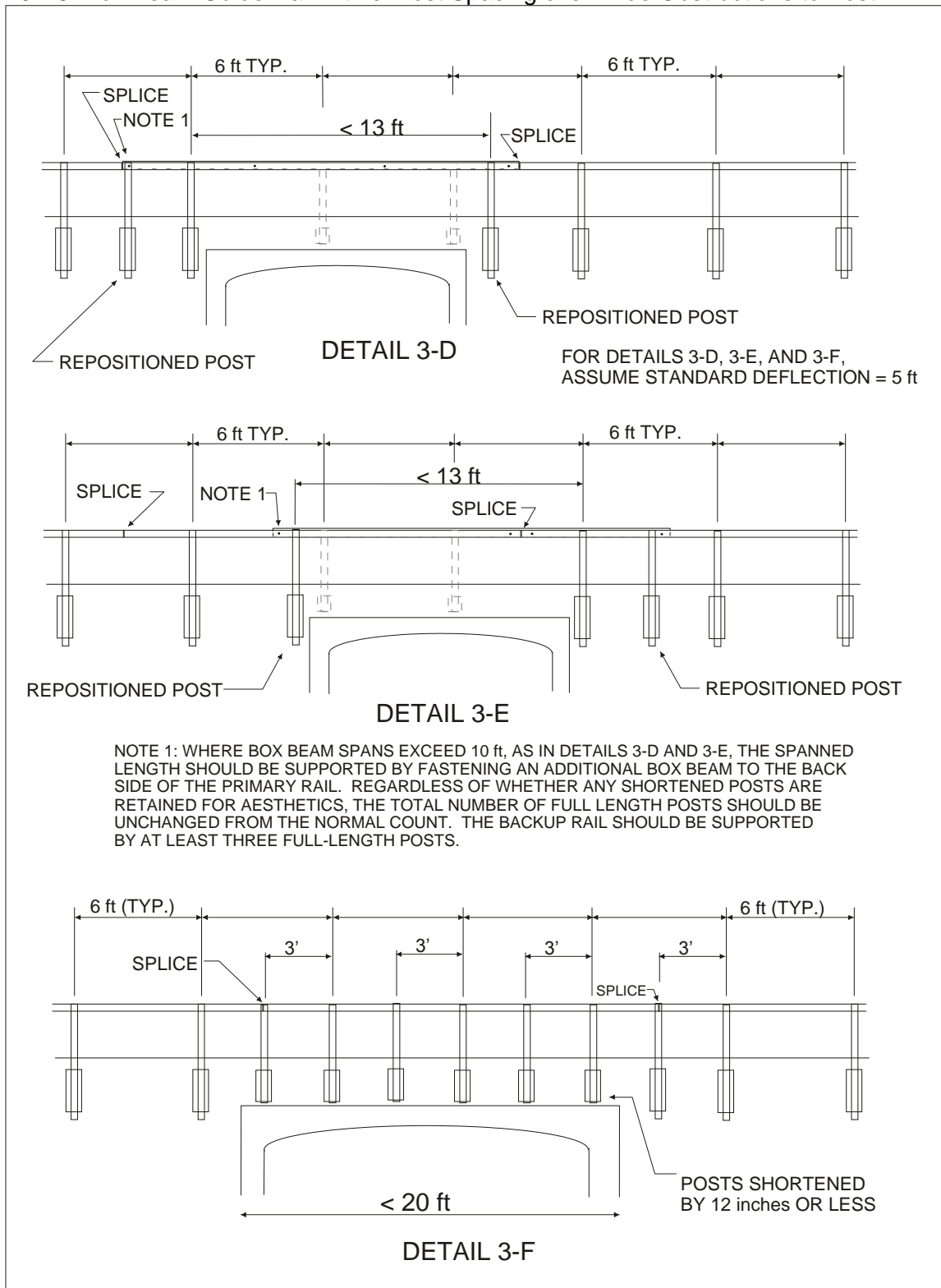
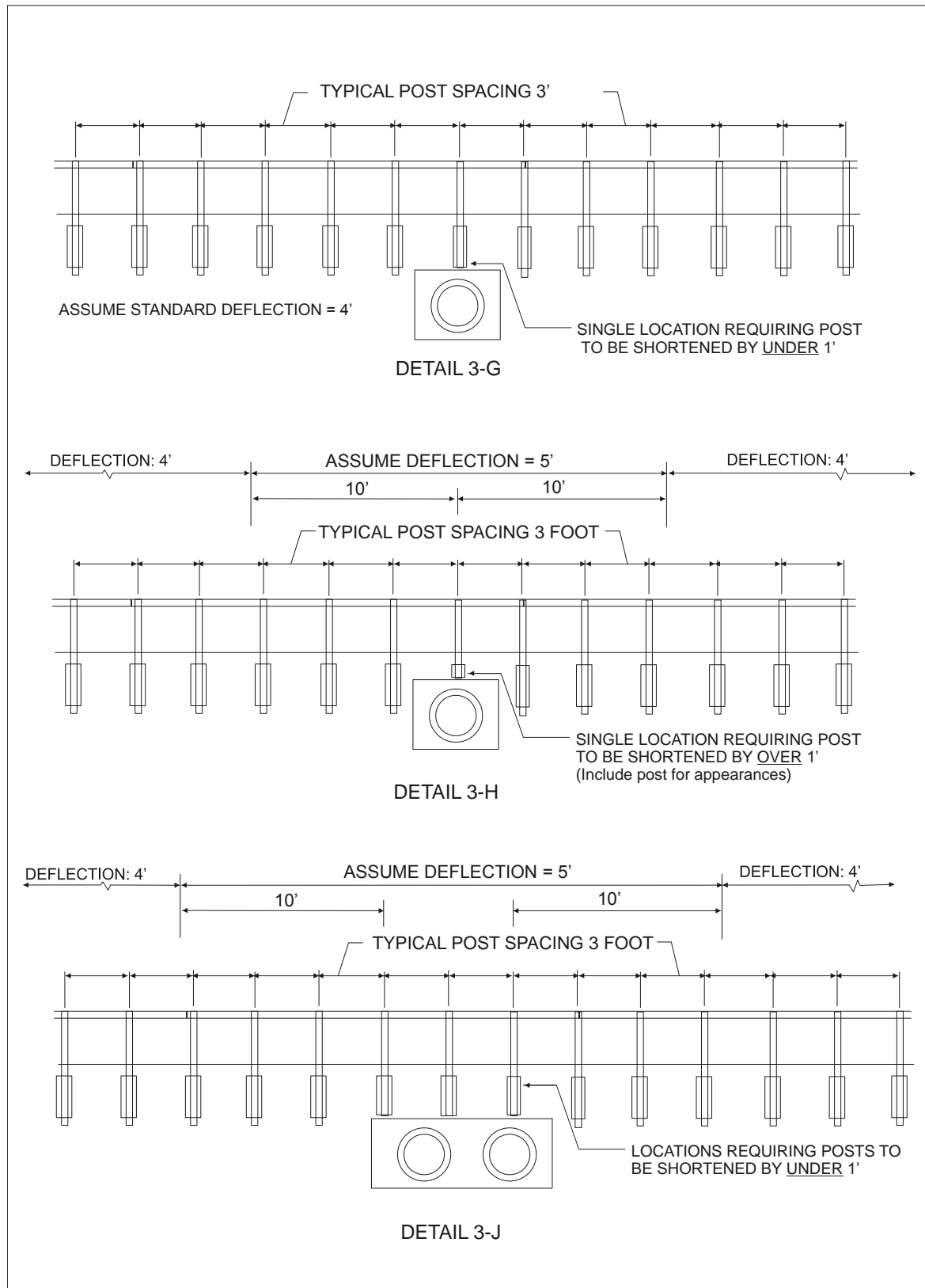


