OS-299 (7-08)

pennsylvania
DEPARTMENT OF TRANSPORTATION

# TRANSMITTAL LETTER

**PUBLICATION:**

Publication 13M
March 2015 Edition

**DATE:**

April 15, 2015

**SUBJECT:**

**Design Manual, Part 2**
**Highway Design**
**March 2015 Edition**

**INFORMATION AND SPECIAL INSTRUCTIONS:**

Publication 13M (Highway Design) is to be re-issued with this letter. The enclosed March 2015 Edition represents a complete publication. This Edition supersedes the August 2009 Edition and all subsequent changes. The effective date of the March 2015 Edition is April 15, 2015.

These new guidelines should be adopted on all new and existing projects as soon as practical without affecting any letting schedules.

This release includes incorporation of outstanding Strike-off Letters issued through February 28, 2015, and those changes are already in effect. Strike-off Letters issued on or after March 1, 2015 are still effective until they are incorporated into this publication.

Also, this release includes additions / deletions / revisions for the following:

-Chapter 1, Section 1.0 (revised section, deleted four paragraphs, updated DM-1C reference)

-Chapter 1, Section 1.2 (revised section)

-Chapter 1, Section 1.3 (new section for Pavement Preservation Criteria; replaced previous Section 1.3, Interstate Programming Guidelines)

-Chapter 1, Section 1.4 (this section intentionally left blank; replaced previous Section 1.4, Pavement Preservation Guidelines)

-Chapter 1, Section 1.5 (revised page number references in Typical Sections)

-Chapter 1, Appendix A (revised appendix, Reduced Bridge Width Criteria Documentation)

-Chapter 2, Section 2.9.C (new section, Existing Roadways with No Posted Regulatory Speed Limit)

-Chapter 2, Section 2.9.D (new section, Non-Applicable Design Speeds)

**CANCEL AND DESTROY THE FOLLOWING:**

Publication 13M (August 2009 Edition and all associated changes)

SOL 482-13-18 (Aug. 20, 2013)
SOL 482-13-34 (Dec. 20, 2013)
SOL 481-14-06 (Jun. 17, 2014)
SOL 482-15-08 (Feb. 25, 2015)

NOTE: Publication 13M is only available electronically via the PennDOT website.

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BUREAU OF PROJECT DELIVERY
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# Design Manual Part 2 Highway Design

**Publication 13M - March 2015 Edition**

PUB 13M (3-15)

# DESIGN MANUAL, PART 2
# HIGHWAY DESIGN

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# CHAPTER 1

## GENERAL DESIGN

### 1.0 INTRODUCTION

The purpose of this Manual is to provide its users with the current, uniform procedures and guidelines for the application and design of safe, convenient, efficient and attractive highways that are compatible with their service characteristics and that optimally satisfy the needs of highway users while maintaining the integrity of the environment.

This Manual does not attempt to encompass the total scope of important, published information and literature relative to the formulation of highway design criteria, policies and procedures. Sources of additional publications and related material which may complement the concepts contained herein include the following:

- Publication 408, *Specifications*, and associated changes, Pennsylvania Department of Transportation (PennDOT).
- *A Policy on Geometric Design of Highways and Streets*, 2004 AASHTO Publication.*
- *Roadside Design Guide*, 2011 AASHTO Publication.**
- *Highway Capacity Manual*, Transportation Research Board, 2010 or newer edition.***
- *Manual on Uniform Traffic Control Devices*, Federal Highway Administration, 2009 or newer edition.****
- *A Policy on Design Standards---Interstate System*, 2005 AASHTO Publication.

The Department develops Federal-aid highway projects in accordance with the standards and guides identified in 23 U.S.C. 109, 23 CFR 625 (as well as other FHWA policies identified in the Federal Register, the Federal-Aid Policy Guide and elsewhere) and/or Department standards or manuals approved by FHWA. Appropriate design and construction standards are provided by the application of the publications listed in Publication 10X, *Appendices to Design Manuals 1, 1A, 1B, and 1C,* Appendix C (FHWA/PennDOT Stewardship & Oversight Agreement).

The Department provides numerous publications electronically and in hardcopy. Additional publications related to design, construction and materials, highway safety and traffic engineering, and maintenance and operations are found on the Department's website at two locations:

- Forms, Publications & Maps (listing of items available electronically):
  http://www.dot.state.pa.us/Internet/Bureaus/pdBOS.nsf/FormsAndPubsHomePage?OpenFrameSet
- Publication 12, *Sales Store Price List* (listing of items available in hardcopy):
  ftp://ftp.dot.state.pa.us/public/PubsForms/Publications/PUB%2012.pdf

Initiative should be exercised to utilize the most appropriate design values within the given ranges based upon the project context and roadway typology wherever practicable and within reasonable economic limitations and sound engineering judgment. When design criteria presented in this Manual differs from criteria presented in other

* Hereinafter referred to as the 2004 AASHTO Green Book.
** Hereinafter referred to as the AASHTO Roadside Design Guide.
*** Hereinafter referred to as the *HCM*.
**** Hereinafter referred to as the *MUTCD*.

sources, this Manual shall take precedence. However, for Federal-aid projects on the National Highway System (NHS), this Manual only takes precedence when criteria in this Manual exceed the criteria in the 2004 AASHTO Green Book and the 2005 AASHTO publication, *A Policy on Design Standards---Interstate System* (for Interstate Federal-aid projects). The design criteria and text presented herein provide guidance to the designer by referencing a range of values for critical dimensions.

Since the concepts, practices and procedures described in this Manual are subject to future change, the contents shall be updated accordingly to reflect those changes in order to retain its usefulness. The Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section shall be responsible for keeping the Manual current by incorporating revisions, additions or deletions when required.

Whenever a District Executive determines that modifications or additions are required to improve the current design criteria in this Manual, the following procedures shall be followed:

**1.** The recommended modifications or additions shall be transmitted to the Director, Bureau of Project Delivery with the following information:

**a.** The title and page number of the existing practice, if applicable.

**b.** The recommended modifications or additions and the Chapter(s) and the appropriate page number(s) into which they should be incorporated.

**c.** The reasons for recommending the modifications or additions.

**2.** The Director, Bureau of Project Delivery shall review the recommended modifications or additions and transmit copies to the various Bureau Directors and District Executives involved for their comments. FHWA comments shall also be solicited.

**3.** All comments shall be submitted to the Director, Bureau of Project Delivery and, upon review, appropriate action shall be taken.

**4.** If modifications or additions are required to the current criteria, they shall be made through standard procedures for incorporation into this Manual.

**5.** As future changes to this publication are developed and released, there will be direct coordination between PennDOT and the Pennsylvania Turnpike Commission (PTC). When PTC develops/updates design guidance, the PTC update will be coordinated with PennDOT by the Clearance Transmittal (CT) Process. When the Department develops/updates this Publication, it will coordinate with PTC by the CT Process. Additionally, proposed revisions will be discussed and coordinated directly between PTC and PennDOT personnel responsible for the applicable publication. This coordination will take place as modifications are developed and before the Department's CT process commences.

The intent of the collaborative process above is for the Department and PTC to follow these basic principles for other design publications (DM-1 Series, DM-3, PennDOT Drainage Manual, etc.). This approach will share knowledge and best practices across agency boundaries.

The numerical measurements presented in this Manual are generally stated in metric values followed by English values in parentheses. Also, refer to the current AASHTO and ASTM Material Standards, AASHTO Designation R1 (ASTM E 380), which uses the International System of Units (SI) as required by Federal Law.

The inclusion of specified design criteria in this Manual does not imply that existing roadways, which were designed and constructed using different criteria, are either substandard or must be reconstructed to meet the criteria contained herein. Many existing facilities which met the design criteria at the time of their construction are adequate to safely and efficiently accommodate current traffic demands.

Since it is not feasible to provide a highway system that is continuously in total compliance with the most current design criteria, it is imperative that both new construction and reconstruction projects are selected from a carefully planned program which identifies those locations in need of improvement and then treats them in priority order. Once a new construction or reconstruction project is selected in this manner, this Manual shall be used in determining the appropriate design criteria.

The policies contained in this Manual, as well as the 2004 AASHTO Green Book, place emphasis on the joint use of transportation corridors by pedestrians, cyclists, and public transit vehicles. Designers should recognize the implications of this sharing of the transportation corridors and are encouraged to consider not only vehicular movement, but also movement of people, distribution of goods, and provision of essential services. A more comprehensive transportation program is thereby emphasized. Refer to Chapter 19, Considerations for Alternative Transportation Modes, for more information about considering the needs of bicyclists, pedestrians, and transit users in designing all roadway projects.

An important concept in highway design is that every project is unique. The setting and character of the area, the values of the community, the needs of the highway users, and the challenges and opportunities are unique factors that designers must consider with each highway project. Whether the design to be developed is for a safety improvement or several kilometers (miles) of rural freeway on new location, there are no patented solutions. For each potential project, designers are faced with the task of balancing the need for the highway improvement with the need to safely integrate the design into the surrounding natural and human environments.

Another important concept in highway design is the development of Context Sensitive Solutions (CSS). CSS is a collaborative, interdisciplinary approach that involves all stakeholders to develop a transportation facility that fits its physical setting and preserves scenic, aesthetic, historic, and environmental resources, while maintaining safety and mobility. Context sensitive design is an approach that considers the total context within which a transportation improvement project will exist.

For more information regarding these two important concepts, refer to the material described for CSS in Publication 10C, Design Manual, Part 1C, *Transportation Engineering Procedures,* Chapter 3, Section 3.4.B.

## 1.1 STANDARDS FOR ROADWAY CONSTRUCTION

The Department has prepared standard roadway drawings (Publication 72M, *Roadway Construction Standards*) to provide engineering personnel, designers and contractors with a catalog of specific design conditions for use as a guide in the development of the design of highways. The standard drawings shall be used in conjunction with the specifications, special provisions and construction plans to provide a more uniform design and construction practice for all projects.

In order to keep current with state of the art practices and materials, the RC Standards are also updated as needs are identified and science advances. As future Standards are developed and released, there will be direct coordination between PennDOT and PTC. When PTC develops/updates a Standard, the PTC Standard will be coordinated with PennDOT by the CT Process. When the Department develops/updates a Standard or develops/updates a Publication, it will coordinate with PTC by the CT Process. Additionally, proposed revisions will be discussed and coordinated directly between the PTC and PennDOT personnel responsible for the applicable standard.

## 1.2 DESIGN CRITERIA

The scope of work of a project determines which roadway design criteria is applied to a highway or bridge project. For each set of design criteria discussed below, there is a unique set of geometric requirements.

When designing a project, the proposed geometric design elements shall be compared to the applicable required criteria. A design exception is required if any of the 13 controlling criteria is not met, as defined in Publication 10X, Design Manual Part 1X, *Appendices to Design Manuals 1, 1A, 1B, and 1C*, Appendix P, *Design Exceptions*. If non-controlling criteria are not met, some form of documentation must be provided. Documentation may include meeting minutes or Design Field View Reports, etc.

**A. Definitions of Design Criteria.** The definitions of various design criteria are presented below. These definitions are general guidelines for when to use each set of criteria.

**1.** New Construction and Reconstruction.

**a.** Definition.

**(1)** New Construction. A new transportation facility that did not previously exist at that location. The addition of new appurtenances to an existing facility such as striping, signs, signals, or noise barrier are not considered new construction.

**(2)** Reconstruction. Rebuilding an existing facility that may include substantial upgrading of major highway features. Typical reconstruction projects include:

Roadway projects:

- Reconstructing the roadway to the subgrade (pavement reconstruction) for more than 30% of the existing travelled surface area.
- Adding through lanes.
- Realignment of interchange ramps.
- Major vertical and/or horizontal realignment.
- Major intersection improvements.
- Structural pavement overlays on freeways (see Publication 242, *Pavement Policy Manual*).

Bridge projects:

- Full bridge replacements
- Full and partial superstructure replacements on freeways
- Deck Replacements on freeways

**b.** Criteria. For NHS roadways, the 2004 AASHTO Green Book governs. The design criteria in this Manual takes precedence for NHS roadways when it is more conservative than the criteria in the 2004 AASHTO Green Book.

New Construction and Reconstruction criteria are presented in this Manual, including the Matrices of Design Values Transportation Typology tables. A determination of the roadway's typology should be identified early in project design during the scoping field view based on a project's context, the current anticipated land use, and the functional classification of the roadway. Roadway typology captures the role of the roadway within its context, focusing on characteristics of access, mobility and speed. Roadway typologies cannot be reduced further than the functional classification, i.e., a roadway with an arterial functional classification cannot be reduced to a collector typology classification. The roadway classes and typologies shown in Table 1.2 correspond to the classifications of arterial, collector, and local roads, as described in the 2004 AASHTO Green Book. Typology criteria are listed in the following tables:

- Regional Arterial (Table 1.3)
- Community Arterial (Table 1.4)
- Community Collector (Table 1.5)
- Neighborhood Collector (Table 1.6)
- Local Road (Table 1.7) - This refers to the "local" functional classification, which may not coincide with locally owned roads. Local Road Criteria only applies to off Federal-aid system projects.
- Limited Access Freeway (Table 1.8) - Design values for freeways are in accordance with the 2004 AASHTO Green Book and AASHTO's *A Policy on Design Standards---Interstate System* for interstates.

**c.** Design Year. The Design Year is typically 20 years or more from when the project is open to traffic for these types of projects. Note that the geometric design year may be different than the pavement design year or bridge design year.

**2.** Resurfacing, Restoration and Rehabilitation (3R).

**a.** Definition. A 3R project is the improvement of an existing non-freeway facility on similar alignment in order to extend the service life of the facility and/or improve the pavement structural and functional capacity. It typically does not address capacity improvements, major realignment or major upgrading of geometric features. It may include selective improvements to highway geometry and other roadway features and safety appurtenances. It includes reconstruction of limited portions of the project's length. Full reconstruction down to the subgrade is limited to 30% or less of the existing travelled way area. For portions within a 3R project which have a crash history attributable to a geometric element, New and Reconstruction Criteria shall be used for that geometric element. This does not mean the entire project needs to use New and Reconstruction criteria.

The definitions below for resurfacing, restoration and rehabilitation may also apply to Pavement Preservation projects as defined in Publication 242, *Pavement Policy Manual*. Typically pavement projects, which do not add structural capacity to the pavement, are pavement preservation type projects, which use Pavement Preservation criteria. See Section 1.2.A.3 for more information on Pavement Preservation criteria.

**(1)** Resurfacing. Application of a new or recycled layer(s) of pavement material to existing pavements, shoulders and/or bridge decks.

**(2)** Restoration. Improvements to return the pavement, shoulders and/or bridges to an acceptable condition to ensure safe operations for a substantial period.

**(3)** Rehabilitation. Improvements to remove and replace major structural elements of a highway or bridge to an acceptable condition. This includes pavement rehabilitation as defined in Publication 242, *Pavement Policy Manual*, with the exception of freeways.

**(4)** Typical non-freeway 3R projects include:

Roadway projects:

- Resurfacing which may add structural capacity to the pavement and up to 30% base repair to existing traveled way surface area.
- Minor widening of a through lane (less than a full lane).
- Shoulder widening.
- Minor alterations to vertical and/or horizontal geometry as part of a larger paving project.
- Adding climbing lanes.
- Adding or removing parking lanes.
- Adding turning lanes (without modifying the through lanes or median).
- Adding a new signal to an existing intersection with roadway work (If no roadway or restriping work, then non-roadway criteria may be applicable.).
- Minor intersection improvements.

Bridge projects:

- Full and Partial superstructure replacements.
- Deck replacements.

**b.** Criteria. Refer to Section 1.2.E for 3R criteria design values, except for lane and shoulder widths on bridge structures. Bridge width criteria is presented in Section 1.2.C, Minimum Width Criteria for Bridges.

**c.** Design Year. The Design Year is typically the year that a project is opened to traffic. Note that that the design year for highway geometrics may be different than the pavement design year or bridge design life.

**3.** Pavement Preservation.

**a.** Definition. Refer to Publication 242, *Pavement Policy Manual*, for determining when Pavement Preservation criteria is applicable. Typically pavement projects which do not add structural capacity to the pavement are pavement preservation type projects.

**b.** Criteria. Geometric design criteria for pavement preservation projects is found in Section 1.3.

**c.** Design Year. The Design Year for highway geometrics is typically the year the project opens to traffic for these types of projects. Note that that the design year for highway geometrics may be different than the pavement design year.

**4.** Bridge Preservation.

**a.** Definition. See Publication 15M, Design Manual Part 4, *Structures*, Section A.5.6.1 to determine which projects qualify as Bridge Preservation projects.

**b.** Criteria. Geometric design criteria for the 13 controlling criteria for Bridge Preservation projects is as follows:

- Bridge Width Criteria: Refer to Section 1.2.C for required minimum bridge widths.
- Vertical Clearance Criteria: Refer to Chapter 2, Section 2.20.

The other controlling criteria:

- Existing geometric elements not meeting New and Reconstruction Criteria are not to be adversely affected.
- Existing geometric elements that meet or exceed New and Reconstruction Criteria are not to be affected to the extent of not meeting New and Reconstruction Criteria.

**c.** Design Year. The Design Year is typically the year the bridge is fully open to traffic for these types of projects. Note that that the design year for highway geometrics may be different than bridge design year.

**5.** Maintenance. Maintenance is defined as maintaining the existing roadway, bridge and related appurtenances. Geometric design improvements are typically not the normal intent of maintenance operations. Maintenance projects do typically not require right-of-way acquisition and need minimal coordination with permitting agencies and/or utilities. Pavement repairs such as seal coats, full width patching, crack sealing, correcting minor irregularities, etc. are generally considered maintenance activities. Refer to Publication 23, *Maintenance Manual*, and Publication 55, *Bridge Maintenance Manual*, for guidance on maintenance work.

Work performed by Department Force Maintenance crews which does not qualify as maintenance type work, such as bridge and culvert replacements or pavement rehabilitations (3R) projects, must use New and Reconstruction, 3R, Pavement Preservation, or Bridge Preservation criteria, as applicable. This includes minimum bridge width criteria in Section 1.2.C.

Maintenance type work which adversely affects the existing geometry of the roadway may require a design exception. The District may contact the Highway Design Technology Section for determining if a design exception is required.

**6.** Non-Roadway and Non-Bridge Projects. For non-roadway and non-bridge projects, the criteria applied should be project specific. For example, for pedestrian trails, ADA criteria per Chapter 6 applies; for bicycle facilities, the AASHTO Guide for Development of Bicycle Facilities applies, etc. A design exception as outlined in Publication 10X, Design Manual Part 1X, *Appendices to Design Manuals 1, 1A, 1B, and 1C*, Appendix P, *Design Exceptions*. may not be required if criteria cannot be met. However, other actions may be required. For example, if ADA criteria cannot be met, a Technically Infeasible Form (TIF) should be submitted. In all cases, some form of documentation must be provided if criteria cannot be met. Documentation may include meeting minutes or Design Field View Reports, etc. The District may contact the Highway Design Technology Section for determining if a design exception is required.

**B. Functional Classifications, Typologies, and Low Cost Safety Measures.** Low Cost Safety Improvement Measures are found in Table 1.1. These are examples of geometric features and associated safety measures that can be considered for adoption and incorporation into various types of projects and/or a design exception request justification when current design criteria is not practical.

Functional Classification System Service Characteristics are found in Figure 1.1. Roadway Typologies and approximate corresponding functional classifications are found in Table 1.2, *Roadway Typologies*.

Illustrated Roadway Typologies are found in Figure 1.2. Matrix of design values (typology) tables are found in Tables 1.3, 1.4, 1.5, 1.6, 1.7 and 1.8.

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## TABLE 1.1
## LOW COST SAFETY IMPROVEMENT MEASURES

| GEOMETRIC FEATURES | SAFETY MEASURES |
|---|---|
| NARROW LANES AND SHOULDERS | Pavement edge lines.<br>Raised pavement markers.<br>Post delineators. |
| STEEP SIDESLOPES AND ROADSIDE OBSTRUCTIONS | Object markings.<br>Slope flattening.<br>Ditch rounding.<br>Obstruction removal.<br>Breakaway safety hardware.<br>Guide rail. |
| NARROW BRIDGES | Traffic control devices.<br>Approach guide rail.<br>Object markers.<br>Pavement markings.<br>Structure delineation.<br>Warning signs.<br>Speed control.<br>Direction control. |
| LIMITED SIGHT DISTANCE AT CREST OR SAG VERTICAL CURVES | Traffic control devices.<br>Fixed object removal.<br>Driveway relocation. |
| SHARP HORIZONTAL CURVES | Traffic control devices.<br>Shoulder widening.<br>Appropriate superelevation.<br>Slope flattening.<br>Pavement antiskid treatment.<br>Obstruction removal or relocation.<br>Obstruction shielding.<br>Warning signs. |
| INTERSECTIONS WITH POINTS OF CONFLICT | Traffic control devices.<br>Traffic signalization.<br>Fixed lighting.<br>Pavement antiskid treatment.<br>Speed controls. |

# FIGURE 1.1
# FUNCTIONAL CLASSIFICATION SYSTEM
# SERVICE CHARACTERISTICS

## URBAN AREA SYSTEM

**INTERSTATE AND OTHER LIMITED ACCESS FREEWAYS**

1. Provides limited access facilities.

**ARTERIALS**

- **PRINCIPAL ARTERIALS**
  1. Serves major centers of activity and carries high proportion of area travel even though it constitutes a relatively small percentage of the total roadway network.
  2. Integrated both internally and between major rural connections.
  3. Carries most trips entering and leaving the area and serves intra area travel.
  4. Provides continuity for rural arterials.
  5. Spacing related to trip-end density characteristics.
- **MINOR ARTERIALS**
  1. Interconnects with and augments principal arterials.
  2. Accommodates trips of moderate length.
  3. Distributes travel to areas smaller than identified with higher systems.
  4. Places emphasis on land access and offers lower traffic mobility.
  5. Spacing normally not more than 2 km (1 mi).

**COLLECTORS**

1. Provides both land access services and traffic circulation.
2. Distributes trips from arterials through residential neighborhoods to ultimate destination.
3. Collects traffic from local streets and channels to arterials.

**LOCAL ROADS**

1. Comprises all facilities not in one of the higher systems.
2. Permits direct access to abutting lands and connects to higher systems.
3. Discourages through-traffic movement.

## RURAL AREA SYSTEM

**INTERSTATE AND OTHER LIMITED ACCESS FREEWAYS**

1. Provides limited access facilities.

**ARTERIALS**

- **PRINCIPAL ARTERIALS**
  1. Serves statewide or interstate level.
  2. Serves all urbanized areas.
  3. Provides integrated movements without stub connections.
- **MINOR ARTERIALS**
  1. Links cities, larger towns and other traffic generators.
  2. Provides integrated interstate and inter county service.
  3. Spaced at proper intervals consistent with population density.
  4. Corridor movements consistent with 1. through 3. with greater trip lengths and travel densities than those served by rural collector or local systems.

**COLLECTORS**

- **MAJOR COLLECTORS**
  1. Provides service to county seats, larger towns and other traffic generators.
  2. Connects routes of higher classification.
  3. Serves intracounty travel corridors.
- **MINOR COLLECTORS**
  1. Spaced at intervals to collect traffic from local roads.
  2. Provides services to remaining smaller communities.
  3. Links local traffic generators with rural hinterland.

**LOCAL ROADS**

1. Provides access to land adjacent to collector network.
2. Serves travel over relatively short distances.
3. Constitutes all rural roads not classified in one of the higher systems.