Figure 10B-9 Box Beam Rail with 3' Post Spacing Over Shallow Obstructions



3D. W-Beam on Heavy Posts at Shallow Obstructions

W-beam does not possess great beam strength when impacted, particularly since the impacting vehicle has a tendency to flatten the corrugations, which essentially produces a sheet of steel with a very low section modulus. To limit the anticipated deflection of the HPBO system, it is designed with frequent strong posts that individually and successively act to redirect vehicles. These heavy posts might snag some impacting vehicles, so blockouts are provided to hold the rail well in front of the post and thereby limit the chances of that occurring.

For similar reasons, it is important that the posts provide consistent lateral support to the rail, as a “soft” spot could permit an errant vehicle to penetrate into the line of the rail and contact a subsequent post. (That would be an example of the process referred to as “pocketing”.) Because of this significant reliance on each individual post, the removal, overshortening, or relocation of posts should be avoided. The normal heavy post is both wider and longer than the normal weak post. Where necessitated by shallow obstructions, up to 16½ inches may be cut from the bottom of a single heavy post (leaving 25½ inches of embedment) without assuming any significant increase in the deflection of the guide rail system. Because of the possibility of pocketing, post spacings should not be significantly increased and, where they need to be, the rail should be reinforced to minimize the existence of “weak spots.”

Normal Post Spacing of 6' - 3'': With 6' - 3" typical spacings, the posts are typically not provided with soil plates. As mentioned above and illustrated in Detail 4-A, up to 16½ inches may be cut from the bottom of a single post without increasing the assumed deflection beyond the normal 4 feet. Where up to three successive posts need to be shortened by up to 16½ inches, each shortened post is to have a soil plate added and the amount removed from the bottom of each post should be minimized. See Detail 4-B.

If a single post must be shortened by more than 16½ inches, then backup reinforcement may be used to maintain the deflection distance. If the shortened post is not at a beam connection, the reinforcing may be done by nesting an additional W-beam behind the rail, as in Detail 4-C, or, where the shortened post is at a beam connection, as in Detail 4-D, by including a reinforcing channel, preferably a C9 x 20 or an MC8 x 18.7, behind the rail. In the latter case, the posts on either side of the obstruction should have soil plates added to provide extra support for the channel-spanned area.

Normal Post Spacing of 3' - 1½'': In an HPBO run requiring 3' - 1½" post spacings, up to three posts may be shortened by amounts not exceeding 16½ inches, but the deflection distance within 10' of the shortened posts must be taken as 4 feet. See Detail 4-E. One or two posts may be shortened by more than 16½ inches, provided a reinforcing channel is placed behind the rail and its ends are supported by at least two full-length posts on either side of the spanned area. See Detail 4-F.

As indicated on Standard Sheet 606-09, heavy posts may be further shortened to a minimum embedment depth of 18 inches, provided the entire embedment depth is encased in concrete with a diameter of at least 12 inches.

If the shallow obstruction is even closer to the ground surface and is composed of sound concrete with sufficient structural strength, a base plate, as indicated on Standard Sheet 606-10, may be welded to the bottom of the post and bolted to the concrete.