## TABLE 1.2
## ROADWAY TYPOLOGIES

| ROADWAY CLASS | ROADWAY TYPE | DESIRED OPERATING SPEED | AVERAGE TRIP LENGTH | VOLUME | INTERSECTION SPACING | COMMENTS |
|---|---|---|---|---|---|---|
| Arterial | Regional | 50-90 km/h (30-55 mph) | 24-56 km (15-35 mi) | 10,000-40,000 veh/day | 200-400 m (660-1,320 ft) | Roadways in this category would be considered "Principal Arterial" in traditional functional classification. |
| Arterial | Community | 40-90 km/h (25-55 mph) | 11-40 km (7-25 mi) | 5,000-25,000 veh/day | 90-400 m (300-1,320 ft) | Often classified as "Minor Arterial" in traditional classification but may include road segments classified as "Principal Arterial". |
| Collector | Community | 40-90 km/h (25-55 mph) | 8-16 km (5-10 mi) | 5,000-15,000 veh/day | 90-200 m (300-660 ft) | Often similar in appearance to a community arterial. Typically classified as "Major Collector". |
| Collector | Neighborhood | 40-60 km/h (25-35 mph) | < 11 km (< 7 mi) | < 6,000 veh/day | 90-200 m (300-660 ft) | Similar in appearance to local roadways. Typically classified as "Minor Collector". |
| Local | Local | 30-50 km/h (20-30 mph) | < 8 km (< 5 mi) | < 3,000 veh/day | 60-200 m (200-660 ft) | |

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**FIGURE 1.2**
**ILLUSTRATED ROADWAY TYPOLOGIES**

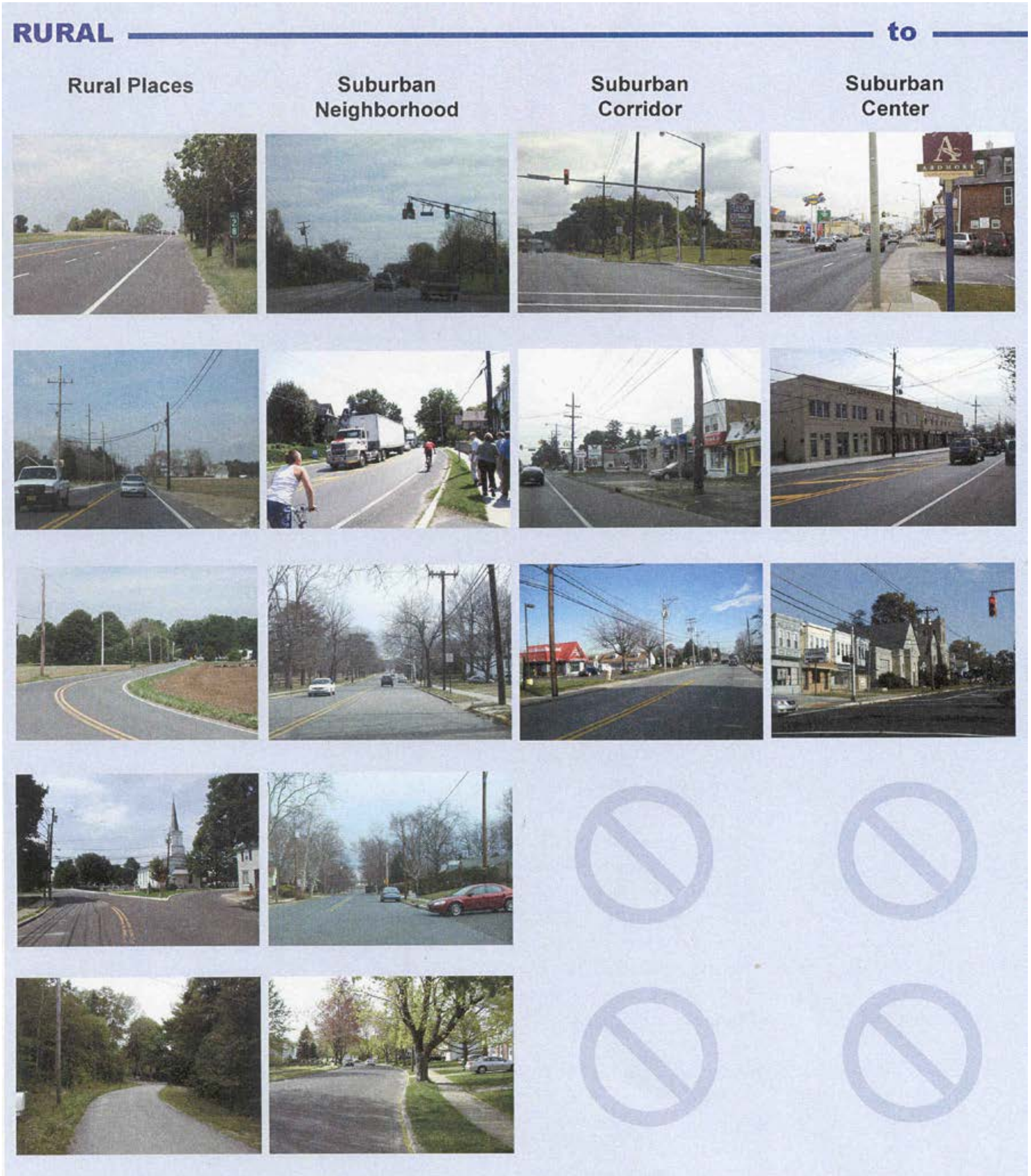
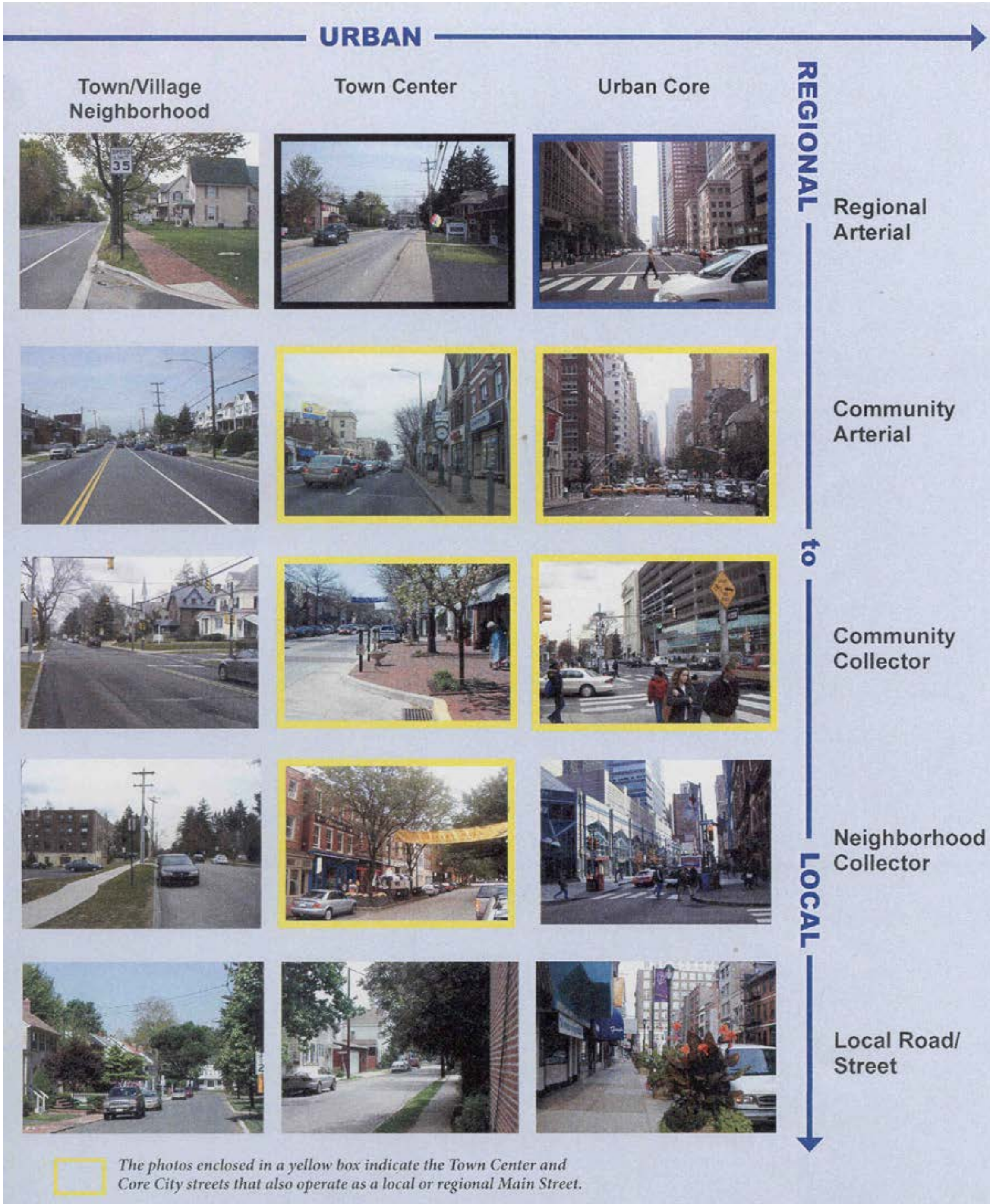


**FIGURE 1.2 (CONTINUED)**
**ILLUSTRATED ROADWAY TYPOLOGIES**



# TABLE 1.3 (ENGLISH)
# MATRIX OF DESIGN VALUES – REGIONAL ARTERIAL

| | Regional Arterial | Rural | Suburban Neighborhood | Suburban Corridor | Suburban Center | Town/Village Neighborhood | Town/Village Center | Urban Core |
|---|---|---|---|---|---|---|---|---|
| Roadway | Lane Width [1] | 11' to 12' | 11' to 12' | 11' to 12' | 11' to 12' | 10' to 12' | 10' to 12' | 10' to 12' |
| Roadway | Shoulder Width [2, 3] | 8' to 10' | 8' to 10' | 8' to 12' | 4' to 6' (if No Parking or Bike Lane) | 4' to 6' (if No Parking or Bike Lane) | 4' to 6' (if No Parking or Bike Lane) | 4' to 6' (if No Parking or Bike Lane) |
| Roadway | Parking Lane | NA | NA | NA | 8' Parallel | 8' Parallel | 8' Parallel | 8' Parallel |
| Roadway | Bike Lane [4] | NA | 5' to 6' (if No Shoulder) | 6' (if No Shoulder) | 5' to 6' | 5' to 6' | 5' to 6' | 5' to 6' |
| Roadway | Median (if needed) | 4' to 6' | 16' to 18' for Left Turn; 6' to 8' for Pedestrians Only | 16' to 18' for Left Turn; 6' to 8' for Pedestrians Only | 16' to 18' for Left Turn; 6' to 8' for Pedestrians Only | 16' to 18' for Left Turn; 6' to 8' for Pedestrians Only | 16' to 18' for Left Turn; 6' to 8' for Pedestrians Only | 16' to 18' for Left Turn; 6' to 8' for Pedestrians Only |
| Roadway | Curb Return [5] | 30' to 50' | 25' to 35' | 30' to 50' | 25' to 50' | 15' to 40' | 15' to 40' | 15' to 40' |
| Roadway | Travel Lanes | 2 to 6 | 2 to 6 | 4 to 6 | 4 to 6 | 2 to 4 | 2 to 4 | 2 to 6 |
| Roadway | Cross Slopes (Minimum) [6, 7] | 2.0% | 2.0% | 2.0% | 2.0% | 2.0% | 2.0% | 2.0% |
| Roadway | Cross Slopes (Maximum) [8] | 8.0% | 6.0% | 6.0% | 6.0% | 6.0% | 6.0% | 6.0% |
| Roadway | Bridge Widths [9, 10, 16, 17] | Lane Widths Plus Shoulders Each Side | Lane Widths Plus Shoulders Each Side | Lane Widths Plus Shoulders Each Side | Lane Widths Plus Shoulders Each Side | Lane Widths Plus Shoulders Each Side | Lane Widths Plus Shoulders Each Side | Lane Widths Plus Shoulders Each Side |
| Roadway | Vertical Grades (Minimum) [11] | 0.5% | 0.5% | 0.5% | 0.5% | 0.5% | 0.5% | 0.5% |
| Roadway | Vertical Clearance (Minimum) | 16'-6", See Chapter 2 | 16'-6", See Chapter 2 | 16'-6", See Chapter 2 | 16'-6", See Chapter 2 | 16'-6", See Chapter 2 | 16'-6", See Chapter 2 | 16'-6", See Chapter 2 |
| Roadside [12] | Clear Sidewalk Width | NA | 5' | 5' to 6' | 5' to 6' | 6' to 8' | 6' to 10' | 6' to 12' |
| Roadside [12] | Buffer [13] | NA | 6'+ | 6' to 10' | 4' to 6' | 4' to 6' | 4' to 6' | 4' to 6' |
| Roadside [12] | Shy Distance | NA | NA | NA | 0' to 2' | 0' to 2' | 2' | 2' |
| Roadside [12] | Total Sidewalk Width | NA | 5' | 5' to 6' | 9' to 14' | 10' to 16' | 12' to 18' | 12' to 20' |
| Roadside [12] | Clear Zone Widths [14] | See Chapter 12 | See Chapter 12 | See Chapter 12 | See Chapter 12 | See Chapter 12 | See Chapter 12 | See Chapter 12 |
| Roadside [12] | Right-of-Way Widths [15] | Varies | Varies | Varies | Varies | Varies | Varies | Varies |
| Speed | Desired Operating Speed (Design Speed) | 45-55 mph | 35-40 mph | 35-55 mph | 30-35 mph | 30-35 mph | 30-35 mph | 30-35 mph |
| Speed | Stopping and Passing Sight Distances (Minimum) | 2004 AASHTO Green Book, Exhibit 7-1 | 2004 AASHTO Green Book, Exhibit 7-1 | 2004 AASHTO Green Book, Exhibit 7-1 | 2004 AASHTO Green Book, Exhibit 7-1 | 2004 AASHTO Green Book, Exhibit 7-1 | 2004 AASHTO Green Book, Exhibit 7-1 | 2004 AASHTO Green Book, Exhibit 7-1 |
| Speed | Vertical Grades (Maximum) | 2004 AASHTO Green Book, Exhibit 7-2 | 2004 AASHTO Green Book, Exhibit 7-10 | 2004 AASHTO Green Book, Exhibit 7-10 | 2004 AASHTO Green Book, Exhibit 7-10 | 2004 AASHTO Green Book, Exhibit 7-10 | 2004 AASHTO Green Book, Exhibit 7-10 | 2004 AASHTO Green Book, Exhibit 7-10 |

**TABLE 1.3 (ENGLISH) (CONTINUED)**

**MATRIX OF DESIGN VALUES – REGIONAL ARTERIAL**

| Matrix of Design Values - Notes (Regional Arterial) |
|---|
| [1] 12' preferred for regular transit routes, and heavy truck volumes > 5%, particularly for design speeds of 35 mph or greater. A 1' to 2' offset to the curb is desirable. 14' for an outside lane with no shoulder or bike lane, if optimal accommodation for bicyclists is desired. |
| [2] Shoulders should only be installed in urban contexts as a retrofit of wide travel lanes to accommodate bicyclists. For rural divided arterials with three or more lanes in each direction, a 10' wide left shoulder within the median is desirable. |
| [3] Paving for railroad grade crossings shall extend 2' beyond the extreme rails for the full graded width of the highway. |
| [4] Design of bike lanes should be considered when identified as part of the Engineering & Environmental (E&E) Scoping process. |
| [5] Curb return radius should be as small as possible. Number of lanes, on street parking, bike lanes, and shoulders should be utilized to determine effective radius. |
| [6] Cross slopes of 3.0% are recommended for design speeds less than 40 mph. |
| [7] In curbed areas with longitudinal slopes of 1% or less, 3.0% cross slopes may be used on tangents. |
| [8] The Maximum superelevation rate is 8% for Rural conditions and 6% for Urban conditions. |
| [9] Where pedestrian traffic is anticipated, provisions for a sidewalk should be considered and shall meet the Department's Standards and requirements (see Chapter 6 and Design Manual, Part 4, Part B, Section 2, Article 2.3). |
| [10] For long bridges over 60 m (200 ft) in length, offsets (shoulders) to the parapet, rail, barrier or curb shall be at least 1.2 m (4 ft) from the travel lane on both the left and the right. |
| [11] Recommended minimum grade of 0.75% on curbed sections. |
| [12] The Roadside design values should be considered and implemented as feasible and reasonable; however, Chapter 6, Pedestrian Facilities, should still be used for minimum design criteria. ADA accommodations must be addressed in accordance with ADA policy. |
| [13] Buffer is assumed to be planted area (grass, shrubs and/or trees) for suburban neighborhood and corridor contexts; street furniture/car door zone for other land use contexts. Minimum of 6' for transit zones. |
| [14] Center piers are not desirable. Increase bridge span where necessary to provide for required horizontal stopping sight distance. Provide clearance for guide rail in front of substructures if protection is required. |
| [15] The procurement of sufficient right-of-way width should be based on the preferable dimensions for all the elements of the composite highway cross section and should be adequate to accommodate the construction and proper maintenance of the highway throughout the project. Future widening should be considered and, where needed for safety, additional right-of-way may be required for adequate sight distance. For additional information on right-of-way widths, refer to the 2004 AASHTO Green Book. |
| [16] Where parking lanes are provided on the approaches, consideration should be given to extending the parking lanes across the bridge. |
| [17] If the conditions listed on the form in Chapter 1, Appendix A, Reduced Bridge Width Criteria Documentation are met, the minimum bridge width may equal the width provided in Table 1.12. |

# TABLE 1.4 (ENGLISH)
# MATRIX OF DESIGN VALUES – COMMUNITY ARTERIAL

| | Community Arterial | Rural | Suburban Neighborhood | Suburban Corridor | Suburban Center | Town/Village Neighborhood | Town/Village Center | Urban Core |
|---|---|---|---|---|---|---|---|---|
| Roadway | Lane Width [1] | 11' to 12' | 10' to 12' | 11' to 12' | 10' to 12' | 10' to 12' | 10' to 12' | 10' to 12' |
| Roadway | Shoulder Width [2, 3] | 8' to 10' | 4' to 8' (if No Parking or Bike Lane) | 8' to 10' | 4' to 6' (if No Parking or Bike Lane) | 4' to 6' (if No Parking or Bike Lane) | 4' to 6' (if No Parking or Bike Lane) | 4' to 6' (if No Parking or Bike Lane) |
| Roadway | Parking Lane | NA | 7' to 8' Parallel | NA | 8' Parallel | 7' to 8' Parallel | 7' to 8' Parallel | 7' to 8' Parallel |
| Roadway | Bike Lane [4] | NA | 5' to 6' (if No Shoulder) | 5' to 6' (if No Shoulder) | 5' to 6' | 5' to 6' | 5' to 6' | 5' to 6' |
| Roadway | Median (if needed) | 4' to 6' | 16' to 18' for Left Turn | 16' to 18' for Left Turn | 16' to 18' for Left Turn | 16' to 18' for Left Turn | 16' to 18' for Left Turn | 16' to 18' for Left Turn |
| | | | 12' to 18' for Left Turn; 6' to 8' for Pedestrians | 12' to 18' for Left Turn; 6' to 8' for Pedestrians | 12' to 18' for Left Turn; 6' to 8' for Pedestrians | 12' to 18' for Left Turn; 6' to 8' for Pedestrians | 12' to 18' for Left Turn; 6' to 8' for Pedestrians | 12' to 18' for Left Turn; 6' to 8' for Pedestrians |
| Roadway | Curb Return [5] | 25' to 50' | 25' to 35' | 25' to 50' | 20' to 40' | 15' to 30' | 15' to 35' | 15' to 40' |
| Roadway | Travel Lanes | 2 to 4 | 2 to 4 | 2 to 4 | 2 to 4 | 2 to 4 | 2 to 4 | 2 to 4 |
| Roadway | Cross Slopes (Minimum) [6, 7] | 2.0% | 2.0% | 2.0% | 2.0% | 2.0% | 2.0% | 2.0% |
| Roadway | Cross Slopes (Maximum) [8] | 8.0% | 6.0% | 6.0% | 6.0% | 6.0% | 6.0% | 6.0% |
| Roadway | Bridge Widths [9, 10, 16, 17] | Lane Widths Plus Shoulders Each Side | Lane Widths Plus Shoulders Each Side | Lane Widths Plus Shoulders Each Side | Lane Widths Plus Shoulders Each Side | Lane Widths Plus Shoulders Each Side | Lane Widths Plus Shoulders Each Side | Lane Widths Plus Shoulders Each Side |
| Roadway | Vertical Grades (Minimum) [11] | 0.5% | 0.5% | 0.5% | 0.5% | 0.5% | 0.5% | 0.5% |
| Roadway | Vertical Clearance (Minimum) | 16'-6", See Chapter 2 | 16'-6", See Chapter 2 | 16'-6", See Chapter 2 | 16'-6", See Chapter 2 | 16'-6", See Chapter 2 | 16'-6", See Chapter 2 | 16'-6", See Chapter 2 |
| Roadside [12] | Clear Sidewalk Width | NA | 5' | 5' to 6' | 6' | 6' to 8' | 6' to 10' | 8' to 14' |
| Roadside [12] | Buffer [13] | NA | 6'+ | 5' to 10' | 4' to 6' | 4' to 6' | 4' to 6' | 4' to 6' |
| Roadside [12] | Shy Distance | NA | NA | NA | 0' to 2' | 0' to 2' | 2' | 2' |
| Roadside [12] | Total Sidewalk Width | NA | 5' | 5' to 6' | 10' to 14' | 10' to 16' | 12' to 18' | 14' to 22' |
| Roadside [12] | Clear Zone Widths [14] | See Chapter 12 | See Chapter 12 | See Chapter 12 | See Chapter 12 | See Chapter 12 | See Chapter 12 | See Chapter 12 |
| Roadside [12] | Right-of-Way Widths [15] | Varies | Varies | Varies | Varies | Varies | Varies | Varies |
| Speed | Desired Operating Speed (Design Speed) | 35-55 mph | 30-35 mph | 35-50 mph | 30 mph | 25-30 mph | 25-30 mph | 25-30 mph |
| Speed | Stopping and Passing Sight Distances (Minimum) | 2004 AASHTO Green Book, Exhibit 7-1 | 2004 AASHTO Green Book, Exhibit 7-1 | 2004 AASHTO Green Book, Exhibit 7-1 | 2004 AASHTO Green Book, Exhibit 7-1 | 2004 AASHTO Green Book, Exhibit 7-1 | 2004 AASHTO Green Book, Exhibit 7-1 | 2004 AASHTO Green Book, Exhibit 7-1 |
| Speed | Vertical Grades (Maximum) | 2004 AASHTO Green Book, Exhibit 7-2 | 2004 AASHTO Green Book, Exhibit 7-10 | 2004 AASHTO Green Book, Exhibit 7-10 | 2004 AASHTO Green Book, Exhibit 7-10 | 2004 AASHTO Green Book, Exhibit 7-10 | 2004 AASHTO Green Book, Exhibit 7-10 | 2004 AASHTO Green Book, Exhibit 7-10 |