10B-10 Accommodating Shallow Obstructions for HPBO W-Beam with 6' - 3" Spacing

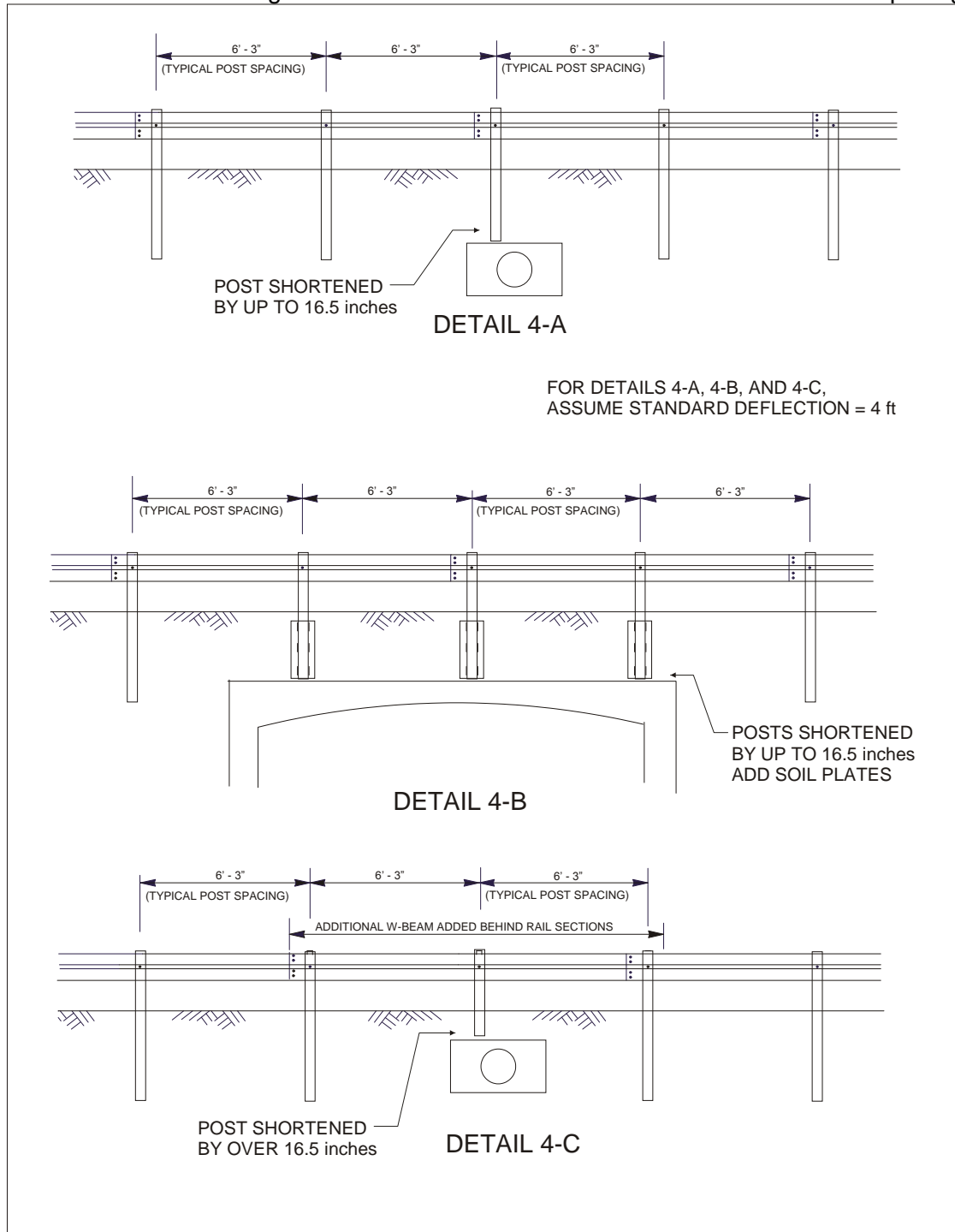
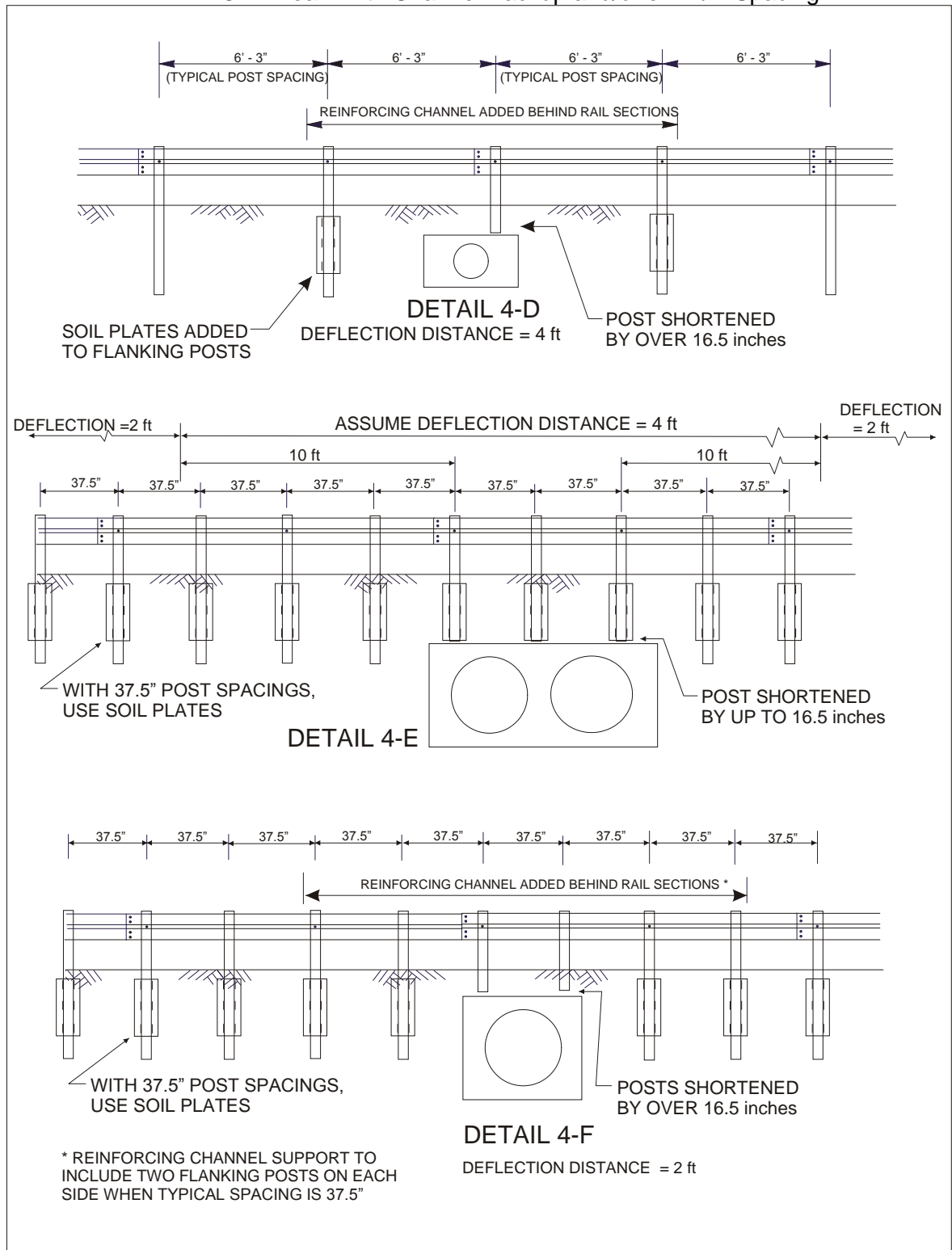


Figure 10B-11 Accommodating Shallow Obstructions to Post Driving for HPBO W-Beam with Channel Backup and/or 3' - 1½" Spacing



3E. Base Plates for Weak Post Rail Systems

In some instances, it is appropriate to weld a base plate to the bottom of a weak post and bolt the base plate into concrete. The following factors should be considered:

1. It is significantly more difficult to replace a bolted post that has been struck by an errant vehicle than it is to replace a driven post.
2. It may not be acceptable to bolt to the “roof” of some concrete box culverts. The Structures Division should be consulted.
3. The base plate may be very difficult to replace if it is not at ground surface, particularly if it is well below an asphalt vegetation control strip.
4. There may be problems with the long term strength of welded and bolted connections, so their use should be limited to cases where other choices would be problematic.
5. Welding and bolting is significantly more expensive than normal post driving, particularly when a concrete foundation must also be provided.
6. If a concrete base must be constructed, it should have its top flush with final grade and be wide enough to function as a vegetation control strip, if one is needed.
7. A grout pad may be needed to set the plate level and the guide rail post vertical.

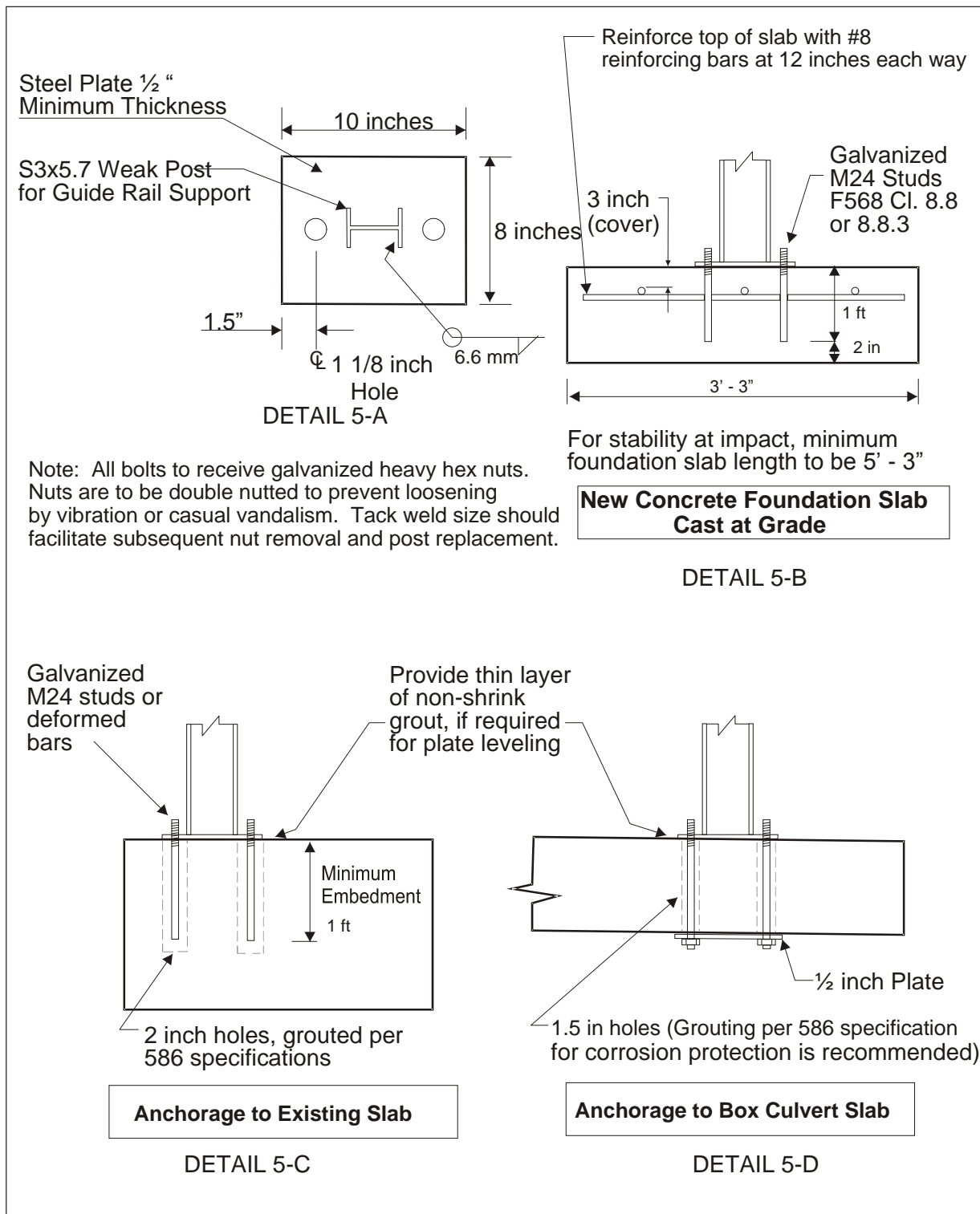
If it is determined that a base plate option is needed, an acceptable base plate may be made from steel plate with dimensions of 10” x 1½” x 8” and bolt holes as indicated in Detail 5-A.

When a new concrete slab must be poured, it should be massive enough that, when the guide rail is struck, failure of the rail to post connection and bending of the post will occur, rather than extraction of the slab. Typically, this may be assumed to be 3.5 cubic feet of concrete per foot of rail, with a minimum of ¾ cy for a single slab. Anchorage may be achieved either by drilling and grouting the bolts into the cured slab (drilling and grouting specification 586.01), or by setting the bolts during the pour, in which case the minimum embedment length should be 12 inches. See Detail 5-B.

When fastening to an existing concrete footing, two 7/8 inch grouted or expansion bolts, F568 galvanized Class 8.8 or 8.8.3, and a minimum embedded length of 12 inches should be used. See Detail 5-C.

When fastening to the top of a box culvert less than 13.5 inches thick, the bolts should extend through the concrete and a matching plate and nuts should be provided on the underside of the culvert’s top. See Detail 5-D.

Fig. 10B-12 Acceptable Base Plate Design & Bolting Options for Weak Post Guide Rail Systems



3F. Concrete Barrier

In some shallow obstruction situations, it may be reasonable to substitute concrete barrier for guide rail. Concrete barrier has the advantages of requiring much shallower embedment depths than guide rail (9 inches vs. 33") and being much less likely to need repair after most impacts. Its low deflection distance may also make it unnecessary to provide grate over a culvert end. It has the disadvantages of producing a more severe impact when struck by an errant vehicle, being more expensive, more difficult to transition to, and more visually obtrusive.

Given the above advantages and disadvantages, the following factors would increase the desirability of substituting concrete barrier for guide rail over shallow obstructions.

- A rail system would have to have several posts bolted to a concrete foundation.
- Traffic volumes and accident history indicate that there would be frequent damage to bolted posts requiring expensive and time-consuming repairs.
- The shielded objects are close to the line of the barrier, therefore requiring use of a barrier with little deflection.
- Sufficient level space is available to flare back the ends of a concrete barrier.

If, after evaluation of the above factors, it is judged that a concrete barrier will be used over the shallow obstructions to post driving, then the Jersey-shape Pier Protection details shown on Standard Sheet M606-19, as of this HDM revision, may be adapted for that purpose. The normal adaptations would be to use full sections of concrete barrier rather than concrete half sections, and to eliminate the use of backup measures.

3G. Lateral Offsets

Infrequently, situations may be encountered where shallow obstructions do not extend for any significant distance behind the rail. For instance, a wing wall may extend in the direction of the rail and interfere with the normal post location. In such instances, it may be acceptable to place a post farther back from the line of the rail and provide blockouts to make up the offset distance.

The following factors constrain the use of this option.