## TABLE 1.4 (ENGLISH) (CONTINUED)
## MATRIX OF DESIGN VALUES – COMMUNITY ARTERIAL

| Matrix of Design Values - Notes (Community Arterial) |
|---|
| [1] 12' preferred for regular transit routes, and heavy truck volumes > 5%, particularly for design speeds of 35 mph or greater.  A 1' to 2' offset to the curb is desirable.  14' for an outside lane with no shoulder or bike lane, if optimal accommodation for bicyclists is desired. |
| [2] Shoulders should be installed in urban contexts only as part of a retrofit of wide travel lanes to accommodate bicyclists. |
| [3] Paving for railroad grade crossings shall extend 2' beyond the extreme rails for the full graded width of the highway. |
| [4] Design of bike lanes should be considered when identified as part of the Engineering & Environmental (E&E) Scoping process. |
| [5] Curb Return radius should be as small as possible.  Number of lanes, on street parking, bike lanes, and shoulders should be utilized to determine effective radius. |
| [6] Cross slopes of 3.0% are recommended for design speeds less than 40 mph. |
| [7] In curbed areas with longitudinal slopes of 1% or less, 3.0% cross slopes may be used on tangents. |
| [8] The Maximum superelevation rate is 8% for Rural conditions and 6% for Urban conditions. |
| [9] Where pedestrian traffic is anticipated, provisions for a sidewalk should be considered and shall meet the Department's Standards and requirements (see Chapter 6 and Design Manual, Part 4, Part B, Section 2, Article 2.3). |
| [10] For long bridges over 60 m (200 ft) in length, offsets (shoulders) to the parapet, rail, barrier or curb shall be at least 1.2 m (4 ft) from the travel lane on both the left and the right. |
| [11] Recommended minimum grade of 0.75% on curbed sections. |
| [12] The Roadside design values should be considered and implemented as feasible and reasonable; however, Chapter 6, Pedestrian Facilities, should still be used for minimum design criteria.  ADA accommodations must be addressed in accordance with ADA policy. |
| [13] Buffer is assumed to be planted area (grass, shrubs and/or trees) for suburban neighborhood and corridor contexts; street furniture/car door zone for other land use contexts.  Minimum of 6' for transit zones. |
| [14] Center piers are not desirable.  Increase bridge span where necessary to provide for required horizontal stopping sight distance.  Provide clearance for guide rail in front of substructures if protection is required. |
| [15] The procurement of sufficient right-of-way width should be based on the preferable dimensions for all the elements of the composite highway cross section and should be adequate to accommodate the construction and proper maintenance of the highway throughout the project.  Future widening should be considered and, where needed for safety, additional right-of-way may be required for adequate sight distance.  For additional information on right-of-way widths, refer to the 2004 AASHTO Green Book. |
| [16] Where parking lanes are provided on the approaches, consideration should be given to extending the parking lanes across the bridge. |
| [17] If the conditions listed on the form in Chapter 1, Appendix A, Reduced Bridge Width Criteria Documentation are met, the minimum bridge width may equal the width provided in Table 1.12. |

## TABLE 1.5 (ENGLISH)
## MATRIX OF DESIGN VALUES – COMMUNITY COLLECTOR

| | Community Collector | Rural | Suburban Neighborhood | Suburban Corridor | Suburban Center | Town/Village Neighborhood | Town/Village Center | Urban Core |
|---|---|---|---|---|---|---|---|---|
| Roadway | Lane Width [1] | 11' to 12' | 10' to 12' | 11' to 12' | 10' to 11' | 10' to 11' | 10' to 11' | 10' to 11' |
| | Shoulder Width [2, 3] | 4' to 8' | 4' to 8' (if No Parking or Bike Lane) | 8' to 10' | 4' to 6' (if No Parking or Bike Lane) | 4' (if No Parking or Bike Lane) | 4' (if No Parking or Bike Lane) | 4' (if No Parking or Bike Lane) |
| | Parking Lane | NA | 7' | NA | 7' to 8' Parallel | 7' to 8' Parallel | 7' to 8' Parallel | 7' to 8' Parallel |
| | Bike Lane [4] | NA | 5' | 5' to 6' | 5' to 6' | 5' to 6' | 5' to 6' | 5' to 6' |
| | Median (if needed) | NA | 12' to 16' for Left Turn; 6' for Pedestrians Only | 12' to 16' for Left Turn; 6' for Pedestrians Only | 12' to 16' for Left Turn; 6' for Pedestrians Only | 12' to 16' for Left Turn; 6' for Pedestrians Only | 12' to 16' for Left Turn; 6' for Pedestrians Only | 12' to 16' for Left Turn; 6' for Pedestrians Only |
| | Curb Return [5] | 20' to 40' | 15' to 35' | 20' to 40' | 20' to 35' | 10' to 25' | 10' to 25' | 10' to 30' |
| | Travel Lanes | 2 | 2 to 4 | 2 to 4 | 2 to 4 | 2 to 4 | 2 to 4 | 2 to 4 |
| | Cross Slopes (Minimum) [6, 7] | 2.0% | 2.0% | 2.0% | 2.0% | 2.0% | 2.0% | 2.0% |
| | Cross Slopes (Maximum) [8] | 8.0% | 6.0% | 6.0% | 6.0% | 6.0% | 6.0% | 6.0% |
| | Bridge Widths | Refer to the Minimum Width Criteria for Bridges Section in this Chapter. | Refer to the Minimum Width Criteria for Bridges Section in this Chapter. | Refer to the Minimum Width Criteria for Bridges Section in this Chapter. | Refer to the Minimum Width Criteria for Bridges Section in this Chapter. | Refer to the Minimum Width Criteria for Bridges Section in this Chapter. | Refer to the Minimum Width Criteria for Bridges Section in this Chapter. | Refer to the Minimum Width Criteria for Bridges Section in this Chapter. |
| | Vertical Grades (Minimum) [9] | 0.5% | 0.5% | 0.5% | 0.5% | 0.5% | 0.5% | 0.5% |
| | Vertical Clearance (Minimum) | 14'-6", See Chapter 2 | 14'-6", See Chapter 2 | 14'-6", See Chapter 2 | 14'-6", See Chapter 2 | 14'-6", See Chapter 2 | 14'-6", See Chapter 2 | 14'-6", See Chapter 2 |
| Roadside [12] | Clear Sidewalk Width | NA | 4' to 5' | 5' to 6' | 6' to 8' | 5' to 6' | 6' to 8' | 6' to 10' |
| | Buffer [11] | NA | 5'+ | 5' to 10' | 4' to 5' | 4' to 5' | 4' to 5' | 4' to 6' |
| | Shy Distance | NA | NA | NA | 0' to 2' | 0' to 2' | 2' | 2' |
| | Total Sidewalk Width | NA | 4' to 5' | 5' to 6' | 10' to 15' | 9' to 13' | 12' to 15' | 12' to 18' |
| | Clear Zone Widths [12] | See Chapter 12 | See Chapter 12 | See Chapter 12 | See Chapter 12 | See Chapter 12 | See Chapter 12 | See Chapter 12 |
| | Right-of-Way Widths [13] | Varies | Varies | Varies | Varies | Varies | Varies | Varies |
| Speed | Desired Operating Speed (Design Speed) | 35-55 mph | 25-30 mph | 30-35 mph | 25-30 mph | 25-30 mph | 25-30 mph | 25-30 mph |
| | Stopping and Passing Sight Distances (Minimum) | 2004 AASHTO Green Book, Exhibits 6-2 & 6-3 | 2004 AASHTO Green Book, Exhibits 6-2 & 6-3 | 2004 AASHTO Green Book, Exhibits 6-2 & 6-3 | 2004 AASHTO Green Book, Exhibits 6-2 & 6-3 | 2004 AASHTO Green Book, Exhibits 6-2 & 6-3 | 2004 AASHTO Green Book, Exhibits 6-2 & 6-3 | 2004 AASHTO Green Book, Exhibits 6-2 & 6-3 |
| | Vertical Grades (Maximum) [14] | 2004 AASHTO Green Book, Exhibit 6-4 | 2004 AASHTO Green Book, Exhibit 6-8 | 2004 AASHTO Green Book, Exhibit 6-8 | 2004 AASHTO Green Book, Exhibit 6-8 | 2004 AASHTO Green Book, Exhibit 6-8 | 2004 AASHTO Green Book, Exhibit 6-8 | 2004 AASHTO Green Book, Exhibit 6-8 |

## TABLE 1.5 (ENGLISH) (CONTINUED)
## MATRIX OF DESIGN VALUES – COMMUNITY COLLECTOR

| | |
|---|---|
| **Matrix of Design Values - Notes (Community Collector)** | [1] 11' to 12' preferred for heavy truck volumes > 5% and regular transit routes. A 1' to 2' offset to the curb is desirable. 14' for an outside lane with no shoulder or bike lane, if optimal accommodation for bicyclists is desired. |
| | [2] Shoulders should be installed in urban contexts only as part of a retrofit of wide travel lanes to accommodate bicyclists. |
| | [3] Paving for railroad grade crossings shall extend 2' beyond the extreme rails for the full graded width of the highway. |
| | [4] Design of bike lanes should be considered when identified as part of the Engineering & Environmental (E&E) Scoping process. |
| | [5] Curb Return radius should be as small as possible. Number of lanes, on street parking, bike lanes, and shoulders should be utilized to determine effective radius. |
| | [6] Cross slopes of 3.0% are recommended for design speeds less than 40 mph. |
| | [7] In curbed areas with longitudinal slopes of 1% or less, 3.0% cross slopes may be used on tangents. |
| | [8] The Maximum superelevation rate is 8% for Rural conditions and 6% for Urban conditions. |
| | [9] Recommended minimum grade of 0.75% on curbed sections. |
| | [10] The Roadside design values should be considered and implemented as feasible and reasonable; however, Chapter 6, Pedestrian Facilities, should still be used for minimum design criteria. ADA accommodations must be addressed in accordance with ADA policy. |
| | [11] Buffer is assumed to be planted area (grass, shrubs, and/or trees) for suburban neighborhood and corridor contexts. |
| | [12] Center piers are not desirable. Increase bridge span where necessary to provide for required horizontal stopping sight distance. Provide clearance for guide rail in front of substructures if protection is required. |
| | [13] The procurement of sufficient right-of-way width should be based on the preferable dimensions for all the elements of the composite highway cross section and should be adequate to accommodate the construction and proper maintenance of the highway throughout the project. Future widening should be considered and, where needed for safety, additional right-of-way may be required for adequate sight distance. For additional information on right-of-way widths, refer to the 2004 AASHTO Green Book. |
| | [14] For short grades less than 500', one-way downgrades, and grades on low-volume rural or urban collectors, maximum grades may be up to 2% steeper. |

# TABLE 1.6 (ENGLISH)
# MATRIX OF DESIGN VALUES – NEIGHBORHOOD COLLECTOR

| | Neighborhood Collector | Rural | Suburban Neighborhood | Suburban Corridor | Suburban Center | Town/Village Neighborhood | Town/Village Center | Urban Core |
|---|---|---|---|---|---|---|---|---|
| Roadway | Lane Width [1] | 10' to 11' | 10' to 11' | NA | NA | 9' to 11' | 9' to 11' | 9' to 11' |
| Roadway | Shoulder Width [2, 3] | 4' to 8' | 4' to 8' (if No Parking or Bike Lane) | NA | NA | 4' to 6' or Curbed | 4' to 6' or Curbed | 4' to 6' or Curbed |
| Roadway | Parking Lane | NA | 7' Parallel | NA | NA | 7' to 8' Parallel | 7' to 8' Parallel | 7' to 8' Parallel |
| Roadway | Bike Lane [4] | NA | 5' | NA | NA | 5' | 5' | 5' |
| Roadway | Median (if needed) | NA | 8' to 10' Landscaping; 6' to 8' for Peds | NA | NA | 8' to 10' Landscaping; 6' to 8' for Peds | 8' to 10' Landscaping; 6' to 8' for Peds | 8' to 10' Landscaping; 6' to 8' for Peds |
| Roadway | Curb Return [5] | 15' to 35' | 15' to 35' | NA | NA | 10' to 25' | 10' to 25' | 10' to 25' |
| Roadway | Travel Lanes | 2 | 2 | NA | NA | 2 | 2 | 2 |
| Roadway | Cross Slopes (Minimum) [6, 7] | 2.0% | 2.0% | NA | NA | 2.0% | 2.0% | 2.0% |
| Roadway | Cross Slopes (Maximum) [8] | 8.0% | 6.0% | NA | NA | 6.0% | 6.0% | 6.0% |
| Roadway | Bridge Widths | Refer to the Minimum Width Criteria for Bridges Section in this Chapter. | Refer to the Minimum Width Criteria for Bridges Section in this Chapter. | NA | NA | Refer to the Minimum Width Criteria for Bridges Section in this Chapter. | Refer to the Minimum Width Criteria for Bridges Section in this Chapter. | Refer to the Minimum Width Criteria for Bridges Section in this Chapter. |
| Roadway | Vertical Grades (Minimum) [9] | 0.5% | 0.5% | NA | NA | 0.5% | 0.5% | 0.5% |
| Roadway | Vertical Clearance (Minimum) | 14'-6", See Chapter 2 | 14'-6", See Chapter 2 | NA | NA | 14'-6", See Chapter 2 | 14'-6", See Chapter 2 | 14'-6", See Chapter 2 |
| Roadside [12] | Clear Sidewalk Width | NA | 4' to 5' | NA | NA | 5' to 6' | 6' | 6' to 8' |
| Roadside [12] | Buffer [11] | NA | 4'+ | NA | NA | 3' to 5' | 3' to 5' | 4' to 6' |
| Roadside [12] | Shy Distance | NA | NA | NA | NA | 0' to 2' | 2' | 2' |
| Roadside [12] | Total Sidewalk Width | NA | 4' to 5' | NA | NA | 8' to 13' | 11' to 13' | 12' to 16' |
| Roadside [12] | Clear Zone Widths [12] | See Chapter 12 | See Chapter 12 | NA | NA | See Chapter 12 | See Chapter 12 | See Chapter 12 |
| Roadside [12] | Right-of-Way Widths [13] | Varies | Varies | NA | NA | Varies | Varies | Varies |
| Speed | Desired Operating Speed (Design Speed) | 20-35 mph | 25-30 mph | NA | NA | 25-30 mph | 25-30 mph | 25-30 mph |
| Speed | Stopping and Passing Sight Distances (Minimum) | 2004 AASHTO Green Book, Exhibits 6-2 & 6-3 | 2004 AASHTO Green Book, Exhibits 6-2 & 6-3 | NA | NA | 2004 AASHTO Green Book, Exhibits 6-2 & 6-3 | 2004 AASHTO Green Book, Exhibits 6-2 & 6-3 | 2004 AASHTO Green Book, Exhibits 6-2 & 6-3 |
| Speed | Vertical Grades (Maximum) [14] | 2004 AASHTO Green Book, Exhibit 6-4 | 2004 AASHTO Green Book, Exhibit 6-8 | NA | NA | 2004 AASHTO Green Book, Exhibit 6-8 | 2004 AASHTO Green Book, Exhibit 6-8 | 2004 AASHTO Green Book, Exhibit 6-8 |

## TABLE 1.6 (ENGLISH) (CONTINUED)
## MATRIX OF DESIGN VALUES – NEIGHBORHOOD COLLECTOR

| Matrix of Design Values - Notes (Neighborhood Collector) | |
|---|---|
| | [1] 11' to 12' preferred for heavy truck volumes > 5% and regular transit routes. A 1' to 2' offset to the curb is desirable. 14' for an outside lane with no shoulder or bike lane, if optimal accommodation for bicyclists is desired. |
| | [2] Shoulders should be installed in urban contexts only as part of a retrofit of wide travel lanes to accommodate bicyclists. |
| | [3] Paving for railroad grade crossings shall extend 2' beyond the extreme rails for the full graded width of the highway. |
| | [4] Design of bike lanes should be considered when identified as part of the Engineering & Environmental (E&E) Scoping process. |
| | [5] Curb Return radius should be as small as possible. Number of lanes, on street parking, bike lanes, and shoulders should be utilized to determine effective radius. |
| | [6] Cross slopes of 3.0% are recommended for design speeds less than 40 mph. |
| | [7] In curbed areas with longitudinal slopes of 1% or less, 3.0% cross slopes may be used on tangents. |
| | [8] The Maximum superelevation rate is 8% for Rural conditions and 6% for Urban conditions. |
| | [9] Recommended minimum grade of 0.75% on curbed sections. |
| | [10] The Roadside design values should be considered and implemented as feasible and reasonable; however, Chapter 6, Pedestrian Facilities, should still be used for minimum design criteria. ADA accommodations must be addressed in accordance with ADA policy. |
| | [11] Buffer is assumed to be planted area (grass, shrubs and/or trees) for suburban neighborhood and corridor contexts. |
| | [12] Center piers are not desirable. Increase bridge span where necessary to provide for required horizontal stopping sight distance. Provide clearance for guide rail in front of substructures if protection is required. |
| | [13] The procurement of sufficient right-of-way width should be based on the preferable dimensions for all the elements of the composite highway cross section and should be adequate to accommodate the construction and proper maintenance of the highway throughout the project. Future widening should be considered and, where needed for safety, additional right-of-way may be required for adequate sight distance. For additional information on right-of-way widths, refer to the 2004 AASHTO Green Book. |
| | [14] For short grades less than 500', one-way downgrades, and grades on low-volume rural or urban collectors, maximum grades may be up to 2% steeper. |

# TABLE 1.7 (ENGLISH)
## MATRIX OF DESIGN VALUES – LOCAL ROAD

| | Local Road | Rural | Suburban Neighborhood | Suburban Corridor | Suburban Center | Town/Village Neighborhood | Town/Village Center | Urban Core |
|---|---|---|---|---|---|---|---|---|
| Roadway | Lane Width [1] | 9' to 11' | See Roadway Width | NA | NA | See Roadway Width | 9' to 11' | 9' to 11' |
| Roadway | Roadway Width [2] | See Lane and Shoulder Width | Wide: 34' to 36'<br>Medium: 30'<br>Narrow: 26'<br>Very Narrow: 20' | NA | NA | Wide: 34' to 36'<br>Medium: 30'<br>Narrow: 26'<br>Very Narrow: 20' | See Lane and Parking Width | See Lane and Parking Width |
| Roadway | Shoulder Width [3] | 2' to 8' | See Roadway Width | NA | NA | See Roadway Width | 2' to 6' or Curbed | 2' to 6' or Curbed |
| Roadway | Parking Lane | NA | 7' Parallel | NA | NA | 7' to 8' Parallel | 7' to 8' Parallel | 7' to 8' Parallel |
| Roadway | Bike Lane [4] | NA | NA | NA | NA | NA | NA | NA |
| Roadway | Median | NA | NA | NA | NA | NA | NA | NA |
| Roadway | Curb Return [5] | 10' to 25' | 10' to 25' | NA | NA | 5' to 25' | 5' to 25' | 5' to 25' |
| Roadway | Travel Lanes | 2 | 2 | NA | NA | 2 | 2 | 2 |
| Roadway | Cross Slopes (Minimum) [6, 7] | 2.0% | 2.0% | NA | NA | 2.0% | 2.0% | 2.0% |
| Roadway | Cross Slopes (Maximum) [8] | 8.0% | 6.0% | NA | NA | 6.0% | 6.0% | 6.0% |
| Roadway | Bridge Widths | Refer to the Minimum Width Criteria for Bridges Section in this Chapter. | Refer to the Minimum Width Criteria for Bridges Section in this Chapter. | NA | NA | Refer to the Minimum Width Criteria for Bridges Section in this Chapter. | Refer to the Minimum Width Criteria for Bridges Section in this Chapter. | Refer to the Minimum Width Criteria for Bridges Section in this Chapter. |
| Roadway | Vertical Grades (Minimum) [9] | 0.5% | 0.5% | NA | NA | 0.5% | 0.5% | 0.5% |
| Roadway | Vertical Clearance (Minimum) | 14'-6", See Chapter 2 | 14'-6", See Chapter 2 | NA | NA | 14'-6", See Chapter 2 | 14'-6", See Chapter 2 | 14'-6", See Chapter 2 |
| Roadside [12] | Clear Sidewalk Width | NA | 4' to 5' | NA | NA | 5' | 5' to 6' | 6' to 8' |
| Roadside [12] | Buffer [11] | NA | 4'+ | NA | NA | 3' to 5' | 3' to 5' | 3' to 5' |
| Roadside [12] | Shy Distance | NA | NA | NA | NA | 0' to 2' | 2' | 2' |
| Roadside [12] | Total Sidewalk Width | NA | 4' to 5' | NA | NA | 8' to 12' | 10' to 13' | 11' to 15' |
| Roadside [12] | Clear Zone Widths [12] | See Chapter 12 | See Chapter 12 | NA | NA | See Chapter 12 | See Chapter 12 | See Chapter 12 |
| Roadside [12] | Right-of-Way Widths [13] | Varies | Varies | NA | NA | Varies | Varies | Varies |
| Speed | Desired Operating Speed (Design Speed) | 20-30 mph | 20-25 mph | NA | NA | 20-25 mph | 20-25 mph | 20-25 mph |
| Speed | Stopping and Passing Sight Distances (Minimum) | 2004 AASHTO Green Book, Exhibits 5-2 & 5-3 | 2004 AASHTO Green Book, Exhibits 5-2 & 5-3 | NA | NA | 2004 AASHTO Green Book, Exhibits 5-2 & 5-3 | 2004 AASHTO Green Book, Exhibits 5-2 & 5-3 | 2004 AASHTO Green Book, Exhibits 5-2 & 5-3 |
| Speed | Vertical Grades (Maximum) | 2004 AASHTO Green Book, Exhibit 5-4 | 8% to 15% [14] | NA | NA | 8% to 15% [14] | 8% to 15% [14] | 8% to 15% [14] |

## TABLE 1.7 (ENGLISH) (CONTINUED)
## MATRIX OF DESIGN VALUES – LOCAL ROAD

| Matrix of Design Values - Notes (Local Road) | |
|---|---|
| | [1] 11' to 12' recommended for industrial districts. A 1' to 2' offset to the curb is desirable. 14' for an outside lane with no shoulder or bike lane, if optimal accommodation for bicyclists is desired. |
| | [2] Index to residential streets:<br>**Wide:** High-density neighborhoods, two-way, parking both sides<br>**Medium:** Can be used in all neighborhoods - two-way, parking both sides<br>**Narrow:** Low-density and medium density - two-way, parking both sides; all neighborhoods - one-way street, parking both sides, or two-way, parking one side<br>**Very Narrow:** All neighborhoods - one-way, parking one side; two-way, no parking |
| | [3] Paving for railroad grade crossings shall extend 2' beyond the extreme rails for the full graded width of the highway. |
| | [4] Design of bike lanes should be considered when identified as part of the Engineering & Environmental (E&E) Scoping process. |
| | [5] Curb Return radius should be as small as possible. Number of lanes, on street parking, bike lanes, and shoulders should be utilized to determine effective radius. |
| | [6] Cross slopes of 3.0% are desirable for design speeds less than 40 mph. |
| | [7] In curbed areas with longitudinal slopes of 1% or less, 3.0% cross slopes may be used on tangents. |
| | [8] The Maximum superelevation rate is 8% for Rural conditions and 6% for Urban conditions. |
| | [9] Recommended minimum grade of 0.75% on curbed sections. |
| | [10] The Roadside design values should be considered and implemented as feasible and reasonable; however, Chapter 6, Pedestrian Facilities, should still be used for minimum design criteria. ADA accommodations must be addressed in accordance with ADA policy. |
| | [11] Buffer is assumed to be planted area (grass, shrubs and/or trees) for suburban neighborhood and corridor contexts; street furniture/car door zone for other land use contexts. |
| | [12] Increase bridge span where necessary to provide for required horizontal stopping sight distance. Provide clearance for guide rail in front of substructures if protection is required. |
| | [13] The procurement of sufficient right-of-way width should be based on the preferable dimensions for all the elements of the composite highway cross section and should be adequate to accommodate the construction and proper maintenance of the highway throughout the project. Future widening should be considered and, where needed for safety, additional right-of-way may be required for adequate sight distance. For additional information on right-of-way widths, refer to the 2004 AASHTO Green Book. |
| | [14] The gradient for local suburban and urban residential streets should be less than 15%. For streets in commerical and industrial areas, gradient design should be less than 8%. |