1. At the setback position, the post must have enough soil support to provide the needed lateral support to the rail. Guidance on the soil support requirements is contained in Table 10-4 of the Highway Design Manual.
2. The amount of offset must be limited. When the rail is struck, the post will bend at the base. If too much blocking-out is provided, there will be a tendency for the rail to be lifted as the blockout rotates toward the vertical. If the rail is raised too much, vehicles with low front end geometries will be able to pass under the rail, allowing them to snag on a heavy post system, or to enter the shielded area of a weak post system. In a worst case, the rail could pass through a windshield.
3. Consideration must be given to the interaction between the blockout and the vehicle. Unlike blockouts on HPBO where the stiffness of the system allows the rail to essentially shield the vehicle from the blockout, impacted weak post systems typically separate the rail from the post. When this occurs, the vehicle often strikes the post. If the blockout separates from the post, it could potentially enter the passenger compartment. If the blockout does not separate, it may contribute to snagging of the vehicle. Consequently, the fastening of the blockout to the post should be strong enough to prevent the blockout separating from the post when the post is struck, but weak enough to allow the blockout to be ripped from the post when the vehicle engages the blockout.

Based on the above considerations, the following limitations should be applied to lateral offsetting.

1. At the setback position, each post must have adequate soil support.
2. If only one post is being set back, its maximum offset should not exceed 20 inches.
3. If more than one post needs to be set back, the maximum offset of any one post should not exceed 12 inches.
4. The maximum length of rail supported by offset posts should not exceed 24 feet.
5. Blocking out of cable guide rail should be avoided. However, if it is judged necessary, blockouts may be built up from sections of standard box beam, cut to 10 inch lengths. The blockouts should be oriented vertically to prevent the accumulation of debris which could retain water and promote rusting. The blockouts should be drilled to accept the typical three J-bolts on the face that is in contact with the cables. The blockouts should be drilled to permit fastening to the posts using the top and bottom holes normally provided in the posts to receive the J-bolts.
6. The blockouts for weak post W-beam may be made from treated wood, approved plastic blockouts, or from box beam as above, except that the blockouts should be 14 inches in length. If box beam is used, the blockouts should be joined to each other and the post in the same manner as described above. The connection to the rail should be as shown on Standard Sheet for Corrugated Beam Guide Railing. If treated timber blockouts are used, the width of the blocks should be approximately 5½ inches (commercially available 6x6 timbers). A 3/8 inch deep by 2½" wide rabbet should be cut in the side that will receive the post. Bolting should be similar to that

indicated for standard blockouts for Heavy Post Blocked Out (HPBO) W-Beam. If the offset requires the use of more than one wooden block, the blockouts should be toenailed together with #12 galvanized finishing nails to prevent the blocks from rotating about the single bolt.

7. The blockouts for box beam guide rail may be made from 10 inch lengths of box beam fastened to the posts in the same manner described above for cable guide rail blockouts. However, the holes drilled in the blockout should be positioned to place the top of the blockout flush with the top of the post. The angle used to seat the rail should be connected between the rail and the blockout in a manner similar to that indicated on the standard sheet for Box Beam Guide Rail.
8. If an HPBO system needs to have a post or posts offset farther than the distance provided by the standard blockout, the additional offset may be achieved by incorporating additional standard blockouts and using a longer bolt. To prevent the blockouts from rotating about the bolt, the blocks should be fastened together with either galvanized nails or screws.

3H. Payment Considerations

In general, designers specify the required areas of coverage for a run of guide rail and do not address the placement of individual posts. Consequently, it is not reasonable for designers to address potential post driving conflicts with narrow obstructions, since they would have no way of knowing whether the posts would straddle that obstruction or not. The burden is therefore on the contractor to be aware of the observable potential conflicts and to bid accordingly. This responsibility is spelled out in the Standard Specifications, Section 102-04 No Misunderstanding, which states that, "The bidder agrees that its proposed contract prices include all costs arising solely from existing conditions shown, or specified in the contract documents...or readily observable from a site inspection..."

Where potential conflicts with post driving are identified during design, the nature of those conflicts should be indicated in the contract documents, preferably including notes on the plans. This is more important for features that are not readily apparent by a visual inspection of the site, such as buried utilities or footings.

When it is known that special provisions will need to be constructed to support the railing, such as the furnishing of a concrete slab and the bolting of posts to that slab, the details should be provided in the contract plans.

In some instances, obstructions to post driving will be encountered that could not reasonably have been predicted from a reasonable site investigation. Typically, this will be the case with unanticipated boulders or shallow bedrock. In these instances, payment should be determined in accordance with Standard Specification section 109-16, Changed Conditions and Delay Provisions, subsection A, 1, Different Site Conditions, which requires written notification of parties when unanticipated conditions are encountered. The specification further charges the Engineer with investigating the conditions and determining the need for cost or time adjustments and their amount.

Appendix 10C

Barrier Impact Testing and Its Relation to In-Service Performance

Table of Contents

Section	Page
1.0 Introduction	10C-3
2.0 Crash Testing Standards	10C-3
2.1 Test Levels	10C-3
2.2 Test Conditions for Test Level 3	10C-3
2.3 Changes from NCHRP350 to MASH	10C-4
3.0 Limitations of TL3 Crash Testing	10C-4
3.1 Vehicles	10C-4
3.2 Speeds	10C-4
3.3 Topography	10C-4
3.4 Vehicle Orientation	10C-4
3.5 Barrier or Terminal Installation	10C-4
4.0 In-Service Performance of Barriers and Terminals	10C-5
4.1 Absence of Implied Warranty	10C-5
4.2 Forced Compromises and Safety Conflicts	10C-5
4.3 Common Contributing Factors to Unfavorable Outcomes	10C-6
5.0 Afterword	10C-7

1.0 Introduction: Designers are not required, nor expected, to be familiar with the testing processes that are used to develop the barrier, attenuator, and terminal systems that are used in their roadside designs. However, this appendix is provided as a convenience for the many designers who have expressed an interest in developing a basic understanding of these matters.

2.0 Crash Testing Standards: There have been three successive testing standards that affected the barrier and guide rail systems that are and will be on New York's highways.

1. NCHRP 230 – The National Cooperative Highway Research Project's Report 230 was issued in March 1981 as the "Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances"
2. NCHRP 350 – Report 350 was issued in 1993 as a replacement for NCHRP230. The last word of the title was changed to "Features".
3. MASH – The "Manual for Assessing Safety Hardware" was issued in 2009 as a replacement for Report 350.