# TABLE 1.8 (ENGLISH)
# MATRIX OF DESIGN VALUES – LIMITED ACCESS FREEWAY

| | Limited Access Freeway | **Rural Interstate** | **Rural Non-Interstate** | **Urban Interstate** | **Urban Non-Interstate** |
|---|---|---|---|---|---|
| **Roadway** | Lane Widths [1] | 4 or More 12'-0" Lanes | 4 or More 12'-0" Lanes [2] | 4 or More 12'-0" Lanes | 4 or More 12'-0" Lanes [2] |
| | Shoulder Widths [3, 4, 5] | 10'-0" Right<br>8'-0" Left, 4'-0"<br>Left with median barrier | 10'-0" Right<br>8'-0" Left, 4'-0"<br>Left with median barrier | 10'-0" Right<br>8'-0" Left, 4'-0"<br>Left with median barrier | 10'-0" Right<br>8'-0" Left, 4'-0"<br>Left with median barrier |
| | Median Widths | 10'-0" to 50'-0" [6, 7]<br>(Mountainous)<br>36'-0" to 100'-0" [8]<br>(Level or Rolling) | 10'-0" to 100'-0" [6, 7, 8] | 10'-0" [6] | 10'-0" [6] |
| | Cross Slopes (Minimum) | 2.0% | 2.0% | 2.0% | 2.0% |
| | Cross Slopes (Maximum) | 8.0% | 8.0% | 6.0% | 6.0% |
| | Bridge Widths [9, 10] | Lane Widths<br>Plus Shoulders | Lane Widths<br>Plus Shoulders | Lane Widths<br>Plus Shoulders | Lane Widths<br>Plus Shoulders |
| | Vertical Grades (Minimum) | 0.5% | 0.5% | 0.5% | 0.5% |
| | Vertical Clearance (Minimum) | 16'-6",<br>See Chapter 2 | 16'-6",<br>See Chapter 2 | 16'-6",<br>See Chapter 2 | 16'-6",<br>See Chapter 2 |
| **Roadside** | Clear Zone [11] | See Chapter 12 | See Chapter 12 | See Chapter 12 | See Chapter 12 |
| | Right-of-Way Widths [12] | Varies | Varies | Varies | Varies |
| **Speed** | Design Speed [13] | 70 mph | 70 mph | 50-70 mph | 50-70 mph |
| | Stopping Sight Distances (Minimum) | 2004 AASHTO Green Book, Exhibit 3-72 | 2004 AASHTO Green Book, Exhibit 3-72 | 2004 AASHTO Green Book, Exhibit 3-72 | 2004 AASHTO Green Book, Exhibit 3-72 |
| | Vertical Grades (Maximum) [14, 15] | 2004 AASHTO Green Book, Exhibit 8-1 | 2004 AASHTO Green Book, Exhibit 8-1 | 2004 AASHTO Green Book, Exhibit 8-1 | 2004 AASHTO Green Book, Exhibit 8-1 |

## TABLE 1.8 (ENGLISH) (CONTINUED)
## MATRIX OF DESIGN VALUES – LIMITED ACCESS FREEWAY

| Matrix of Design Values - Notes (Limited Access Freeway) |
|---|
| [1] Number of lanes determined by lane capacity design for selected Level of Service. |
| [2] Paving for railroad grade crossings shall extend 2' beyond the extreme rails for the full graded width of the highway. |
| [3] Where truck traffic exceeds 250 DDHV, a paved width of 12' for the right shoulder should be provided. |
| [4] On sections with six or more through lanes, a paved minimum width of 10' for the left shoulder should be provided. Where truck traffic exceeds 250 DDHV, a paved width of 12' for the left shoulder should be considered. |
| [5] In mountainous terrain, a reduced paved shoulder width together with a minimal median width may be used to reduce the high costs associated with providing a full width roadway cross section. In these instances, a 8' minimum paved right shoulder and a 4' minimum paved left shoulder may be used on a traveled way consisting of four or six lanes. Where seven or more lanes are provided, a 8' minimum paved shoulder width should be used on both sides. |
| [6] Use a minimum width of 10' for a two-lane directional facility which provides for two 4' shoulders and a 2' median barrier. For three or more lane directional facilities, the minimum width is 22' and preferably 26' where DDHV is greater than 250 Trucks. |
| [7] All median widths 20' or less should be paved. When Type 1 shoulders are specified for the 4' median shoulders, Type 3 shoulders may be used for the remainder if the remaining width is 8' or greater. |
| [8] The 100' dimension shown in the 2004 AASHTO Green Book, Exhibit 8-3B permits the designer to use independent profiles in rolling terrain to blend the freeway more appropriately with the environment while maintaining flat slopes for vehicle recovery. |
| [9] Selection of single or dual structures shall be made based on an economic analysis. Such items as structure length and width, horizontal and vertical curvature and ramp geometry shall be considered. |
| [10] For long bridges over 60 m (200 ft) in length, offsets (shoulders) to the parapet, rail, or barrier shall be at least 1.2 m (4 ft) from the travel lane on both the left and the right. |
| [11] Center piers are not desirable. Increase bridge span where necessary to provide for required horizontal stopping sight distance. Provide clearance for guide rail in front of substructures if protection is required. |
| [12] No minimum right-of-way width is suggested. The procurement of sufficient right-of-way width should be based on the preferable dimensions for all the elements of the composite highway cross section and should be adequate to accommodate the construction and proper maintenance of the highway throughout the project. Future widening should be considered and, where needed for safety, additional right-of-way may be required for adequate sight distance. For additional information on right-of-way widths, refer to the 2004 AASHTO Green Book. |
| [13] Where terrain is mountainous, a design speed from 50 to 60 mph may be used. In urban areas, the design speed shall be at least 50 mph. |
| [14] For short grades less than 500' and for one-way downgrades, maximum grades may be up to 1% steeper. |
| [15] Grades up to 1% steeper than the value shown in Exhibit 8-1 may be provided in urban areas with crucial right-of-way constraints or where needed in mountainous terrain. |

**C. Minimum Width Criteria for Bridges.** The minimum width of bridges shall be determined as described in this Section. The bridge width is the curb-to-curb, barrier-to-barrier or rail-to-rail width, whichever is less. The widths provided in this Section are based on two-lane roadways. The widths must be increased for each additional lane based on the applicable lane widths. For bridge design specifications including applicable design loads, refer to Publication 15M, Design Manual, Part 4, *Structures* and AASHTO LRFD Bridge Design Specifications.

**1.** Limited Access Freeway Facilities.

**a.** New, Reconstructed and Rehabilitated Bridges. This includes new location, replacement, superstructure replacement, partial superstructure replacement, deck replacement and partial deck replacement. The applicable minimum bridge widths are provided in Table 1.8.

**b.** Bridge Preservation and Safety Items. Bridge preservation is defined in Publication 15M, Design Manual, Part 4, *Structures*, Part A, Chapter 5, Article 5.6. Safety items may include repair and replacement of parapet and barrier as well as approach guide rail and connections. The bridge width is not to be reduced below existing width or new criteria provided in Table 1.8, whichever is less.

**2.** Arterial Facilities.

**a.** New and Reconstructed Bridges. This includes new location, replacement and superstructure replacement. The applicable minimum bridge widths are provided in Tables 1.3 and 1.4.

**b.** Deck Replacement and Partial Superstructure Replacement. The applicable minimum bridge widths are provided in Table 1.9.

**c.** Bridge Preservation and Safety Items. Bridge preservation is defined in Publication 15M, Design Manual, Part 4, *Structures*, Part A, Chapter 5, Article 5.6. Safety items may include repair and replacement of parapet and barrier as well as approach guiderail and connections. The bridge width is not to be reduced below existing width, criteria provided in Tables 1.3, 1.4, 1.9 or 1.12 (if non-NHS), whichever is less.

**3.** Collector and Local Road Facilities.

**a.** New and Reconstructed Bridges. This includes new location, replacement and superstructure replacement. The applicable minimum bridge widths are provided in Table 1.11.

**b.** Deck Replacement and Partial Superstructure Replacement. The applicable minimum bridge widths are provided in Table 1.10.

**c.** Bridge Preservation and Safety Items. Bridge preservation is defined in Publication 15M, Design Manual, Part 4, *Structures*, Part A, Chapter 5, Article 5.6 Safety items may include repair and replacement of parapet and barrier as well as approach guiderail and connections. The bridge width is not to be reduced below existing width, criteria provided in Tables 1.10, 1.11, or 1.12 Width (if non-NHS), whichever is less.

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## TABLE 1.9
## ARTERIAL FACILITIES
## DECK REPLACEMENT AND PARTIAL SUPERSTRUCTURE REPLACEMENT (a)

| CURRENT ADT | MINIMUM BRIDGE WIDTH (METRIC) (m) | MINIMUM BRIDGE WIDTH (ENGLISH) (ft) |
|---|---|---|
| 400 and Under | 9.0 | 30 |
| 401 to 1500 | 9.6 | 32 |
| Over 1501 | 10.2 | 34 |

See Bridge Width Notes.

## TABLE 1.10
## COLLECTOR AND LOCAL ROAD FACILITIES
## DECK REPLACEMENT AND PARTIAL SUPERSTRUCTURE REPLACEMENT (a)

| CURRENT ADT | MINIMUM BRIDGE WIDTH (METRIC) (m) | MINIMUM BRIDGE WIDTH (ENGLISH) (ft) |
|---|---|---|
| 400 and Under | 7.2 (c) (e) | 24 (c) (e) |
| 401 to 1500 | 8.4 | 28 |
| 1501 to 2000 | 9.0 (f) | 30 (f) |
| Over 2000 | 10.2 (f) | 34 (f) |

See Bridge Width Notes.

## TABLE 1.11
## COLLECTOR AND LOCAL ROAD FACILITIES
## NEW AND RECONSTRUCTED BRIDGES (b)

| DESIGN YEAR ADT | MINIMUM BRIDGE WIDTH (METRIC) (m) | MINIMUM BRIDGE WIDTH (ENGLISH) (ft) |
|---|---|---|
| 400 and Under | 7.2 (d) (e) | 24 (d) (e) |
| 401 to 1500 | 8.4 | 28 |
| 1501 to 2000 | 9.6 | 32 |
| Over 2000 | 12.0 | 40 |

See Bridge Width Notes.

## BRIDGE WIDTH NOTES

**The following notes are applicable to Tables 1.9, 1.10 and 1.11:**

- The lane widths plus the shoulder widths indicated in Table 1.3 through Table 1.7 may be considered for bridge widths if they are less than the bridge width shown in Tables 1.9, 1.10 and 1.11.

- The bridge width is not to be less than the approach roadway width including shoulders with the exception of one-lane bridges and bridges over 60 m (200 ft) in length. On curbed approaches, the minimum bridge width may equal the approach curb-to-curb width. Where parking lanes are provided on the approaches, consideration should be given to extending the parking lanes across the bridge.

- Where pedestrian traffic is anticipated, provisions for a sidewalk should be considered and shall meet the Department's Standards and requirements (See Chapter 6 and Publication 15M, Design Manual, Part 4, *Structures*, Part B, Section 2, Article 2.3).

- When special conditions warrant, such as two-way traffic operations for future rehabilitation (repair or overlay), consideration should be given to increased widths which may require additional girders.

- For bridges over 60 m (200 ft) in length, offsets to the parapet, rail, barrier or curb shall be at least 1.2 m (4 ft) from the travel lane on both the left and the right except where there are narrower curbed approaches or where a narrower width is permitted by the below notes.

**The following notes are applicable as designated in Tables 1.9, 1.10 and 1.11:**

(a) If the bridge is not on the National Highway System (NHS), the minimum bridge width may be equal to the bridge width provided in Table 1.12, Reduced Bridge Width.

(b) If the conditions listed on the form in Chapter 1, Appendix A, Reduced Bridge Width Criteria Documentation are met, the minimum bridge width may be equal to the bridge width provided in Table 1.12, Reduced Bridge Widths.

(c) On facilities functionally classified as a local road not on the NHS with no evidence of a site specific safety problem related to the width of the bridge, the existing bridge width can remain.

(d) On facilities functionally classified as a local road not on the NHS with a current average daily traffic (ADT) of 250 and less and a design speed less than 60 km/h (40 mph), the minimum bridge width may be 0.6 m (2 ft) less than the value indicated.

(e) One-lane bridges:
- May be provided on single-lane roads and on two-lane roads with ADT less than 100 vehicles per day where the designer finds that a one-lane bridge can operate effectively.
- May be provided when there is an existing bridge in place that meets all of the following conditions:
  - The facility is functionally classified as a local road off the National Highway System
  - Has an ADT less than or equal to 400
  - There is no evidence of a site-specific safety problem
  - There are no existing or anticipated significant land use conflicts exist
- The minimum width of a one-lane bridge is 4.5 m (15 ft) and the maximum width is 4.9 m (16 ft).
- Alignment and sight distance should be carefully studied so that they are not compromised. Appropriate safety mitigation measures should be provided (See Table 1.1, Low Cost Safety Improvement Measures).

(f) For design speeds less than 80 km/h (50 mph), the minimum bridge widths may be 0.6 m (2 ft) less than the values indicated.

## TABLE 1.12
## REDUCED BRIDGE WIDTHS

| DESIGN YEAR ADT | DESIGN SPEED (km/h) | MINIMUM BRIDGE WIDTH(1) (m) | DESIGN SPEED (mph) | MINIMUM BRIDGE WIDTH(1) (ft) |
|---|---|---|---|---|
| ≤ 400 | < 80 | 6.6 | < 50 | 22 |
| | ≥ 80 | 7.2 | ≥ 50 | 24 |
| 401 to 1,000 | < 80 | 7.2 | < 50 | 24 |
| | ≥ 80 | 7.8 | ≥ 50 | 26 |
| 1,001 to 2,000 | < 80 | 7.8 | < 50 | 26 |
| | ≥ 80 | 8.4 | ≥ 50 | 28 |
| 2,001 to 4,000 | < 80 | 8.4 | < 50 | 28 |
| | ≥ 80 | 9.0 | ≥ 50 | 30 |
| 4,001 to 10,000 | < 80 | 9.0 | < 50 | 30 |
| | ≥ 80 | 9.6 | ≥ 50 | 32 |
| 10,001 to 20,000 | < 80 | 9.6 | < 50 | 32 |
| | ≥ 80 | 10.2 | ≥ 50 | 34 |
| ≥ 20,000 | ALL | 10.2 | ALL | 34 |

(1) If the number of heavy vehicles exceeds 10% of the high end of the ADT range, then increase the minimum bridge width by 0.6 m (2 ft).

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**D. Shoulder Criteria for New Construction and Reconstruction Projects.**

**1**. General. Any new construction or reconstruction project having a rigid pavement structure shall have Portland Cement Concrete shoulders provided. On any new construction or reconstruction project having a flexible pavement, the pavement shall be constructed 0.6 m (2 ft) wider into the shoulder area. The remainder of the shoulder shall be constructed with the type of shoulder designated below. The shoulder area is defined as the appropriate shoulder width indicated on the design criteria charts. The 0.6 m (2 ft) widening does not apply to the inside shoulders on Interstate and Other Limited Access Freeways. See Publication 72M, *Roadway Construction Standards,* RC-25M. Types 1-F, 1-S, 1-SP, 6-F, 6-S and 6-SP Shoulders have been developed primarily to provide smooth surfaces for bicyclists and pedestrians where it is anticipated such activities would take place. At the discretion of the District Executive, these types of shoulders may be provided elsewhere.

**2.** Provide Concrete Shoulders adjacent to rigid pavements. Concrete Shoulders, Type 1 shall be provided on Interstate and Other Limited Access Freeways. Concrete Shoulders, Type 2 shall be provided on Arterials, Collectors and Local Roads.

**3**. Provide Type 1, 1-F, 1-S or 1-SP Shoulders adjacent to flexible pavements in the following cases:

**a.** On all Interstate and Other Limited Access Freeways and Arterials.
**b.** On other type roadways where serious drainage problems are anticipated.
**c.** On two-lane roadways where truck traffic exceeds a Design Hourly Volume (DHV) of 150.
**d.** On two-lane roadways where it is anticipated that traffic shall utilize the shoulder:

(**1**) At intersections with ramps having tight radii and roadways with curves having radii less than 140 m (curves sharper than 12°-30').

(**2**) At intersection approaches adjacent to the through movement where it is anticipated that left turn vehicles shall be causing vehicles wishing to proceed straight through to use the right side shoulder. In such cases, either the roadway pavement structure may be extended through the shoulder area or Type 1, 1-F or 1-S Shoulder may be used, starting 75 m (250 ft) before the intersection and stopping 45 m (150 ft) downstream from the intersection.

(**3**) For approaches to an intersection, where it is anticipated that right turning vehicles shall utilize the shoulder area as a turning lane, the shoulder area shall be paved with a Type 1, 1-F, 1-S or 1-SP Shoulder or the roadway pavement structure may be extended through the shoulder area. The length of higher type paving approaching the intersection shall be in accordance with the following chart:

| RIGHT TURNING VEHICLES/h | <100 | 100 TO 200 | >200 |
|---|---|---|---|
| MIN LENGTH | 30 m (100 ft) | 55 m (175 ft) | 75 m (250 ft) |

(**4**) At other locations at the discretion of the Engineer.

**4.** Provide Type 3 Shoulders adjacent to flexible pavements on Collectors and Local Roads of the same surface material as the pavement structure or provide Type 1, 1-F, 1-S or 1-SP Shoulders.

**5**. For proper application of bicycle tolerable shoulder rumble strips and edge line rumble strips, see Publication 638, *District Highway Safety Guidance Manual***.** Refer to Publication 72M, *Roadway Construction Standards,* RC-25M for standard rumble strips.

**E. Design Criteria for Resurfacing, Reconstruction and Rehabilitation (3R) Projects.**

**1.** Refer to Section 1.2.A to determine if 3R criteria is applicable to a project. Design criteria for 3R projects are provided in Table 1.13, Table 1.14 and associated notes. Shoulder criteria notes are found in Section 1.2.E.2.

**TABLE 1.13**
**RESURFACING, RESTORATION AND REHABILITATION (3R) DESIGN CRITERIA***

| | RURAL AREA SYSTEM | URBAN AREA SYSTEM |
|---|---|---|
| DESIGN SPEED (km/h or mph) | SEE NOTE ① | SEE NOTE ② |
| PAVEMENT WIDTHS ③ ④ | SEE TABLE 1.14 | 3.6 m (12 ft) LANES (DESIRABLE) ⑤<br>3.0 m (10 ft) LANES (MINIMUM) ⑥ |
| SHOULDER WIDTHS ③ ⑦ | SEE TABLE 1.14 | EXISTING ⑧ |
| MEDIAN WIDTHS | EXISTING | EXISTING |
| CROSS SLOPES ⑨ | TANGENT: 2.0% (DESIRABLE)<br>1.0% (MINIMUM) WHERE<br>GRADES ARE ≥ 1%<br>SUPERELEVATION: SEE NOTE ⑩ | EXISTING ⑪ |
| VERTICAL CURVATURE AND GRADES | EXISTING ⑫ | EXISTING ⑫ |
| HORIZONTAL CURVATURE | EXISTING ⑫ | EXISTING ⑫ |
| SIGHT DISTANCES | EXISTING ⑫ | EXISTING ⑫ |
| GUIDE RAIL AND MEDIAN BARRIER | SEE NOTE ⑬ | SEE NOTE ⑬ |
| CLEAR ZONE WIDTHS | SEE CHAPTER 12 | SEE CHAPTER 12 |
| BRIDGE WIDTHS | SEE SECTION 1.2.C | SEE SECTION 1.2.C |
| PARKING LANES | NONE | SEE CHAPTER 1, TABLE 1.3 THROUGH TABLE 1.7 |
| VERTICAL CLEARANCE | SEE CHAPTER 2, SECTION 2.20 | SEE CHAPTER 2, SECTION 2.20 |

◯ SEE 3R DESIGN CRITERIA NOTES ON PAGES 1 - 34 AND 1 - 35.

***3R criteria is not applicable for freeways. For freeways, use New Construction and Reconstruction criteria or Pavement Preservation criteria, as applicable.

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# TABLE 1.14
# MINIMUM WIDTH CRITERIA
# FOR RESURFACING, RESTORATION AND REHABILITATION (3R) RURAL PROJECTS [(a)]

METRIC

| OPEN TO TRAFFIC ADT | NUMBER OF HEAVY VEHICLES [(b)] | DESIGN SPEED (km/h) | MINIMUM WIDTHS [(c)] |
|---|---|---|---|
| ≤ 400 | 40 OR LESS | < 80 | 5.4 m PAVEMENT PLUS 0.6 m SHOULDERS EACH SIDE |
| | | ≥ 80 | 6.0 m PAVEMENT PLUS 0.6 m SHOULDERS EACH SIDE |
| 401 TO 1000 | 100 OR LESS | < 80 | 6.0 m PAVEMENT PLUS 0.6 m SHOULDERS EACH SIDE |
| | | ≥ 80 | 6.6 m PAVEMENT PLUS 0.6 m SHOULDERS EACH SIDE |
| 1001 TO 2000 | 200 OR LESS | < 80 | 6.6 m PAVEMENT PLUS 0.6 m SHOULDERS EACH SIDE |
| | | ≥ 80 | 6.6 m PAVEMENT PLUS 0.9 m SHOULDERS EACH SIDE |
| 2001 TO 4000 | 400 OR LESS | < 80 | 6.6 m PAVEMENT PLUS 0.9 m SHOULDERS EACH SIDE |
| | | ≥ 80 | 6.6 m PAVEMENT PLUS 1.2 m SHOULDERS EACH SIDE |
| 4001 TO 10 000 | 1000 OR LESS | < 80 | 6.6 m PAVEMENT PLUS 1.2 m SHOULDERS EACH SIDE |
| | | ≥ 80 | 6.6 m PAVEMENT PLUS 1.5 m SHOULDERS EACH SIDE |
| 10 001 TO 20 000 | 2000 OR LESS | < 80 | 6.6 m PAVEMENT PLUS 1.5 m SHOULDERS EACH SIDE |
| | | ≥ 80 | 7.2 m PAVEMENT PLUS [(d)] 1.5 m SHOULDERS EACH SIDE |
| > 20 000 | 2000 OR LESS [(e)] | ALL | 7.2 m PAVEMENT PLUS [(d)] 1.5 m SHOULDERS EACH SIDE |

ENGLISH

| OPEN TO TRAFFIC ADT | NUMBER OF HEAVY VEHICLES [(b)] | DESIGN SPEED (mph) | MINIMUM WIDTHS [(c)] |
|---|---|---|---|
| ≤ 400 | 40 OR LESS | < 50 | 18′-0" PAVEMENT PLUS 2′-0" SHOULDERS EACH SIDE |
| | | ≥ 50 | 20′-0" PAVEMENT PLUS 2′-0" SHOULDERS EACH SIDE |
| 401 TO 1000 | 100 OR LESS | < 50 | 20′-0" PAVEMENT PLUS 2′-0" SHOULDERS EACH SIDE |
| | | ≥ 50 | 22′-0" PAVEMENT PLUS 2′-0" SHOULDERS EACH SIDE |
| 1001 TO 2000 | 200 OR LESS | < 50 | 22′-0" PAVEMENT PLUS 2′-0" SHOULDERS EACH SIDE |
| | | ≥ 50 | 22′-0" PAVEMENT PLUS 3′-0" SHOULDERS EACH SIDE |
| 2001 TO 4000 | 400 OR LESS | < 50 | 22′-0" PAVEMENT PLUS 3′-0" SHOULDERS EACH SIDE |
| | | ≥ 50 | 22′-0" PAVEMENT PLUS 4′-0" SHOULDERS EACH SIDE |
| 4001 TO 10000 | 1000 OR LESS | < 50 | 22′-0" PAVEMENT PLUS 4′-0" SHOULDERS EACH SIDE |
| | | ≥ 50 | 22′-0" PAVEMENT PLUS 5′-0" SHOULDERS EACH SIDE |
| 10001 TO 20000 | 2000 OR LESS | < 50 | 22′-0" PAVEMENT PLUS 5′-0" SHOULDERS EACH SIDE |
| | | ≥ 50 | 24′-0" PAVEMENT PLUS [(d)] 5′-0" SHOULDERS EACH SIDE |
| > 20000 | 2000 OR LESS [(e)] | ALL | 24′-0" PAVEMENT PLUS [(d)] 5′-0" SHOULDERS EACH SIDE |

SEE NOTES ON PAGE 1-33.