In NCHRP 230, barrier design parameters were based on crash tests with an 1800 lb car as the small test vehicle and a four-door, 4500 lb sedan as the large test vehicle. Since then, vehicle preferences changed to the extent that *NCHRP* was issued with a 2000 kg pickup truck specified as the large test vehicle. Changes were also made to the crash testing criteria. As a result, several long-accepted barrier systems failed the crash testing and some aspects of the barrier design became more complex. As an interpretation and expansion of a resulting FHWA mandate, all barriers and terminals installed within the clear zone on the NHS and other high-speed arterials had to pass, or be judged by FHWA to be capable of passing, the NCHRP 350 tests, for projects advertised after September 1998. Traditional terminals may still be used on these high-speed highways, provided the terminals are located close to, at, or beyond the limit of the clear zone.

2.1 Test Levels: There are various levels of test severity corresponding to the situations where a barrier will be used. Test Levels 1 through 3 involve impacts with vehicles roughly bracketing passenger vehicle weights: small cars to large pickup trucks. Test Levels 4 through 6 involve progressively heavier or less stable trucks.

1. TL-1 may be used where the vehicle operating speeds will be 30 mph or less.
2. TL-2 may be used where the vehicle operating speeds will be 45 mph or less.
3. TL-3 is used in New York State as the normal test level for all other highways except for bridge railings and pier protection. In practice, TL-3 devices are also used for most low-speed highways, rather than using separate TL-2 or TL-1 systems.
4. TL-4 uses single-unit trucks with weights around 11 tons. It is the general criteria for bridge rails in New York State
5. TL-5 uses large tractor-trailer trucks weighing approximately 40 tons. It is the test level required of bridge rail on routes with high volumes of heavy truck traffic.
6. TL-6 is seldom applied in practice. The test involves a heavy tanker truck with a tank center of gravity nearly 7 feet above grade. In practice, this loading needs to be resisted by stout concrete walls about six feet tall. New York does not require TL-6 barriers.

Test Levels 1 and 2 and 4 through 6 will not be discussed further here.

2.2 Test Conditions for Test Level 3: Essentially all guide rail and terminals placed on state highways in the last decade have been systems tested in accordance with NCHRP350's Test Level 3. All vehicle speeds for Test Level 3 were 100 kph (62 mph) impacts. For

longitudinal barriers, two impacts were used: a 2000P (4400 lb pickup) impacting at an angle of 25 degrees and an 820C (1800 lb car) impacting at 20 degrees.

For terminals and crash cushions, a broader array of impact directions and contact locations needed to be tested. Impacts were required both on the leading end of the systems and on the side. End impacts were required at angles of 0 degrees (in line with the run) and 15 degrees. Side impacts were run at 15 degrees and 20 degrees. Side impact locations were positioned to determine where the terminal was capable of redirecting a vehicle, rather than allowing it to “gate” through the terminal. Additional tests were sometimes required to ensure that pocketing would not happen at the juncture between the terminal (or attenuator) and the barrier. If snagging was possible on reverse-direction impacts, a test had to be run with the test vehicle impacting the side of the terminal as the vehicle was traveling the opposite direction.

For all tests, the vehicle was to be tracking in a straight line into the article (barrier, terminal) being tested.

2.3 Changes from NCHRP350 to MASH: The primary change was made in recognition of the increasing weights of the vehicles on our highways. The light car increased in weight from an 820C to an 1100C (2425 lb car). The pickup truck, which also serves as a surrogate for minivans and SUVs, increased from a 2000P to a 2270P (5000 lb pickup).

Additional relevant changes include the following.

- The side impact angle for small vehicles was increased from 20 to 25 degrees.
- The impact angle for the length of need test was also increased from 20 to 25 degrees.
- For end impacts, the oblique angle test was changed from a fixed 15 degrees to the angle between 5 and 15 degrees presumed most critical for the system.

Numerous other changes were made, but are not particularly significant to this appendix.

3.0 Limitations of TL3 Crash Testing

3.1 Vehicles: In the real world, crashes can come in a wide variety. The vehicles involved include motorcycles, small cars, sedans, mini-vans, SUVs, pickups, panel trucks, large vans, and heavy tractor-trailers. Crash tests at Test Level 3 use only two discrete examples from a broad spectrum of possible vehicles. While the two examples are meant to bracket the majority of the vehicles on the highway, the tests do not cover the high and low ends. As a consequence, barriers and terminals designed to TL3 criteria are not designed to be forgiving to motorcyclists and are not designed to redirect large trucks hitting at significant angles.

3.2 Speeds: Operating speeds often exceed the posted speeds. Furthermore, vehicles traveling at the high end of the operating speeds on any given highway are over-represented in the accident statistics. Particularly on high-speed freeways, operating speeds of 70 to 80 mph are not uncommon. However, the maximum impact speed at any test level is only 62 mph. Considering that the impact energy varies as the square of the velocity, many actual crashes will distinctly exceed the energy that the barrier's strength was designed for.

3.3 Topography: The testing criteria have consistently required that the tests be conducted on level ground. Particularly for terminals, this provision is critical to ensuring that the vehicle remains upright after the impact. In the real world, it will be uncommon for there to be a broad level area behind either a terminal or the barrier, particularly on secondary highways.

3.4 Vehicle Orientation: In many accidents, the driver of an errant vehicle has engaged in some form of avoidance maneuver prior to striking a barrier or terminal. As a result, the vehicle may be spinning, sliding sideways, leaning, or nosing downwards. The required crash tests do not incorporate any of these conditions. Rather, the test vehicle is traveling in a straight line (“tracking”) with no braking occurring.

3.5 Barrier or Terminal Installation: The testing of a given system is performed on an assumed typical installation of that system. In practice, there will be many sites that do not permit the system to be installed as tested, typically because of limited longitudinal space for the system, curvature of the road, shallowly buried utilities, or abrupt slopes. As a result, there will be many situations where engineering judgment must be used to install a modification of a standard system. Some sites require major adaptations of the system. Crash testing is rarely performed on these modifications.

4.0 In-Service Performance of Barriers and Terminals

4.1 Absence of Implied Warranty: The presence of a guide rail, concrete barrier, terminal, or attenuator carries no implied warranty that a favorable outcome will result when the article is impacted. Similarly, there is no warranty that an installed system meets current crash testing criteria. A given installed system is not required to meet standards that evolved after it was installed.

In some circumstances, a given system may be judged sufficiently outmoded that it should be replaced when the first good opportunity presents itself, such as when a major project is undertaken on that stretch of highway. In rarer circumstances, the performance of an existing system may be considered sufficiently unsatisfactory that replacement, modification, or removal of the system should take place, even if there is no other work needing to be done at those locations.