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# RESURFACING, RESTORATION AND REHABILITATION (3R) DESIGN CRITERIA NOTES

## NOTES

(a) FOR CURRENT TRAFFIC ADT, WHERE THE NUMBER OF HEAVY VEHICLES FALLS WITHIN THE RANGE INDICATED, USE THE CORRESPONDING MINIMUM WIDTHS. WHERE THE NUMBER OF HEAVY VEHICLES EXCEEDS THE RANGE INDICATED FOR THE CORRESPONDING ADT, USE THE MINIMUM WIDTH VALUES FOR THE APPROPRIATE RANGE OF HEAVY VEHICLES (SEE EXAMPLES PRESENTED ON THIS PAGE).

(b) NUMBER OF HEAVY VEHICLES = CURRENT TRAFFIC ADT × % OF TRUCKS, BUSES AND RECREATIONAL VEHICLES.

(c) CURVE WIDENING SHALL BE APPLIED TO PAVEMENT WIDTHS AS PRESENTED IN CHAPTER 2. CONSIDERATION SHOULD BE GIVEN TO MAINTAINING CURVE WIDENED PAVEMENTS OVER THE ENTIRE PROJECT LIMITS WHEN A SIGNIFICANT PROPORTION OF THE PROJECT REQUIRES CURVE WIDENING DUE TO MULTIPLE CURVES.

(d) UNDER RESTRICTIVE OR SPECIAL CONDITIONS, SUCH AS RIGHT-OF-WAY OR LATERAL CLEARANCE LIMITATIONS, REDUCTION OF PAVEMENT WIDTH FROM 7.2 m TO 6.6 m (24'-0" TO 22'-0") IS ACCEPTABLE.

(e) OVER 10% HEAVY VEHICLES, INCREASE SHOULDER WIDTH TO 1.8 m (6'-0") EACH SIDE.

## EXAMPLE 1

GIVEN: 4000 ADT
9% HEAVY VEHICLES
DESIGN SPEED = 80 km/h (50 mph)

FIND: MINIMUM WIDTH REQUIRED.

SOLUTION: 4000 ADT × 9% HEAVY VEHICLES = 360 HEAVY VEHICLES. SINCE THE 4000 ADT FALLS BETWEEN 2001 TO 4000 AND THE NUMBER OF HEAVY VEHICLES IS 400 OR LESS, THE MINIMUM WIDTH PROVIDED SHOULD BE A 6.6 m (22'-0") PAVEMENT PLUS 1.2 m (4'-0") SHOULDERS EACH SIDE.

## EXAMPLE 2

GIVEN: 5850 ADT
18% HEAVY VEHICLES
DESIGN SPEED < 80 km/h (50 mph)

FIND: MINIMUM WIDTH REQUIRED.

SOLUTION: 5850 ADT × 18% HEAVY VEHICLES = 1053 HEAVY VEHICLES. ALTHOUGH THE 5850 ADT FALLS BETWEEN 4001 TO 10 000, THE NUMBER OF HEAVY VEHICLES (1053) EXCEEDS THE 1000 OR LESS CRITERIA. THEREFORE, THE APPROPRIATE RANGE OF HEAVY VEHICLES WOULD BE 2000 OR LESS AND THE MINIMUM WIDTH PROVIDED SHOULD BE 6.6 m (22'-0") PAVEMENT PLUS 1.5 m (5'-0") SHOULDERS EACH SIDE.

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## RESURFACING, RESTORATION AND REHABILITATION (3R) DESIGN CRITERIA NOTES

① When the project scope does not include an overlay or a roadway geometry improvement (e.g., drainage, guide rail, shoulder structural upgrading, etc.), a design speed is not applicable to the project. If an overlay or a roadway geometry improvement (e.g., pavement or shoulder widening, increase in superelevation, etc.) is included in the project scope, a design speed shall be used. The minimum design speed selected shall be equal to the average running speed plus any anticipated increase in the average running speed due to the overlay or roadway geometry improvement, rounded upward to the nearest 10 km/h (5 mph) increment (the average running speed, which represents the length of the highway segment divided by the average running time, i.e., the time the vehicle is in motion along the segment, shall be determined as set forth in Publication 212, *Official Traffic Control Devices*. The maximum design speed selected shall be based on the applicable functional classification systems indicated in Chapter 1, Table 1.3 through Table 1.8. The design speed selected may be a range of speeds based upon the governing speed in each subsection of the project.

② Major urban arterial streets and highways with some access control and fairly long distances between intersections should have a design speed determined according to Note ①. However, those major arterials that have obvious "street-like" characteristics, operationally and physically, and most urban, local and collector streets do not require a design speed determination.

③ Where the existing widths are greater than those indicated in the criteria, maintain the existing widths.

④ Railroad grade crossing paving shall extend 0.6 m (2 ft) beyond the extreme rails for the full graded width of the highway.

⑤ Lanes 2.7 m (9 ft) wide may be used on one-way streets or for divided roadways if at least a 0.3 m (1 ft) curb offset is used or if trucks and buses are prohibited.

⑥ Curb Offset:
60 km/h (40 mph) and Less - None
Greater Than 60 km/h (40 mph) - 0.3 m (1 ft) desirable

⑦ In cut sections, on widening or reconstruction projects, where the width available from the edge of pavement to the toe of the cut slope is 2.4 m (8 ft) or less, the shoulder paving should be extended to the toe of the cut slope. Where this width is variable, the shoulder paving may also be variable. If erosion is a problem in this area, consideration should be given to extending the paving 250 mm to 300 mm (10 in to 12 in) up the slope.

⑧ Use Rural 3R Design Criteria if uncurbed section is used in urban areas.

⑨ In order to increase the amount of drainage capacity or to include reconstruction of the shoulder, the shoulder cross slopes may be increased as indicated in Note ⑬.

⑩ When the actual rate of superelevation is within 3.0% of the design superelevation rate, it is not necessary to increase the superelevation rate. When the actual rate of superelevation differs by more than 3.0% from the design superelevation rate, the highest achievable rate should be provided. When the curve superelevation provided does not equal the design superelevation rate, warning signs with advisory speed plates shall be provided. A reduction of the required superelevation rate is acceptable when short tangents between reverse curves do not afford sufficient runout length after consideration to partial runout within the curves. Rates of superelevation and the design speed shall be considered jointly. See Note ⑫ for additional information relative to design speed.

⑪ Since superelevation is not always possible, more attention should be paid to other items such as friction overlays and signing and pavement marking. For additional information, see Notes ⑩ and ⑫.

## RESURFACING, RESTORATION AND REHABILITATION (3R) DESIGN CRITERIA NOTES

⑫ GENERAL: Existing horizontal curvature, vertical curvature and grades and sight distance shall be evaluated against minimum criteria for the design speed. For sites with accident experience, an economic analysis shall be made to determine feasibility for reconstruction. If reconstruction is not feasible, or reconstruction is less than new construction standards, a design exception request shall be prepared. In addition, appropriate safety and other mitigation measures shall be applied to enhance and upgrade these geometric features for extended service life and safer operations. See Chapter 1, Table 1.1 for a list of low cost safety improvement measures as alternates to reconstruction.

HORIZONTAL CURVATURE: When the design speed of a horizontal curve is 25 km/h (15 mph) or less below the design speed of the proposed project and no accident problem is prevalent, warning signs with advisory speed plates shall be provided. Also, the list of low cost safety improvement measures in Chapter 1, Table 1.1 shall be considered. When the difference is greater than 25 km/h (15 mph) and the current average daily traffic (ADT) is 750 or greater, or an accident problem exists, or the design speed of the horizontal curve is less than 30 km/h (20 mph), achievement of the design speed curvature criteria shall be considered through an economic analysis to determine feasibility for reconstruction. If reconstruction to current standards is not feasible, a design exception request shall be prepared. The design speed and rates of superelevation shall be considered jointly. See Note ⑩ for additional information relative to superelevation rates.

VERTICAL CURVATURE AND GRADES: When the design speed of a vertical curve is 30 km/h (20 mph) or less below the design speed of the proposed project, and no accident problem is prevalent, consider the list of low cost safety improvement measures in Chapter 1, Table 1.1. When the difference is greater than 30 km/h (20 mph) and the current average daily traffic (ADT) is 1500 or greater, or an accident problem exists, or the design speed of the vertical curve is less than 30 km/h (20 mph), consider achievement of the design speed curvature criteria and grades through an economic analysis to determine feasibility for reconstruction. Prepare a request for a design exception if reconstruction to current standards is not feasible.

SIGHT DISTANCE: When evaluating sight distance parameters, consider the preceding criteria on horizontal and vertical curvature together.

⑬ Remove existing guide rail and median barrier where not required especially if it does not comply with NCHRP Report 350. Consider slope flattening to eliminate need. Provide upgraded guide rail at bridge approaches and at identifiable accident locations. Replace existing metal guide rail and metal median barrier where the height of the existing barrier after resurfacing is reduced by more than 75 mm (3 in) from the standard height and cannot be raised. Raising the guide rail with modified offset brackets is not permitted. In order to avoid the requirement to replace or adjust guide rail or median barrier, the shoulder slope may be increased to a maximum algebraic difference in pavement and shoulder slopes of 8.0% for shoulders greater than 1.8 m (6 ft) wide, 10.0% for shoulders 1.2 m to 1.8 m (4 ft to 6 ft) wide, 12.0% for shoulders 0.9 m to 1.2 m (3 ft to 4 ft) wide or 14.0% for shoulders 0.6 m to 0.9 m (2 ft to 3 ft) wide.

**2.** Shoulder Criteria for Resurfacing, Reconstruction and Rehabilitation (3R) Projects.

**a.** Without Pavement Widening.

**(1)** On projects involving the rehabilitation of rigid pavement, concrete shoulders may be provided, if desired, to strengthen the existing pavement or provide a relatively maintenance-free shoulder. Special drawings would be required in such cases. At no time shall the joint spacing of the concrete shoulders exceed 6.0 m (20 ft).

**(2)** Provide Type 6, 6-F, 6-S or 6-SP Shoulders on Interstate and Other Limited Access Freeways and Arterials where excavation or scarifying of the existing shoulder is necessary. If the existing shoulder is currently high-type paved (stabilized excluded), and only the first couple of meters (first few feet) adjacent to the pavement is distressed, a 0.9 m (3 ft) minimum width of Type 6, 6-F, 6-S or 6-SP Shoulder may be provided. The remaining existing shoulder should be resurfaced with the same surfacing used on the new shoulder.

**(3)** Provide Type 7 Shoulders on Interstate and Other Limited Access Freeways and Arterials where only cleaning and patching of the existing paved shoulder is necessary.

**(4)** Provide shoulders adjacent to flexible pavements on Collectors and Local Roads of the same surface material as the pavement structure, or provide Type 1, 1-F, 1-S or 1-SP Shoulders.

**b.** With Pavement Widening.

**(1)** On projects where the pavement is being widened and the current traffic ADT is greater than 5000 and/or the number of heavy vehicles (Current Traffic ADT × % of trucks, buses and recreational vehicles) is greater than 500, the widening structure shall be extended into the shoulder area 0.6 m (2 ft), similar to that required for new construction. When the current traffic ADT is 5000 or less and/or the number of heavy vehicles is 500 or less, the widening structure shall be extended 0.3 m (1 ft) into the shoulder area. The entire shoulder may be paved with the same material and design as the pavement widening at the discretion of the District Executive. In areas of heavy turning movement, such as driveway entrances or exits, intersections, etc., paving out-to-out is strongly recommended. Otherwise, the type of shoulder discussed in Sections 1.2.E.2.a(1), 1.2.E.2.a(2) and 1.2.E.2.a(3) above should be specified.

**(2)** The widening portion of the pavement should be constructed at the same slope as the pavement. The shoulder slope should begin at the edge of the widened pavement. When the pavement structure is being extended for the full width of the shoulder, the shoulder slope should begin at the design width of pavement. Typical sections should indicate the shoulder area in these cases even though the materials used may be paid for separately.

**(3)** The 0.3 m (1 ft) or 0.6 m (2 ft) widening in Section 1.2.E.2.b(1) above may be eliminated on Arterials with less than 5000 ADT and on Collectors and Local Roads if the optional shoulder described in Section 1.2.E.2.a(4) above is used or if a Type 6, 6-F, 6-S, 6-SP or 7 Shoulder or a recycled shoulder is provided for the entire width of shoulder.

**c.** Recycled Shoulders on 3R Projects.

**(1)** The use of reclaimed bituminous concrete material, which is generally obtained from milling operations, for shoulder base courses, is acceptable on 3R projects. Refer to Publication 242, *Pavement Policy Manual*, Chapter 2, Project Considerations for guidelines for recycling bituminous pavements.

**(2)** Reclaimed material may be used in a hot-mixed recycled base course for Type 6, 6-F, or 6-S Shoulders or hot-mixed surface course for Type 7 shoulders on any roadway.

**(3)** Reclaimed material may be used in a cold-mixed recycled base course in the shoulders of Arterials, Collectors and Local Roads. A minimum depth of 130 mm (5 in) shall be used on Arterials and 100 mm (4 in) on Collectors and Local Roads.

## 1.3 PAVEMENT PRESERVATION CRITERIA

Refer to Publication 242, *Pavement Policy Manual* for determining when Pavement Preservation criteria is applicable to a project. Typically pavement projects which do not add structural capacity to the pavement are pavement preservation type projects.

Safety guidance in Publication 242, *Pavement Policy Manual* shall be met, including evaluating the crash history to identify safety concerns, and all identified safety concerns are to be addressed as applicable. For example, widening of the traveled way on horizontal curves may be necessary to address a safety concern.

The following is the geometric criteria for pavement preservation projects. The proposed geometric design elements shall be compared to the required criteria presented below, and a design exception is required if any of the 13 controlling criteria is not met (defined in Publication 10X, Design Manual Part 1X, *Appendices to Design Manuals 1, 1A, 1B, and 1C*, Appendix P, *Design Exceptions*). If non-controlling criteria is not met, some form of documentation must be provided. Documentation may include meeting minutes or Design Field View Reports, etc.

**A. Non-Freeway Criteria.**

**1.** Cross Slopes of Lanes in Tangent Sections.

**a.** Rural Classification. Desirable = 2.0%. Minimum = 1.0%. For existing cross slopes between 1.0% and 2.0%, do not reduce below existing.

**b.** Urban Classification.

**(1)** Curbed Roadways. Desirable = 2.0% to 3.0%. Minimum = match existing. Address drainage issues.

**(2)** Non-Curbed Roadways. Same as rural criteria.

**2.** Vertical Clearance Criteria. Refer to Chapter 2, Section 2.20.

**3.** All Other Controlling Criteria.

- Existing geometric elements not meeting New and Reconstruction Criteria are not to be adversely affected.
- Existing geometric elements that meet or exceed New and Reconstruction Criteria are not to be affected to the extent of not meeting New and Reconstruction Criteria.

**B. Freeway Criteria.**

**1.** Cross Slopes in Tangent Sections.

**a.** Lanes. Desirable = 2.0%. Minimum = 1.5%. Maximum = 3.0%. For existing cross slopes between 1.5% and 2.0%, do not reduce below existing.

**b.** Shoulders. Maximum = 8.0%.

**2.** Cross slope in superelevated sections:

**a.** Maximum. 8.0% algebraic cross slope difference in lane/shoulder cross slope. If the algebraic difference in cross slope is greater than 8.0%, then provide rounding as per DM-2, Section 1.5, typical section detail.

**b.** Required superelevation and superelevation transition rate is to meet the statements provided below for the other controlling criteria.

**3.** Vertical Clearance Criteria. Refer to Chapter 2, Section 2.20.

**4.** All Other Controlling Criteria.

- Existing geometric elements not meeting New and Reconstruction Criteria are not to be adversely affected.
- Existing geometric elements that meet or exceed New and Reconstruction Criteria are not to be affected to the extent of not meeting New and Reconstruction Criteria.

## 1.4 THIS SECTION IS INTENTIONALLY LEFT BLANK

## 1.5 TYPICAL ROADWAY CROSS SECTIONS

The Typical Roadway Cross Section details contained in this section shall be used in the design of typical sections for new construction and reconstruction highway construction projects.

For Limited Access Freeways (Interstate and Non-Interstate), the design values for cross sectional elements, as presented in Table 1.8, are intended primarily for reconstruction projects.

For Arterials, Collectors, and Local Roads, the design values for cross sectional elements, as presented in Table 1.3 through Table 1.7, are intended primarily for reconstruction projects.

For Arterials, Collectors, and Local Roads, when designing 3R projects, cross sectional elements shall be designed using the 3R Design Criteria as presented in Section 1.2.

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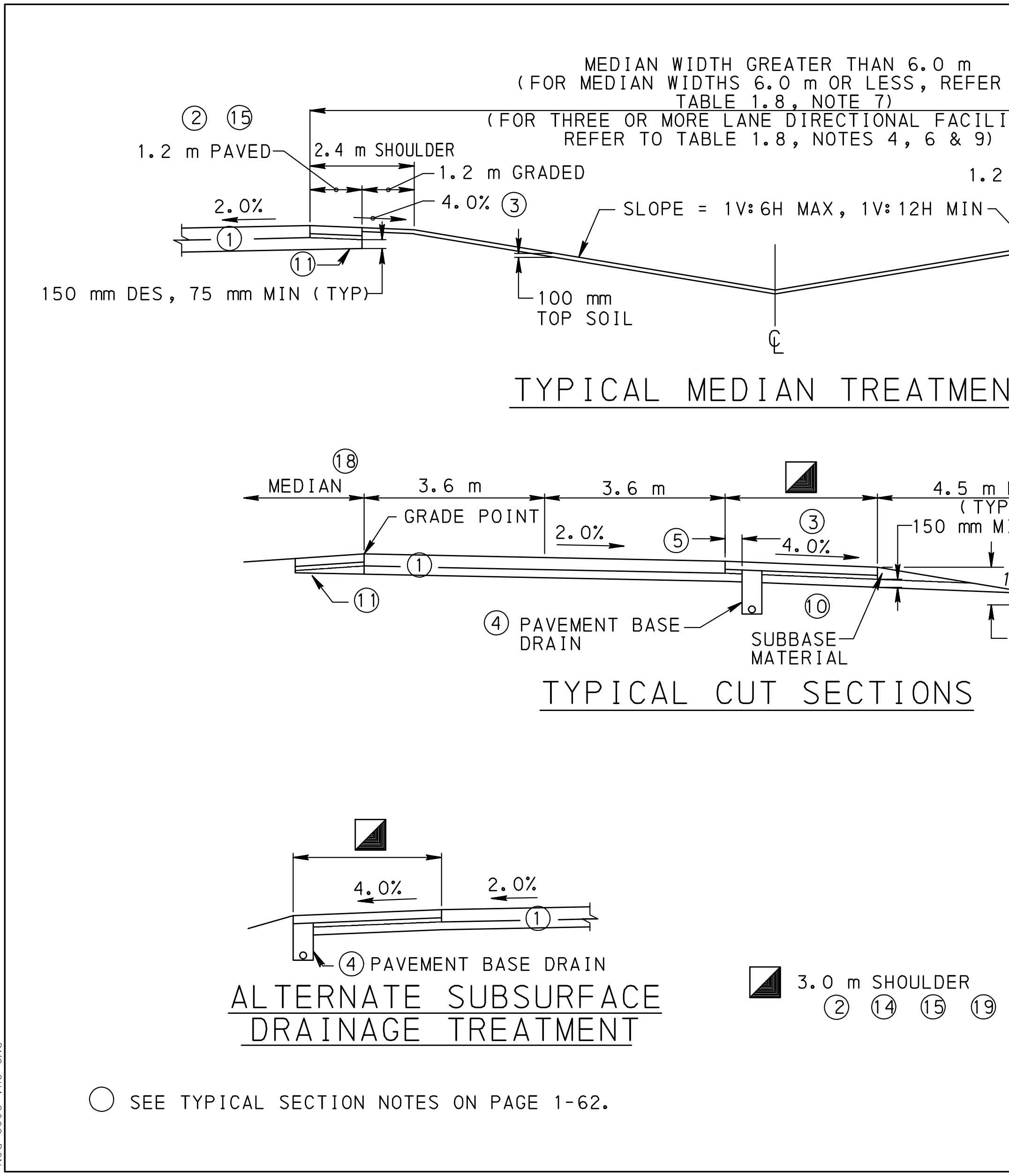
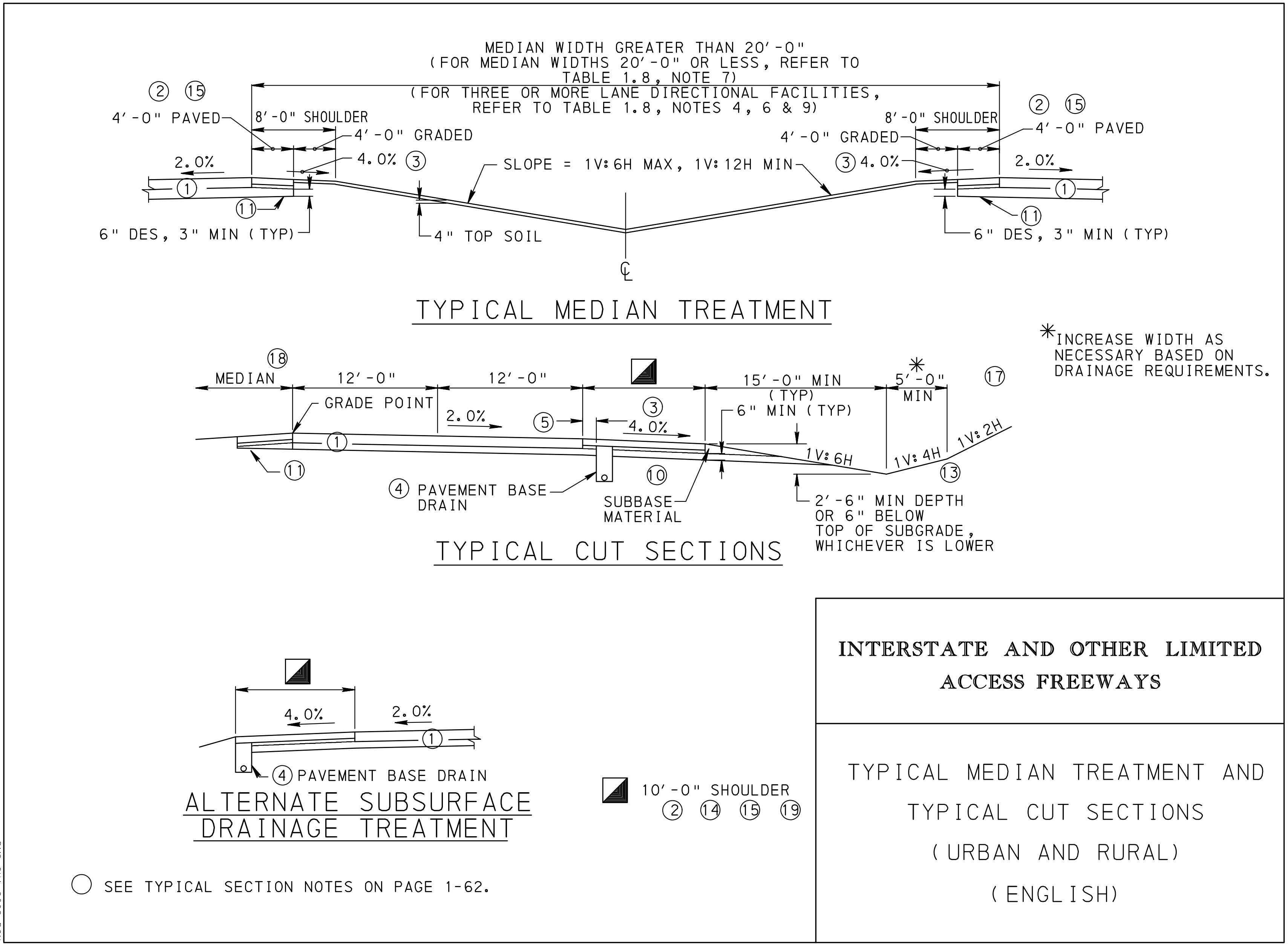