Finally, installation of a system at a given location does not require that the system be installed to prevailing standards at that time. As stated earlier, there are many circumstances where the site does not permit the standard installation details to be used. In those circumstances, engineering judgment must be used to modify the system so that it will both fit within the site constraints and provide a reasonable balance between competing safety considerations. Strength (to ensure vehicle capture or redirection) and yielding (to minimize deceleration severity) are two such commonly conflicting considerations.

4.2 Forced Compromises and Safety Conflicts: It is not possible to design a barrier or terminal that will perform well in all circumstances, particularly where high speeds are involved. Often, conflicts must exist between competing safety considerations. A few of many possible examples follow.

- To safely redirect large trucks, concrete barriers are required. However, a concrete barrier will not yield when struck by a passenger vehicle, making such an impact much more dangerous than an impact with a steel barrier that can yield and redirect the vehicle much less harshly.

- A motorcyclist sliding into any barrier is at severe risk, but much more so when sliding into the posts of a guide rail system. While a “rub rail” could be installed to prevent motorcyclists from impacting directly into the posts, the presence of such an element could largely compromise the performance of the guide rail for passenger vehicles which tend to be much more frequent “customers” of the guide rail. When impacted, guide rails tend to lean back. When the top rail leans back, the rub rail would tend to remain near the bottom of the post, providing an element for the cars tires to climb. As a result of the lean of the main rail and the “step” provided by the rub rail, the chances of passenger vehicles being launched over the rail would be greatly increased.
- An HPBO system is much less likely than a cable system to let a vehicle with a low front end geometry pass under the rail. However, passenger vehicles will experience much more severe lateral decelerations on the heavy post system than on a cable system.

4.3 Common Contributing Factors to Unfavorable Outcomes:

1. Excessive Speed: When impact speeds significantly exceed 62 mph several bad outcomes may occur.
 - a. A barrier may deflect more than under normal conditions, allowing the vehicle to contact the object that the barrier was shielding.
 - b. The strength of the barrier may be exceeded, allowing it to rupture. This is typically most likely with w-beam (corrugated) weak or heavy post blocked out guide rail.
 - c. Most of the terminals designed to satisfy NCHRP350 are designed to absorb a certain amount of impact energy. If the vehicle’s energy significantly exceeds that amount, the terminal may not function as desired.
2. Vehicle Lean: Vehicles that are turning sharply or skidding sideways will lean significantly, reducing their stability for overturning. If a vehicle is leaning significantly when it contacts a rail, the rail needs to provide only a mild amount of tripping force to allow the vehicle to roll sideways over the rail. In some instances, the vehicle may have rolled even without the rail contact.
3. Nosing Down: A significant number of passenger vehicles are designed with aerodynamics in mind. Unfortunately, this often includes a sleek profile with a low front end. When a vehicle brakes, it tends to tip forward, placing the front end even lower to the ground. In some cases, the front of the vehicle may be lowered to the point where it will be below the guide rail. This may permit the vehicle to slide under the rail to the point where the rail impacts the windshield or even penetrates the passenger compartment. While this is a potential problem with all steel rails it may be most likely with cable guide rail systems.
4. Lateral Skids: While statistical studies vary, there are a significant number of accidents, particularly at high speeds, where the vehicle will at some point be skidding sideways. This can be a significant problem if the vehicle runs into the end of an energy-absorbing terminal such as an SKT, ET2000, WyBET, or BEAT (any terminal with an impact head). These terminals, in absorbing impact force, also apply a force to the vehicle. The crash-tested designs apply this force to the front of the vehicle where the momentum of the engine and the strength of the front of the vehicle shield the driver from the impact point. If a vehicle slides into such a terminal sideways, the force is applied through the weak side of the vehicle and into the passenger compartment without benefit of the crumple zone at the front of the vehicle. Consequently, adverse outcomes are not unlikely for high-speed crashes where the vehicle moves sideways into an energy-absorbing terminal.

5. Side Slopes: By themselves, side slopes may make the final contribution needed to allow an accidental excursion to turn into a serious rollover accident. If a vehicle is in a lateral skid towards a shoulder break, the abrupt loss of vertical support for the outside tires may allow the lean to convert to a roll. For vehicles with high centers of gravity, such as pickups or SUVs with oversized tires or chassis raised for off-road use and many large trucks, simply crossing a shoulder break at a shallow angle may permit enough roll inertia to develop that the vehicle will overturn even on a relatively mild 1:3 or 1:4 slope. If a vehicle is at risk for overturning as it crosses the shoulder break, impacting an energy-absorbing terminal with the front, traffic-side corner of the vehicle is likely to apply a destabilizing force that will significantly increase the likelihood of a rollover happening.

5.0 Afterword: Crash testing criteria only establish a minimum threshold of performance for guide rail, concrete barriers, terminals, and attenuators. They do not ensure that an approved system will provide acceptable results for the full range of installation conditions and accident circumstances that will occur. A given approved system may barely meet some criteria while easily meeting others. Different systems will vary in their appropriateness for a given set of site conditions. However, beyond generalities, it is not possible to calculate any clear boundary separating the appropriate uses of two systems. Instead, engineering judgment must be applied to the selection process.

Chapter 10

Index

<u>Subject</u>	<u>Section</u>
Acceptable Deficiencies	10.3.2.1
Access Gaps	10.2.2.6
ADIEM.....	10.2.6.6 A
Aesthetic Barrier Options	10.2.3.7
Anchor Blocks, W-beam	10.2.5.2
Anchor Blocks, cable	10.2.5.1
Anchor Blocks, Box beam.....	10.2.5.3
Any-Speed Hazards	10.2.1.1
Auxiliary Lanes, Clear Zones	10.2.1
Back Slope Anchorage	10.2.5.1, 10.2.5.2
Backup Channels	10.2.2.3
Backup Posts	10.2.2.3, 10.2.3.5, 10.2.3.6, 10.2.5.1
Barricades.....	10.5.5
Barrier, Dead End	10.5.5
Barrier Selection	10.2.2.3
Basic Recovery Width.....	10A.1
Beyond the Clear Zone	10.2.1, 10.2.1.1
Blockouts	10.2.3.5
Bodies of Water	10.2.1.1
Box Beam Guide Rail.....	10.2.3.4
Box Beam Median Barrier.....	10.2.4.5
“Brakemaster”	10.2.5.3 B
Breakaway Base	10.2.1.2
Cable Guide Rail.....	10.2.3.1
Cable Median Barrier	10.2.4.9 D
Camp Areas	10.2.7.5
Cattle Passes	10.5.3
Cattle Fencing.....	10.5.2.2
Chain Link Fencing	10.5.2.2
Clear Area.....	10.2.1
Clear Runout Width.....	10.2.1
Clear Zone	10.2.1
Clotheslining	10.2.5
Concrete Barriers, Temporary	10.4.1
Concrete Barriers.....	10.2.3.6
Concrete Barriers, Median	10.2.4.6
Configuration F	10.2.4.9 C
Continuity	10.2.2.6
Corrugated Guide Rail	10.2.3.2
Corrugated Median Barrier	10.2.4.4
Crash Testing.....	App. 10C
Crossover Areas	10.2.4.4
Curbing	10.2.2.4
Curve Corrected Recovery Width	10.2.1
Cut Slopes	10.2.1
Dead-End Barriers	10.5.5
Deflection Distance	10.2.2.3
Delineation	10.2.1.2