**INTERSTATE AND OTHER LIMITED ACCESS FREEWAYS**

TYPICAL MEDIAN TREATMENT AND TYPICAL CUT SECTIONS (URBAN AND RURAL) (METRIC)


MEDIAN WIDTH GREATER THAN 20'-0"
(FOR MEDIAN WIDTHS 20'-0" OR LESS, REFER TO TABLE 1.8, NOTE 7)
(FOR THREE OR MORE LANE DIRECTIONAL FACILITIES, REFER TO TABLE 1.8, NOTES 4, 6 & 9)
4'-0" PAVED
8'-0" SHOULDER
4'-0" GRADED
2.0%
4.0%
SLOPE = 1V:6H MAX, 1V:12H MIN
6" DES, 3" MIN (TYP)
4" TOP SOIL
TYPICAL MEDIAN TREATMENT
*INCREASE WIDTH AS NECESSARY BASED ON DRAINAGE REQUIREMENTS.
MEDIAN
12'-0"
12'-0"
15'-0" MIN (TYP)
5'-0"* MIN
GRADE POINT
6" MIN (TYP)
1V:6H
1V:4H
1V:2H
PAVEMENT BASE DRAIN
SUBBASE MATERIAL
2'-6" MIN DEPTH OR 6" BELOW TOP OF SUBGRADE, WHICHEVER IS LOWER
TYPICAL CUT SECTIONS
PAVEMENT BASE DRAIN
ALTERNATE SUBSURFACE DRAINAGE TREATMENT
10'-0" SHOULDER
SEE TYPICAL SECTION NOTES ON PAGE 1-62.
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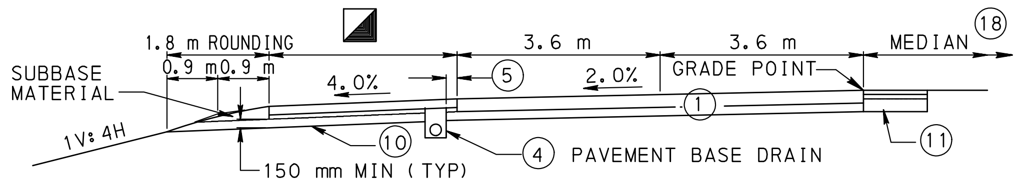
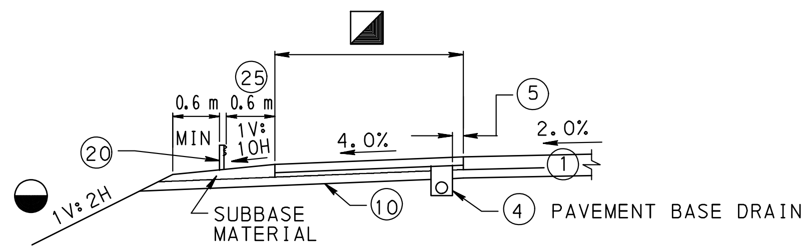
INTERSTATE AND OTHER LIMITED ACCESS FREEWAYS
TYPICAL MEDIAN TREATMENT AND TYPICAL CUT SECTIONS (URBAN AND RURAL) (ENGLISH)



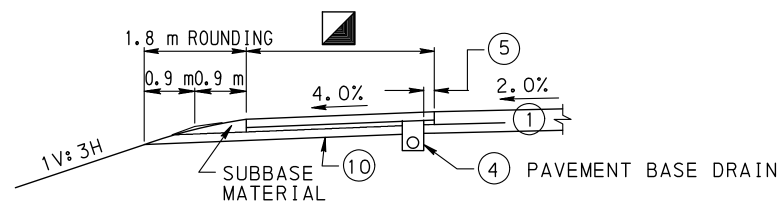

TYPICAL FILL SECTION--4.5 m AND UNDER




TYPICAL TANGENT SECTION

AN ALTERNATE 1V:3H SLOPE WITHOUT GUIDE RAIL MAY BE USED BASED ON ECONOMIC ANALYSIS. SEE "ALTERNATE TANGENT SECTION" DETAIL ON THIS PAGE.

3.0 m SHOULDER (2) (14) (15) (19)




ALTERNATE TANGENT SECTION

TYPICAL FILL SECTIONS--OVER 4.5 m

○ SEE TYPICAL SECTION NOTES ON PAGE 1-62.

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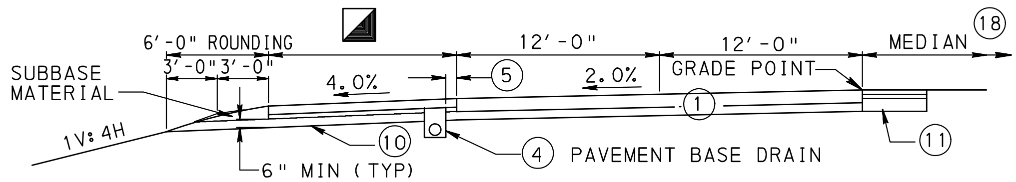
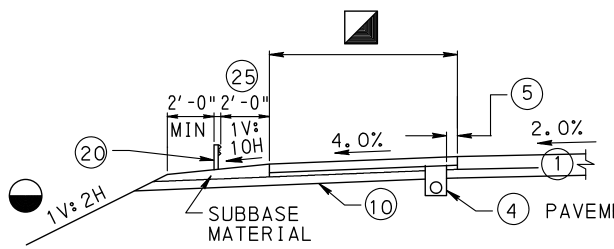
**INTERSTATE AND OTHER LIMITED ACCESS FREEWAYS**

TYPICAL FILL SECTIONS
(URBAN AND RURAL)
(METRIC)



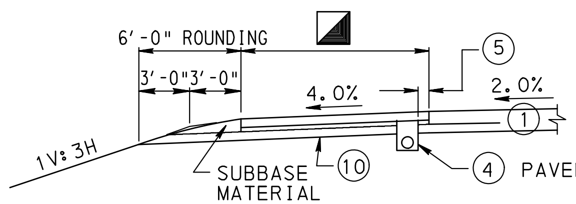

TYPICAL FILL SECTION--15'-0" AND UNDER




TYPICAL TANGENT SECTION

◒ AN ALTERNATE 1V:3H SLOPE WITHOUT GUIDE RAIL MAY BE USED BASED ON ECONOMIC ANALYSIS. SEE "ALTERNATE TANGENT SECTION" DETAIL ON THIS PAGE.

◩ 10'-0" SHOULDER (2) (14) (15) (19)




ALTERNATE TANGENT SECTION

TYPICAL FILL SECTIONS--OVER 15'-0"

○ SEE TYPICAL SECTION NOTES ON PAGE 1-62.

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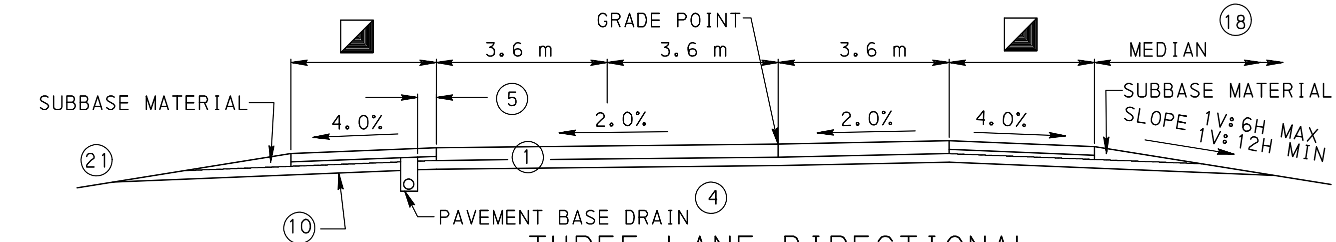
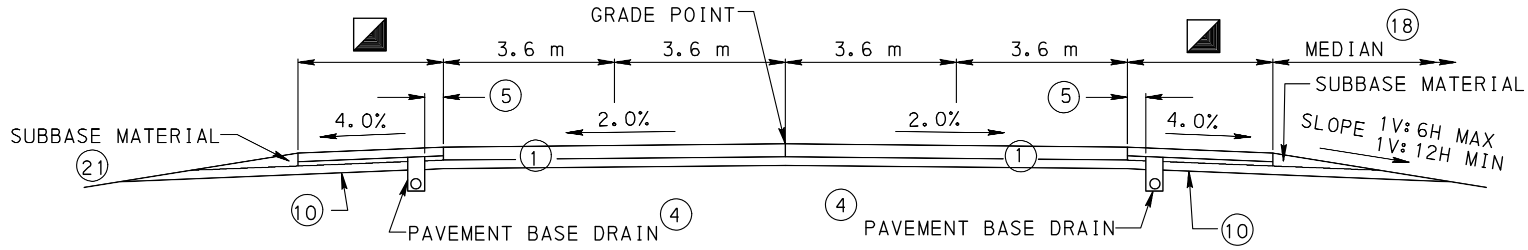
**INTERSTATE AND OTHER LIMITED ACCESS FREEWAYS**

TYPICAL FILL SECTIONS
(URBAN AND RURAL)
(ENGLISH)




THREE LANE DIRECTIONAL




FOUR LANE DIRECTIONAL

3.0 m SHOULDER (2) (14) (15) (19)

◯ SEE TYPICAL SECTION NOTES ON PAGE 1-62.

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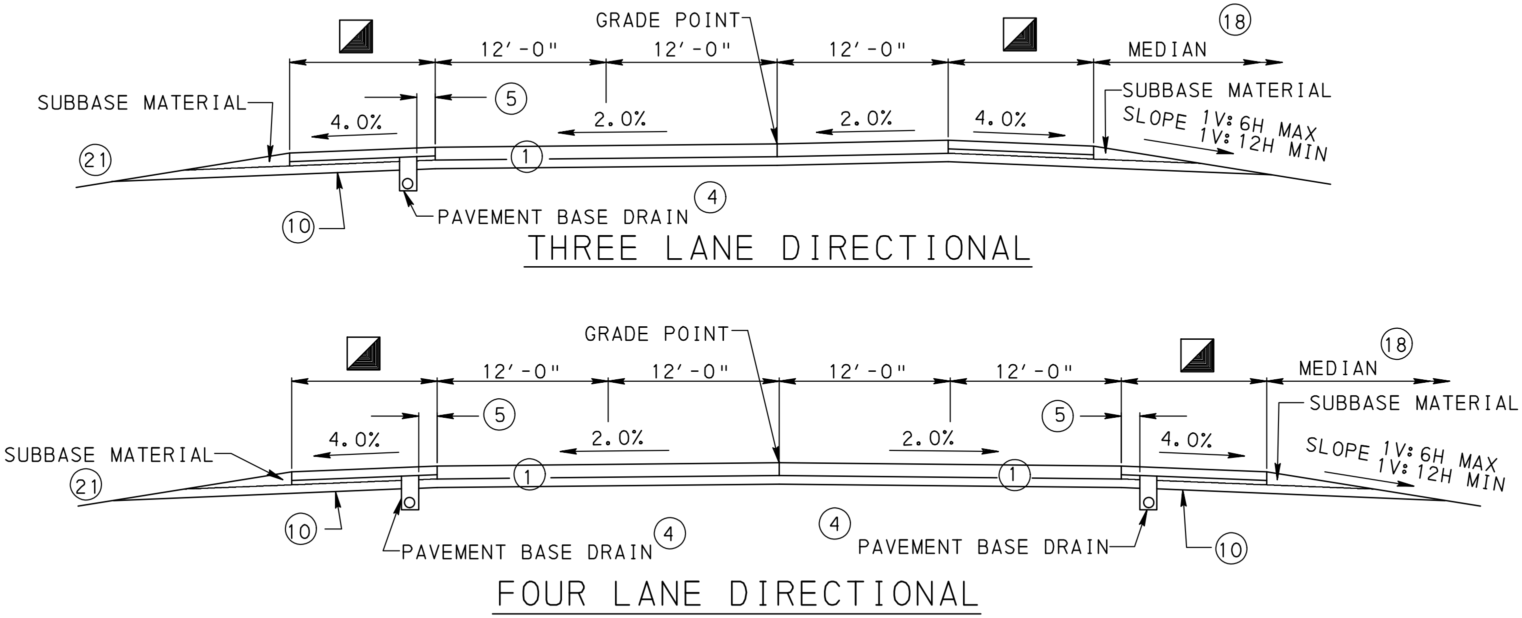
**INTERSTATE AND OTHER LIMITED ACCESS FREEWAYS**

TYPICAL THREE AND
FOUR LANE DIRECTIONAL
(URBAN AND RURAL)
(METRIC)




■ 10'-0" SHOULDER (2) (14) (15) (19)

◯ SEE TYPICAL SECTION NOTES ON PAGE 1-62.

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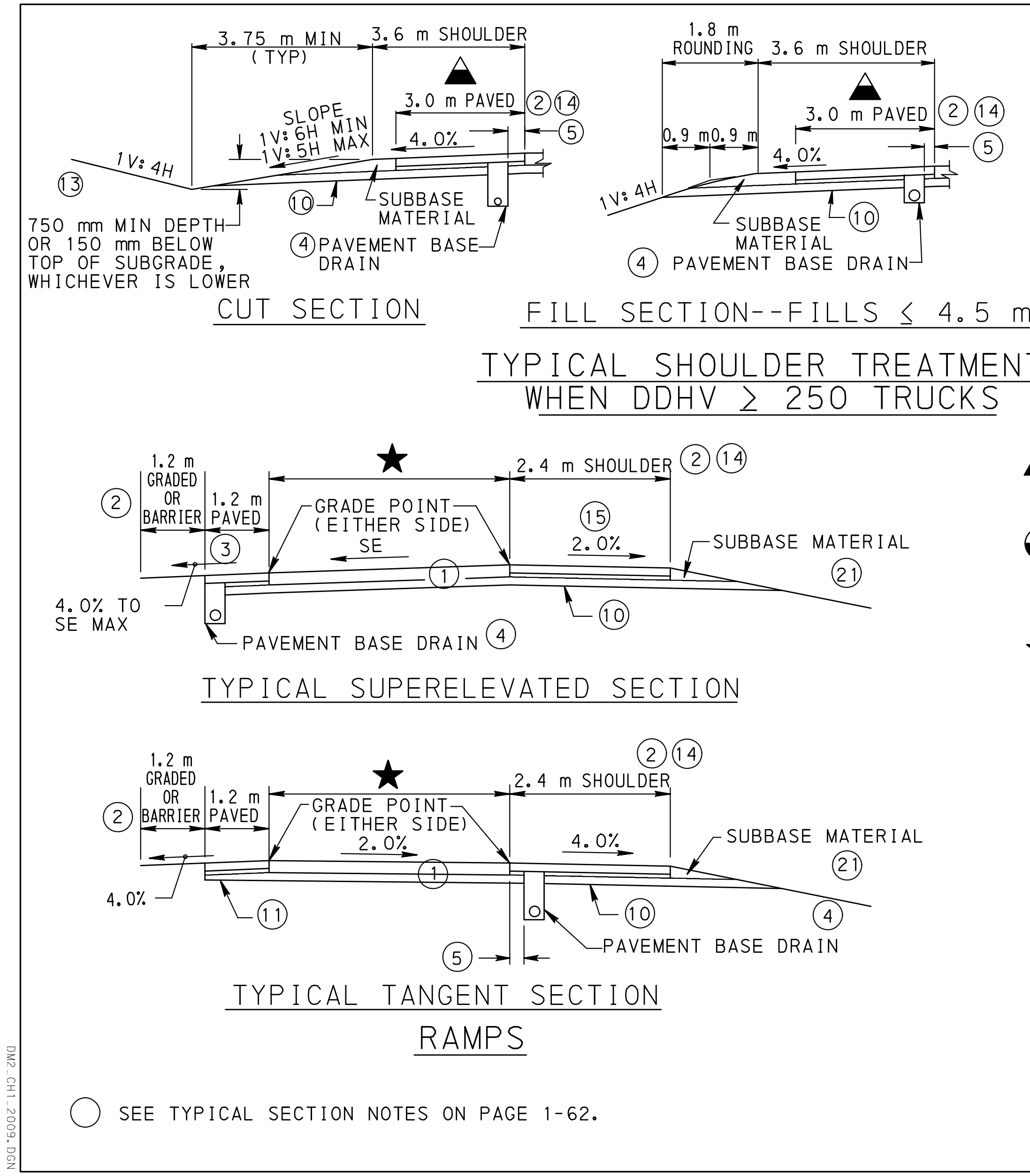
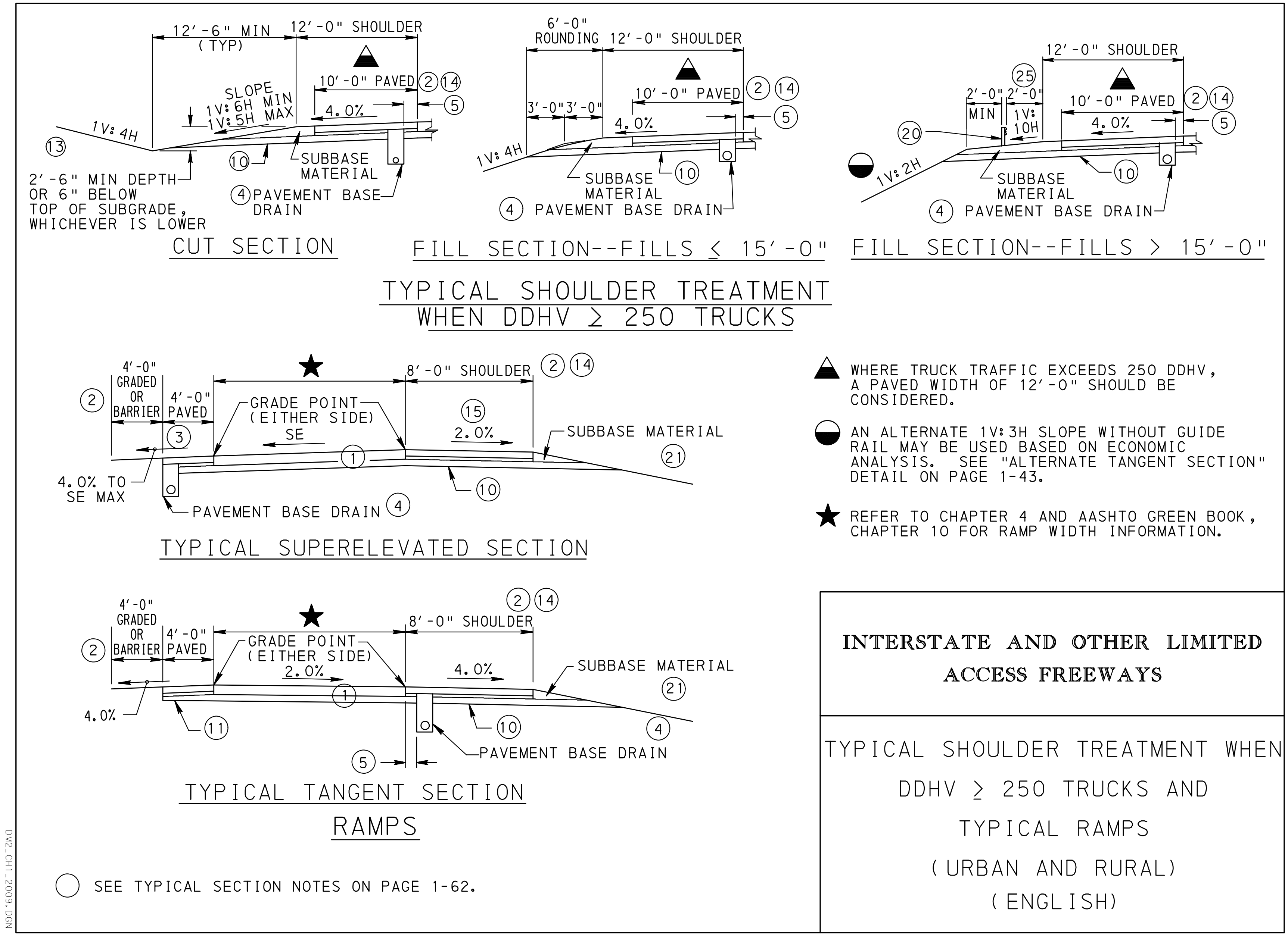
**INTERSTATE AND OTHER LIMITED ACCESS FREEWAYS**

TYPICAL THREE AND
FOUR LANE DIRECTIONAL
(URBAN AND RURAL)
(ENGLISH)




**INTERSTATE AND OTHER LIMITED ACCESS FREEWAYS**

TYPICAL SHOULDER TREATMENT WHEN DDHV ≥ 250 TRUCKS AND TYPICAL RAMPS (URBAN AND RURAL) (METRIC)


12'-6" MIN (TYP)
12'-0" SHOULDER
10'-0" PAVED
SLOPE 1V:6H MIN 1V:5H MAX
4.0%
1V:4H
2'-6" MIN DEPTH OR 6" BELOW TOP OF SUBGRADE, WHICHEVER IS LOWER
SUBBASE MATERIAL
PAVEMENT BASE DRAIN
CUT SECTION
6'-0" ROUNDING
3'-0" 3'-0"
FILL SECTION--FILLS ≤ 15'-0"
2'-0" MIN
2'-0" 1V:10H
1V:2H
FILL SECTION--FILLS > 15'-0"
TYPICAL SHOULDER TREATMENT WHEN DDHV ≥ 250 TRUCKS
WHERE TRUCK TRAFFIC EXCEEDS 250 DDHV, A PAVED WIDTH OF 12'-0" SHOULD BE CONSIDERED.
AN ALTERNATE 1V:3H SLOPE WITHOUT GUIDE RAIL MAY BE USED BASED ON ECONOMIC ANALYSIS. SEE "ALTERNATE TANGENT SECTION" DETAIL ON PAGE 1-43.
REFER TO CHAPTER 4 AND AASHTO GREEN BOOK, CHAPTER 10 FOR RAMP WIDTH INFORMATION.
4'-0" GRADED OR BARRIER
4'-0" PAVED
8'-0" SHOULDER
GRADE POINT (EITHER SIDE)
SE
2.0%
SUBBASE MATERIAL
4.0% TO SE MAX
PAVEMENT BASE DRAIN
TYPICAL SUPERELEVATED SECTION
4.0%
TYPICAL TANGENT SECTION
RAMPS
SEE TYPICAL SECTION NOTES ON PAGE 1-62.
INTERSTATE AND OTHER LIMITED ACCESS FREEWAYS
TYPICAL SHOULDER TREATMENT WHEN DDHV ≥ 250 TRUCKS AND TYPICAL RAMPS (URBAN AND RURAL) (ENGLISH)
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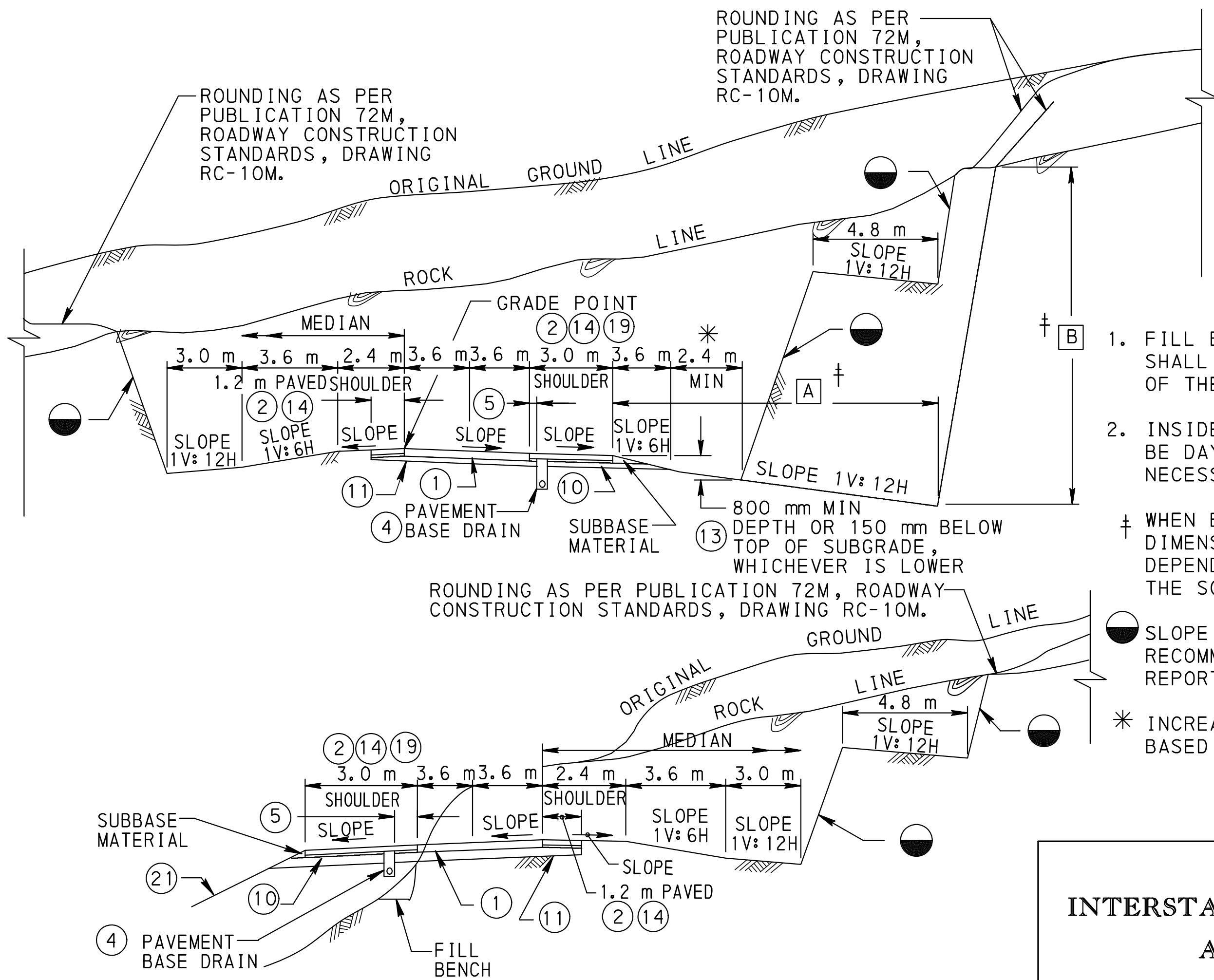


TYPICAL ROADWAY SECTION FOR SPLIT LEVEL AND SEPARATED ROADWAYS WHERE BENCHING IS REQUIRED

◯ SEE TYPICAL SECTION NOTES ON PAGE 1-62.

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## NOTES

1. FILL BENCH DETAILS AND BENCH HEIGHT SHALL BE DEPENDENT UPON RECOMMENDATION OF THE SOIL SURVEY REPORT.
2. INSIDE OF SUPERELEVATED CURVES TO BE DAY-LIGHTED AS REQUIRED FOR NECESSARY SIGHT DISTANCE.

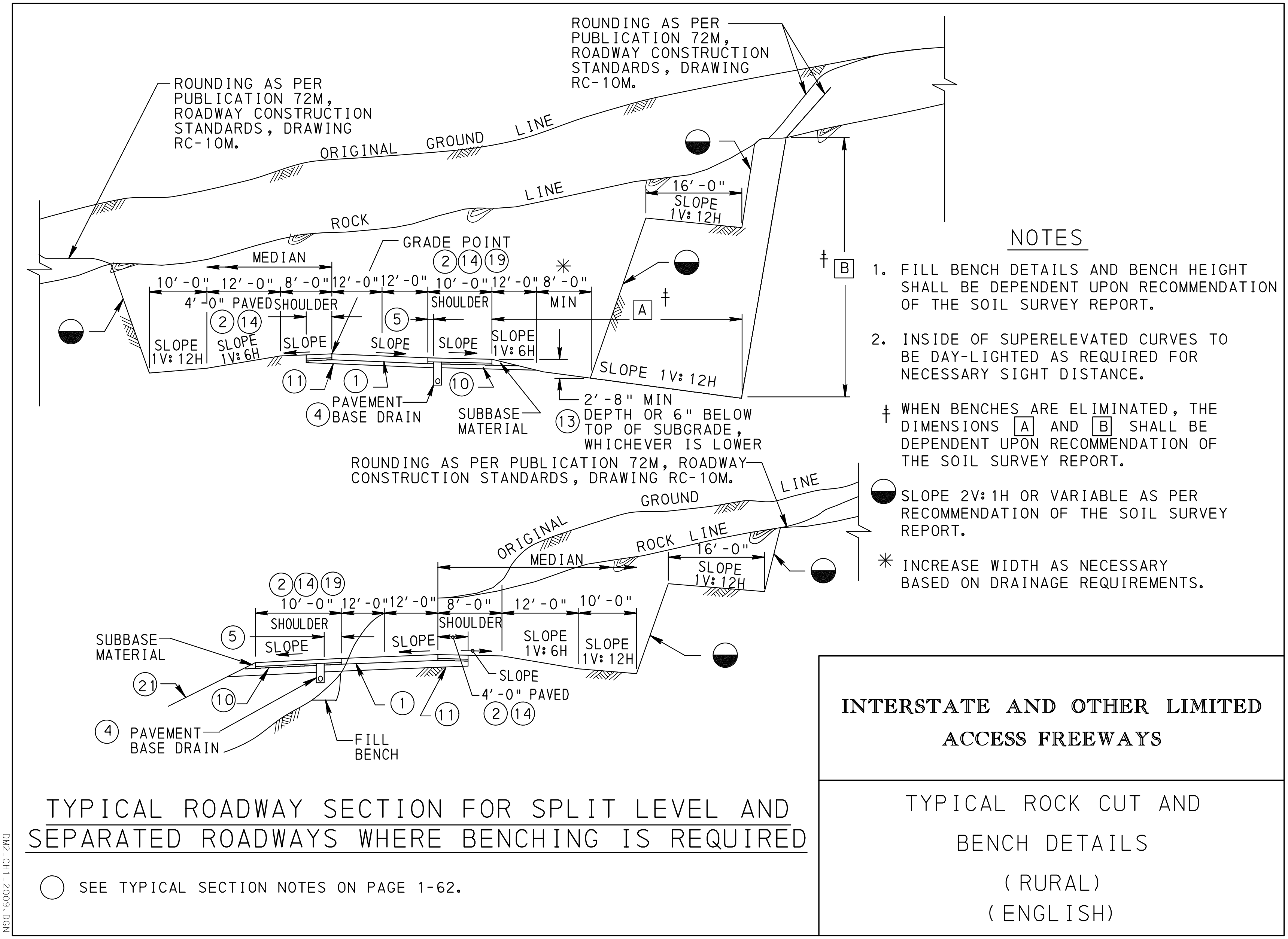
‡ WHEN BENCHES ARE ELIMINATED, THE DIMENSIONS [A] AND [B] SHALL BE DEPENDENT UPON RECOMMENDATION OF THE SOIL SURVEY REPORT.

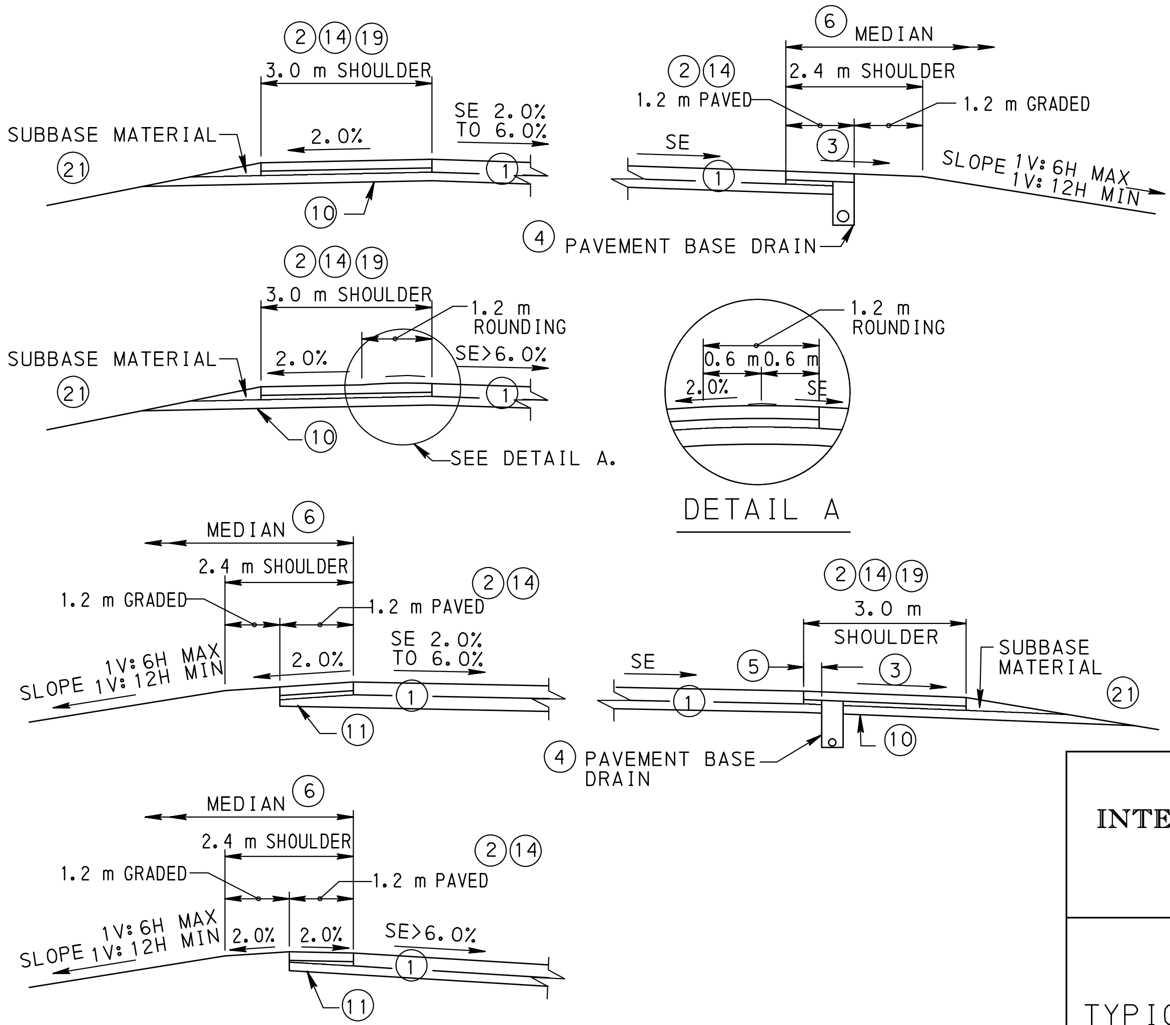
◓ SLOPE 2V:1H OR VARIABLE AS PER RECOMMENDATION OF THE SOIL SURVEY REPORT.

✳ INCREASE WIDTH AS NECESSARY BASED ON DRAINAGE REQUIREMENTS.

**INTERSTATE AND OTHER LIMITED ACCESS FREEWAYS**

TYPICAL ROCK CUT AND BENCH DETAILS (RURAL) (METRIC)


ROUNDING AS PER PUBLICATION 72M, ROADWAY CONSTRUCTION STANDARDS, DRAWING RC-10M.
ROUNDING AS PER PUBLICATION 72M, ROADWAY CONSTRUCTION STANDARDS, DRAWING RC-10M.
ORIGINAL GROUND LINE
ROCK LINE
MEDIAN
GRADE POINT
2 14 19
10'-0" 12'-0" 8'-0" 12'-0" 12'-0" 10'-0" 12'-0" 8'-0"
4'-0" PAVED
SHOULDER
SHOULDER
MIN
2 14
5
A
B
16'-0"
SLOPE 1V:12H
SLOPE 1V:12H
SLOPE 1V:6H
SLOPE
SLOPE
SLOPE
SLOPE 1V:6H
SLOPE 1V:12H
11
1
10
4 PAVEMENT BASE DRAIN
SUBBASE MATERIAL
2'-8" MIN
13 DEPTH OR 6" BELOW TOP OF SUBGRADE, WHICHEVER IS LOWER
ROUNDING AS PER PUBLICATION 72M, ROADWAY CONSTRUCTION STANDARDS, DRAWING RC-10M.
ORIGINAL GROUND LINE
ROCK LINE
MEDIAN
16'-0"
SLOPE 1V:12H
2 14 19
10'-0" 12'-0" 12'-0" 8'-0" 12'-0" 10'-0"
SHOULDER
SHOULDER
SUBBASE MATERIAL
5
SLOPE
SLOPE
SLOPE 1V:6H
SLOPE 1V:12H
SLOPE
21
10
1
11
4'-0" PAVED
2 14
4 PAVEMENT BASE DRAIN
FILL BENCH
NOTES
1. FILL BENCH DETAILS AND BENCH HEIGHT SHALL BE DEPENDENT UPON RECOMMENDATION OF THE SOIL SURVEY REPORT.
2. INSIDE OF SUPERELEVATED CURVES TO BE DAY-LIGHTED AS REQUIRED FOR NECESSARY SIGHT DISTANCE.
‡ WHEN BENCHES ARE ELIMINATED, THE DIMENSIONS A AND B SHALL BE DEPENDENT UPON RECOMMENDATION OF THE SOIL SURVEY REPORT.
SLOPE 2V:1H OR VARIABLE AS PER RECOMMENDATION OF THE SOIL SURVEY REPORT.
✳ INCREASE WIDTH AS NECESSARY BASED ON DRAINAGE REQUIREMENTS.
TYPICAL ROADWAY SECTION FOR SPLIT LEVEL AND SEPARATED ROADWAYS WHERE BENCHING IS REQUIRED
SEE TYPICAL SECTION NOTES ON PAGE 1-62.
INTERSTATE AND OTHER LIMITED ACCESS FREEWAYS
TYPICAL ROCK CUT AND BENCH DETAILS
(RURAL)
(ENGLISH)
DM2.CH1.2009.DGN

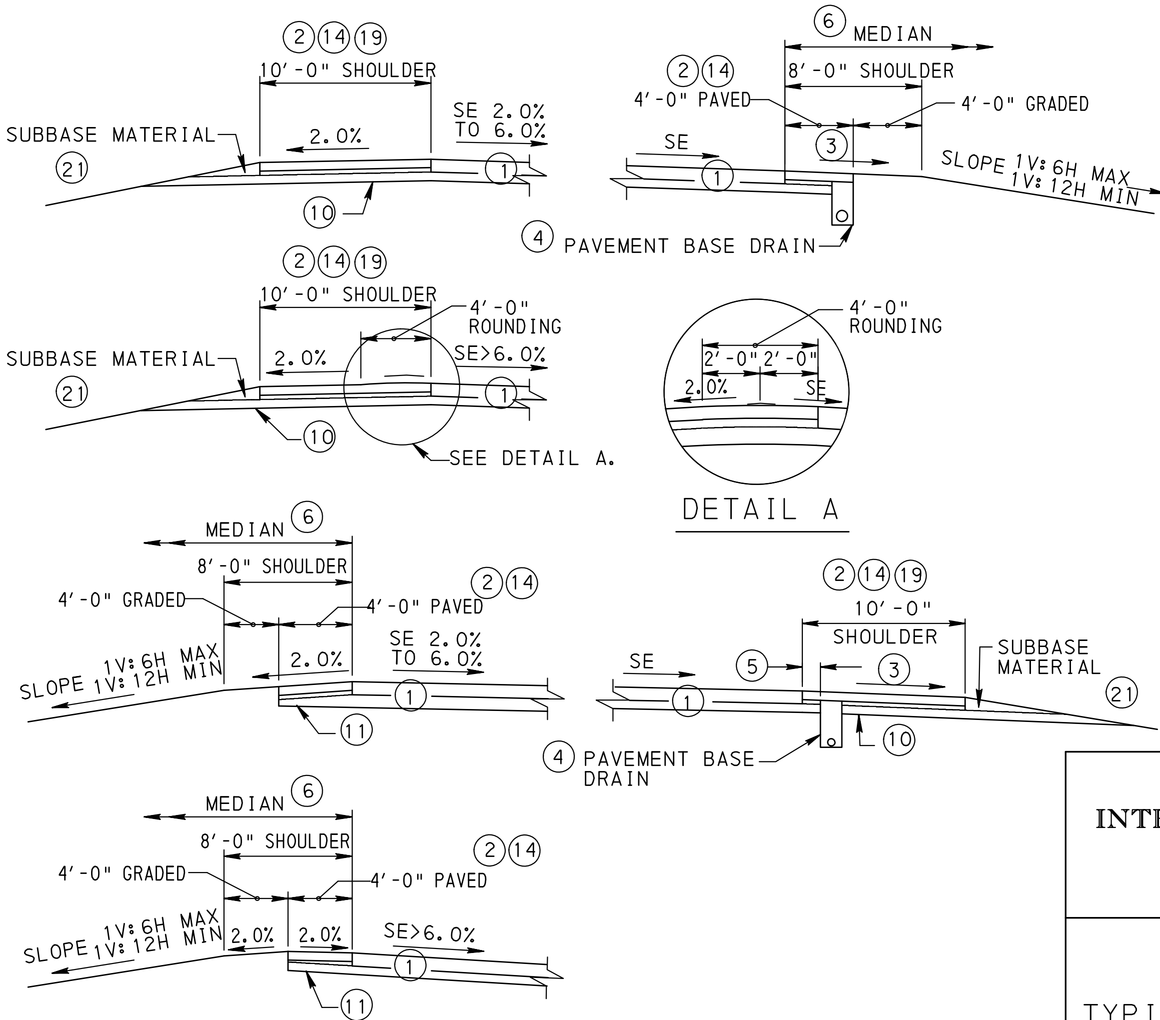



SEE TYPICAL SECTION NOTES ON PAGE 1-62.

DM2_CH1_2009.DGN

**INTERSTATE AND OTHER LIMITED ACCESS FREEWAYS**

TYPICAL SUPERELEVATED SECTIONS
(URBAN AND RURAL)
(METRIC)



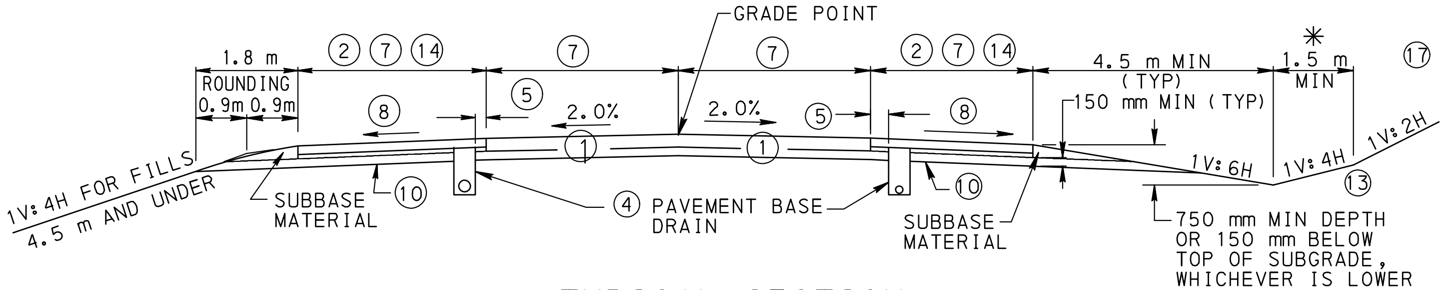

◯ SEE TYPICAL SECTION NOTES ON PAGE 1-62.

**INTERSTATE AND OTHER LIMITED ACCESS FREEWAYS**

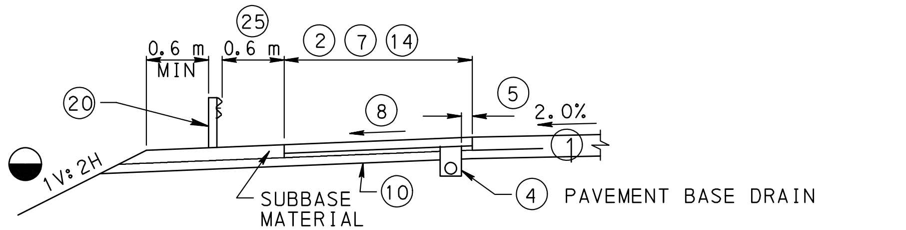
TYPICAL SUPERELEVATED SECTIONS
(URBAN AND RURAL)
(ENGLISH)

DM2_CH1_2009.DGN

✳INCREASE WIDTH AS NECESSARY BASED ON DRAINAGE REQUIREMENTS.

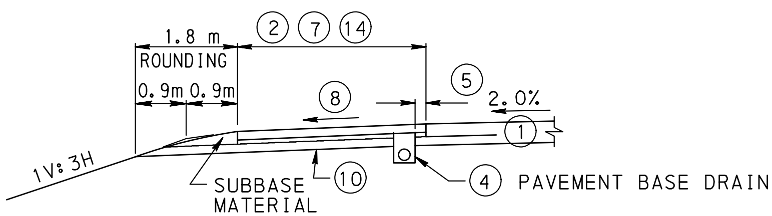



TYPICAL SECTION




TYPICAL TANGENT SECTION--FILLS OVER 4.5 m

◒ AN ALTERNATE 1V:3H SLOPE WITHOUT GUIDE RAIL MAY BE USED BASED ON ECONOMIC ANALYSIS. SEE "ALTERNATE TANGENT SECTION" DETAIL ON THIS PAGE.




ALTERNATE TANGENT SECTION--FILLS OVER 4.5 m

◯ SEE TYPICAL SECTION NOTES ON PAGE 1-62.

DM2_CH1_2009.DGN

**ARTERIALS**

TYPICAL CUT AND FILL SECTIONS

(RURAL)

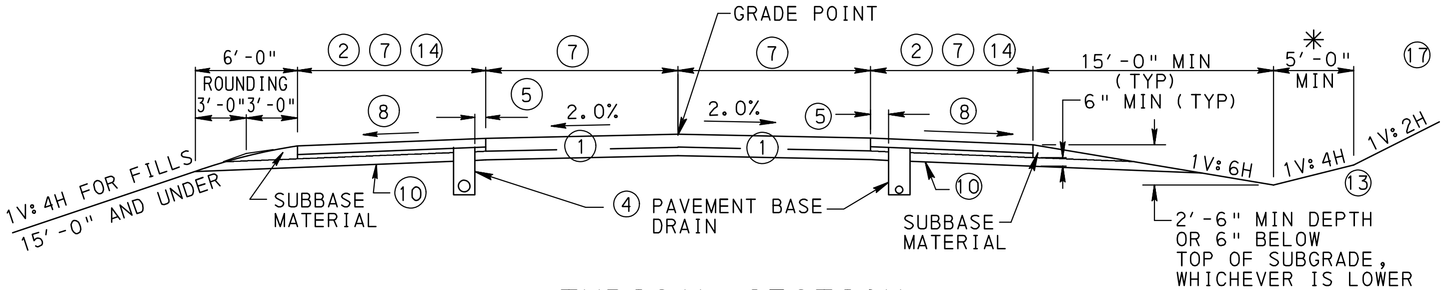
TYPICAL SECTIONS WITHOUT CURBS

FOR SPEEDS > 60 km/h

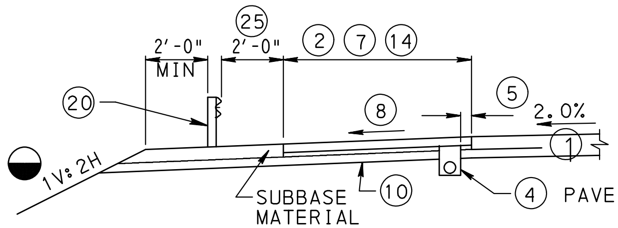
(URBAN)

(METRIC)

* INCREASE WIDTH AS NECESSARY BASED ON DRAINAGE REQUIREMENTS.