Design Clear Zone Width	10A.1
Desired Minimum Clear Zone Width	10A.1
Ditches, Longitudinal.....	10.2.1.1 C
Documentation	10.2.1, 10.2.2, 10.3.3, Appendix B
Downstream Shielding	10.2.2.1
Dragnets	10.4.3
End Sections, Drain Pipe	10.2.4.4 A
End Sections, Barrier	10.2.5
Escape Ramps.....	10.2.6.5
"ET-2000"	10.2.5.2 C
Extra Length Posts.....	10.2.3.5 A
Extruder Terminal	10.2.5.2 C
F-Shape Barrier	10.2.4.9 C
Fences, Chain Link - Top Rail.....	10.5.2.2
Fences, Private	10.5.2.1
Fences, Right of way	10.5.2.2
Fences, Vandalism	10.5.2.3
Fixed Objects	10.2.1.1
Flare Rates, Permanent.....	10.2.5
Flare Rates, Temporary Construction	10.4.1
Flexible Delineators	10.2.1.2
Gaps (in guide rail).....	10.2.2.6
Glare Screens	10.2.4.7
Gratings	10.2.1.2
GREAT.....	10.2.6.3
Guide Posts	10.5.4
Hazardous-at-any-speed Features	10.2.1.1 A
Hazards, Potential.....	10.3.1.2
Hex-Foam Sandwich System.....	10.2.6.3
Hydrant Fenders	10.2.7.6
HydroCell Clusters	10.2.6, 10.2.7.3
Impact Attenuators	10.2.6
Innovative Median Barriers	10.2.4.9
Innovative Attenuation Systems.....	10.2.6.6
Intersections, Guide Rail Use At	10.2.5.6
Interstate Slopes	10.2.1 (p.10-4)
"Ironwood" Guide Rail	10.2.3.7
ISTEA.....	10.1
Jersey barriers	10.2.3.6
Landscape Hazards	10.2.7.4 B
Long Guide Rail Posts	10.2.3.5
Low Profile Barrier	10.2.2.7
Mailboxes.....	10.5.1
MASH.....	Appendix C
Median Barriers.....	10.2.4
Median Crossover Areas	10.2.4.11
Medians, Narrow.....	10.2.4.3
Medians, Transitions.....	10.2.4.10
Medians, Uneven	10.2.4.8
Medians, Wide	10.2.4.2
Moveable Concrete Barrier	10.2.4.9 B
Mowing Strips	10.2.3.5 B
NCHRP 350	10.2.2, Appendix C

Noise Barriers	10.5.2.6
Nonbypassable Hazards.....	10.2.2.2
Nonconforming Feature	10.1
Nonrecoverable Slope	10.2.1
Obstacle.....	10.2.1.1
Pedestrian Shielding	10.2.2.7
Pier Protection	10.2.3.6
Point of Need	10.2.2.1
Point of Redirection.....	10.2.2.1
Posts, Weak.....	10.2.3.5
Posts, Heavy.....	10.2.3.5
Potential Hazards.....	10.2.1.1
Ramps.....	10.2.4.1 B
REACT (Reusable Energy Absorbing Crash Terminal)	10.2.6.3
Redirecting Back Slopes.....	10.2.2.1, 10.2.5.4
Redirection, Point of.....	10.2.2.1
Reducing Deflection	10.2.2.3
Reflective Markers	10.2.1.2
Reflectors on Rustic Rail.....	10.2.3.7
Roadside Design Summary	10.3.3
Roadside Obstacle.....	10.2.1.1
Roadside Safety Concern	10.1
Rounding Slope Intersections	10.2.1, 10.2.2.1
ROW Fencing	10.5.2.2
Resetting Guide Rail	10.5.7
Rock Slopes	10.2.1.2
Runout Length	10.2.2.2
Runout Width	10.2.1
Rustic Guide Rail	10.2.3.7
Sand Barrels	10.2.6.2
Screens, Visual	10.5.2.5
“Self-Oxidizing” Rail	10.2.3.7
Self Restoring Median Barrier.....	10.2.4.9 E
SERB	10.2.4.9 E
Shallow Obstructions	10B-1
Shoulder Breaks, Effect on Guide Rail Support.....	10.2.3.5 A
Shoulder Breaks, Rounding	10.2.1
Single Slope Concrete Median Barriers.....	10.2.4.9 A
Sight Distances	10.2.2.5
Signal Poles	10.2.1.2 C, 10.2.4.6
Site Inspection Record.....	10.3.1.1
Slopes, Height Issues	10.2.1
Slopes, Traversable	10.2.1
Slopes, Recoverable.....	10.2.1
SRT (Slotted Rail Terminal)	10.2.5.2 D
Steep Slopes.....	10.2.1.1
Stone-faced Barrier.....	10.2.3.7
Suburban Roads	10.2.7.4
Taper Rates	10.4.1, 10.2.5
Terminals	10.2.5
Terminating “near” Clear Zone Limit	10.2.5
Thrie Beam	10.2.3.3
Timber Curbs	10.4.2

Timber-faced Barrier	10.2.3.7
Transitions, Guide Rail	10.2.5.5
Transitions, Median	10.2.4.10
Treatment Hierarchy	10.2.1.2
Trees	10.2.1.1
Truck Barrier	10.2.4.9 C
Truck Escape Ramps	10.2.6.5
Underground Utilities	10.2.3.5 A
Utility Poles	10.2.7.4 C
Vaulting	10.2.2.4
Vegetation Control Strips	10.2.3.5 B
Vehicle Arresting Barrier	10.4.3
Visual Screen Fencing	10.5.2.5
Water Features	10.2.1.1
W-Beam Guide Rail	10.2.3.2
Weathering Guide Rail	10.2.3.7
Wide Medians	10.2.4.2
WYBET (Wyoming Box End Terminal)	10.2.5.4 C