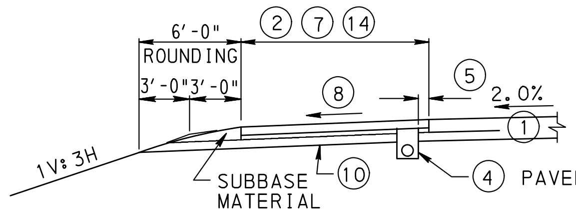



TYPICAL SECTION




TYPICAL TANGENT SECTION--FILLS OVER 15'-0"

◒ AN ALTERNATE 1V:3H SLOPE WITHOUT GUIDE RAIL MAY BE USED BASED ON ECONOMIC ANALYSIS. SEE "ALTERNATE TANGENT SECTION" DETAIL ON THIS PAGE.



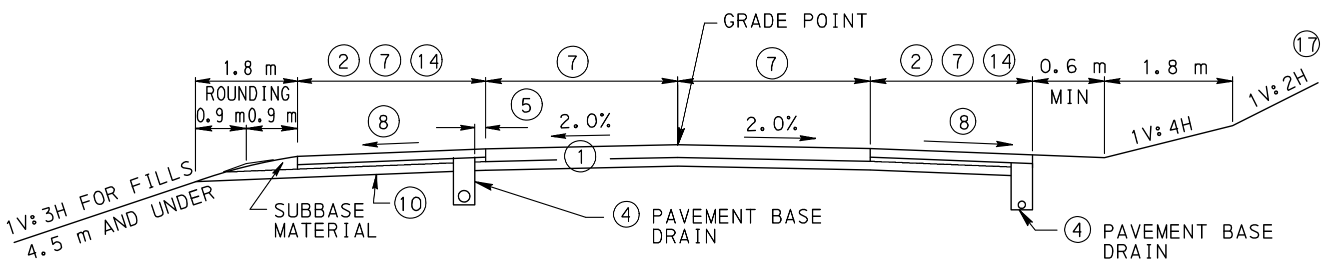

ALTERNATE TANGENT SECTION--FILLS OVER 15'-0"

◯ SEE TYPICAL SECTION NOTES ON PAGE 1-62.

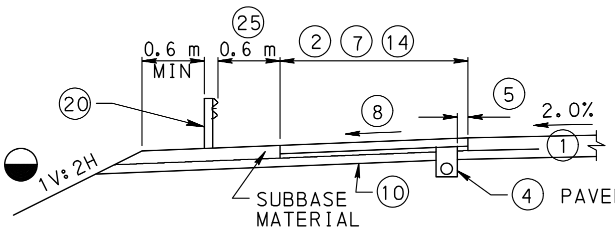
DM2_CH1_2009.DGN

**ARTERIALS**

TYPICAL CUT AND FILL SECTIONS
(RURAL)
TYPICAL SECTIONS WITHOUT CURBS
FOR SPEEDS > 40 mph
(URBAN)
(ENGLISH)

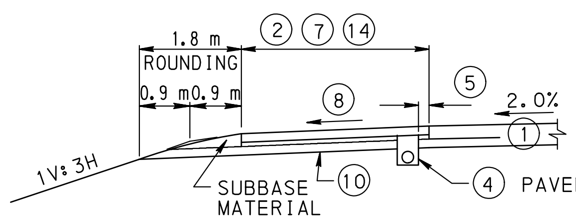



TYPICAL SECTION




TYPICAL TANGENT SECTION--FILLS OVER 4.5 m

◓ AN ALTERNATE 1V:3H SLOPE WITHOUT GUIDE RAIL MAY BE USED BASED ON ECONOMIC ANALYSIS. SEE "ALTERNATE TANGENT SECTION" DETAIL ON THIS PAGE.



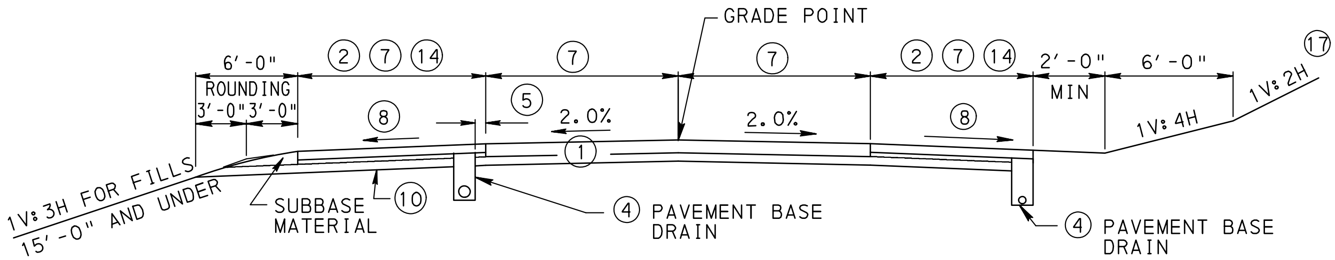

ALTERNATE TANGENT SECTION--FILLS OVER 4.5 m

◯ SEE TYPICAL SECTION NOTES ON PAGE 1-62.

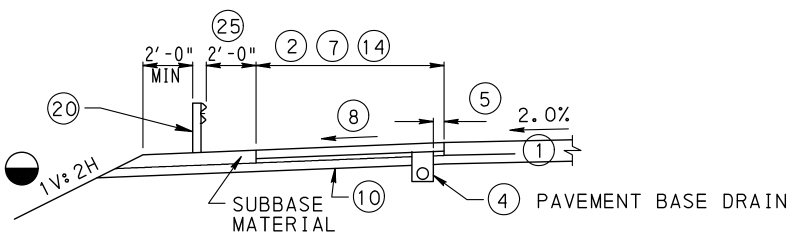
DM2_CH1_2009.DGN

**ARTERIALS**

TYPICAL SECTIONS WITHOUT CURBS
FOR SPEEDS ≤ 60 km/h
(URBAN)
(METRIC)

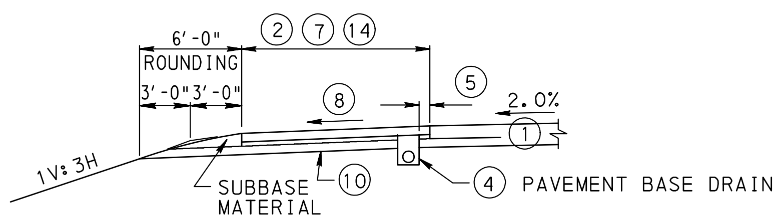



TYPICAL SECTION




TYPICAL TANGENT SECTION--FILLS OVER 15'-0"

◒ AN ALTERNATE 1V:3H SLOPE WITHOUT GUIDE RAIL MAY BE USED BASED ON ECONOMIC ANALYSIS. SEE "ALTERNATE TANGENT SECTION" DETAIL ON THIS PAGE.




ALTERNATE TANGENT SECTION--FILLS OVER 15'-0"

○ SEE TYPICAL SECTION NOTES ON PAGE 1-62.

DM2_CH1.2009.DGN

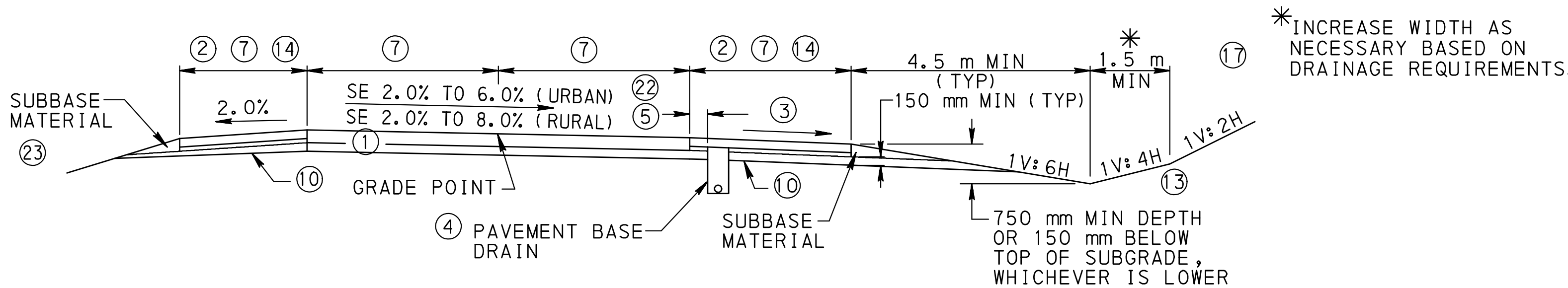
**ARTERIALS**

TYPICAL SECTIONS WITHOUT CURBS

FOR SPEEDS ≤ 40 mph

(URBAN)

(ENGLISH)

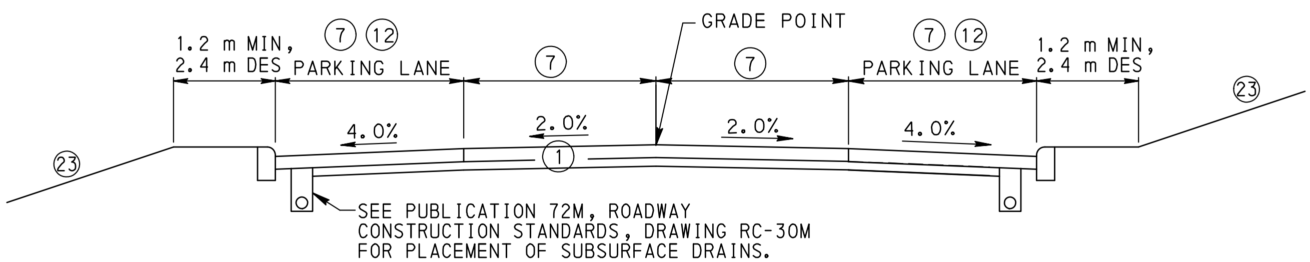



TYPICAL SUPERELEVATED SECTION

◯ SEE TYPICAL SECTION NOTES ON PAGE 1-62.

**ARTERIALS**

TYPICAL SUPERELEVATED SECTION
(URBAN AND RURAL)
(METRIC)



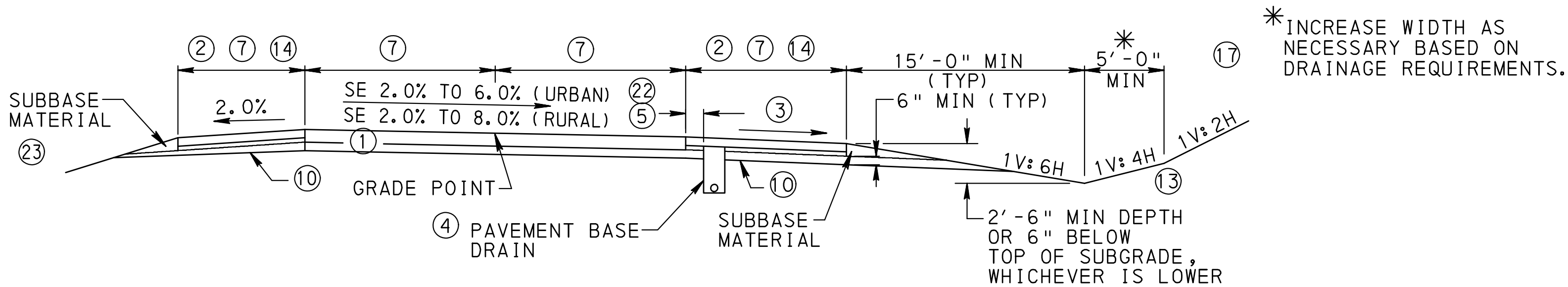

TYPICAL SECTION WITH CURBS

◯ SEE TYPICAL SECTION NOTES ON PAGE 1-62.

DM2_CH1_2009.DGN

**ARTERIALS, COLLECTORS AND LOCAL ROADS**

TYPICAL SECTION WITH CURBS
(URBAN)
(METRIC)




TYPICAL SUPERELEVATED SECTION

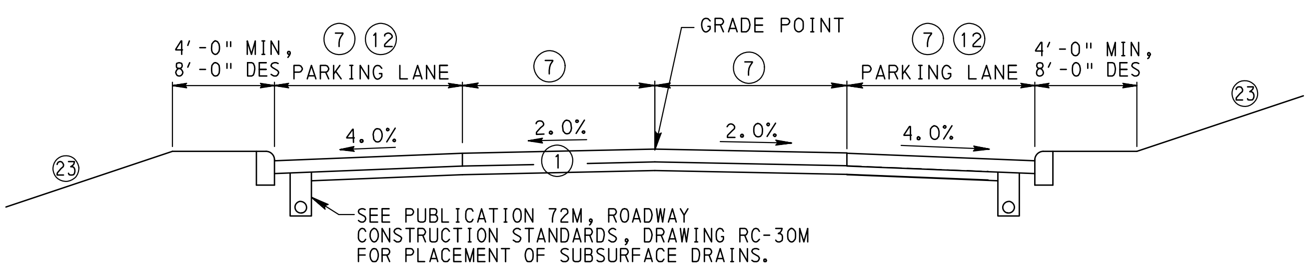
◯ SEE TYPICAL SECTION NOTES ON PAGE 1-62.

**ARTERIALS**

TYPICAL SUPERELEVATED SECTION

(URBAN AND RURAL)

(ENGLISH)




TYPICAL SECTION WITH CURBS

◯ SEE TYPICAL SECTION NOTES ON PAGE 1-62.

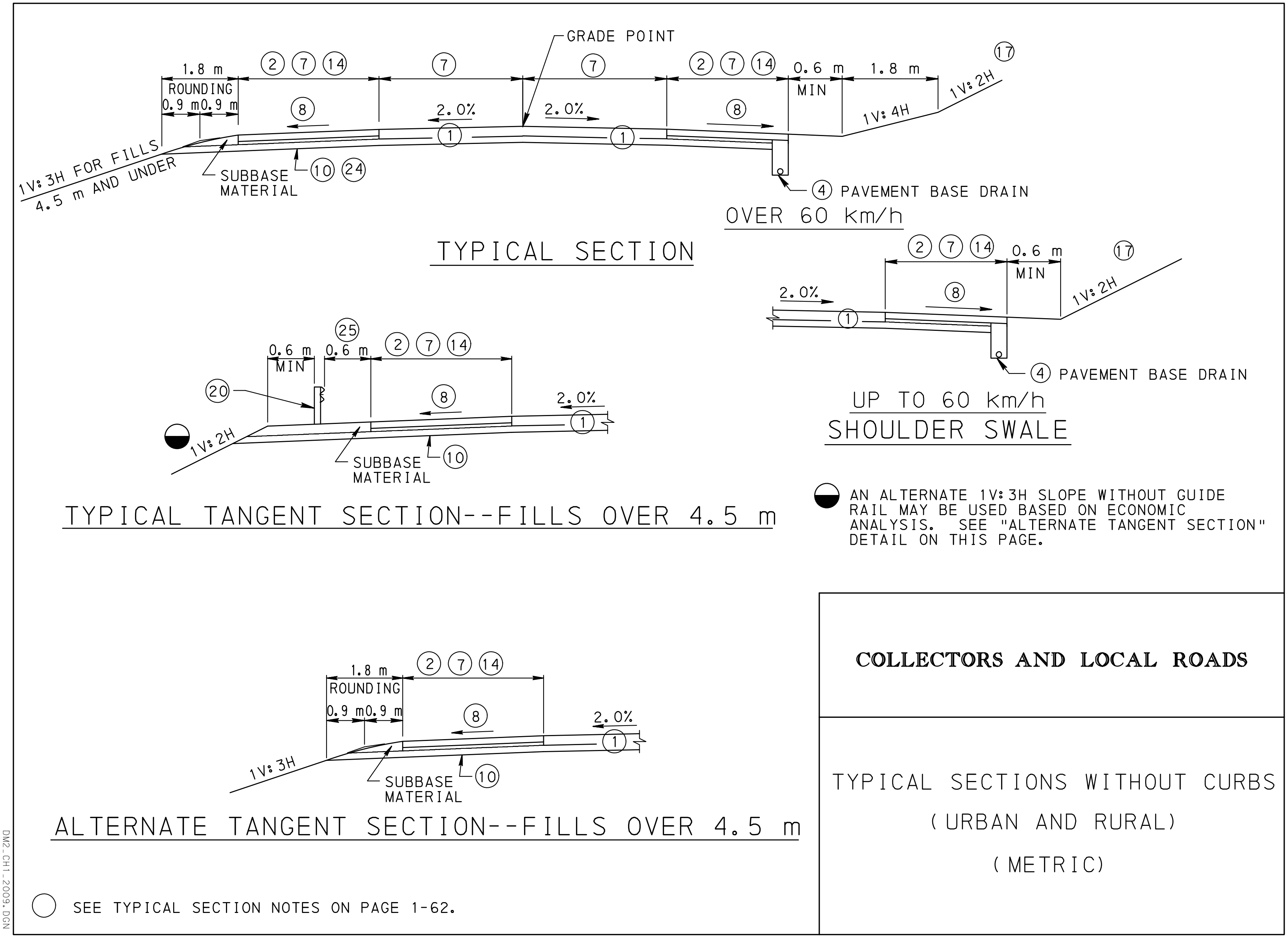
DM2_CH1_2009.DGN

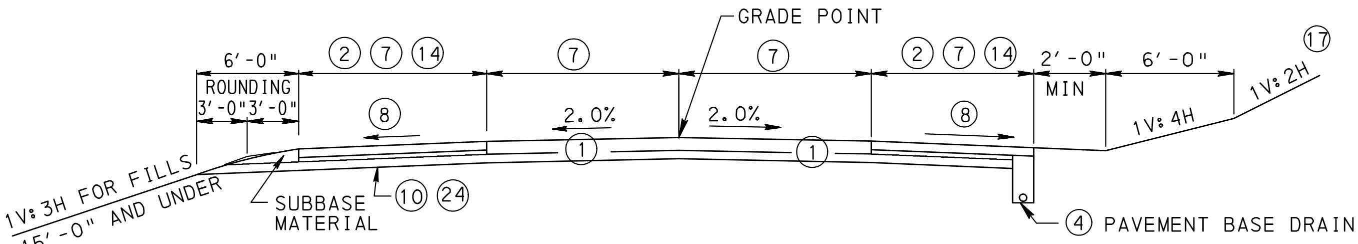
**ARTERIALS, COLLECTORS AND LOCAL ROADS**

TYPICAL SECTION WITH CURBS

(URBAN)

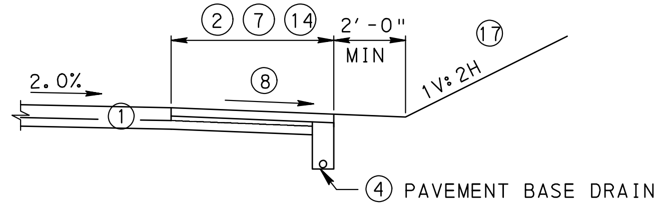
(ENGLISH)


GRADE POINT
1.8 m
ROUNDING
0.9 m
0.9 m
2 7 14
7
7
2 7 14
0.6 m
MIN
1.8 m
17
1V:2H
1V:4H
8
2.0%
2.0%
8
1
1
1V:3H FOR FILLS
4.5 m AND UNDER
SUBBASE
MATERIAL
10 24
4 PAVEMENT BASE DRAIN
OVER 60 km/h
TYPICAL SECTION
2 7 14
0.6 m
MIN
17
1V:2H
2.0%
8
1
4 PAVEMENT BASE DRAIN
UP TO 60 km/h
SHOULDER SWALE
25
0.6 m
MIN
0.6 m
2 7 14
20
8
2.0%
1
1V:2H
SUBBASE
MATERIAL
10
TYPICAL TANGENT SECTION--FILLS OVER 4.5 m
AN ALTERNATE 1V:3H SLOPE WITHOUT GUIDE RAIL MAY BE USED BASED ON ECONOMIC ANALYSIS. SEE "ALTERNATE TANGENT SECTION" DETAIL ON THIS PAGE.
1.8 m
ROUNDING
0.9 m
0.9 m
2 7 14
8
2.0%
1
1V:3H
SUBBASE
MATERIAL
10
ALTERNATE TANGENT SECTION--FILLS OVER 4.5 m
SEE TYPICAL SECTION NOTES ON PAGE 1-62.
DM2_CH1_2009.DGN
COLLECTORS AND LOCAL ROADS
TYPICAL SECTIONS WITHOUT CURBS
(URBAN AND RURAL)
(METRIC)



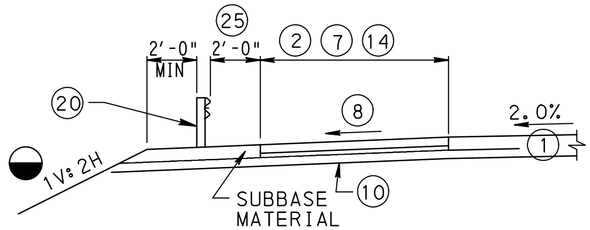

OVER 40 mph

TYPICAL SECTION



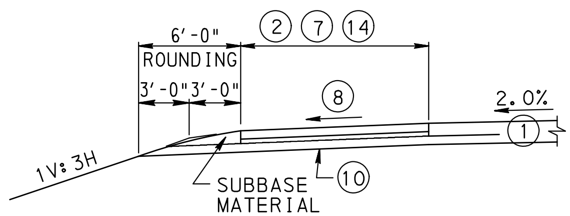

UP TO 40 mph

SHOULDER SWALE




TYPICAL TANGENT SECTION--FILLS OVER 15'-0"

◒ AN ALTERNATE 1V:3H SLOPE WITHOUT GUIDE RAIL MAY BE USED BASED ON ECONOMIC ANALYSIS. SEE "ALTERNATE TANGENT SECTION" DETAIL ON THIS PAGE.




ALTERNATE TANGENT SECTION--FILLS OVER 15'-0"

○ SEE TYPICAL SECTION NOTES ON PAGE 1-62.

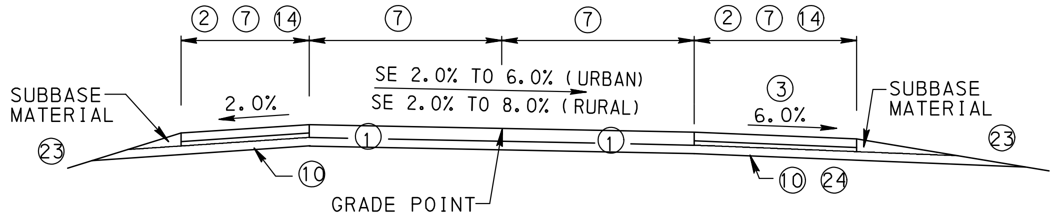
**COLLECTORS AND LOCAL ROADS**

TYPICAL SECTIONS WITHOUT CURBS

(URBAN AND RURAL)

(ENGLISH)

DM2_CH1_2009.DGN

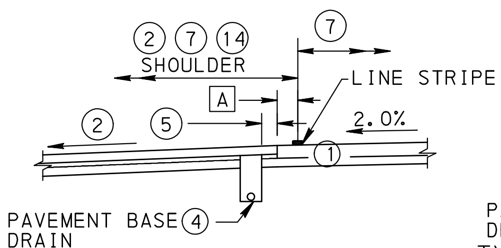



TYPICAL SUPERELEVATED SECTION

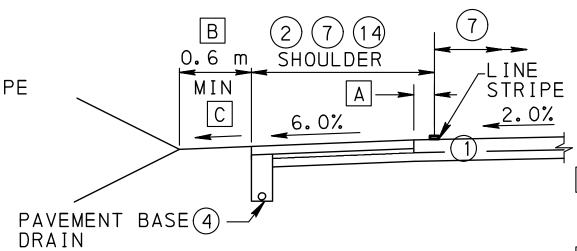
○ SEE TYPICAL SECTION NOTES ON PAGE 1-62.

**COLLECTORS AND LOCAL ROADS**

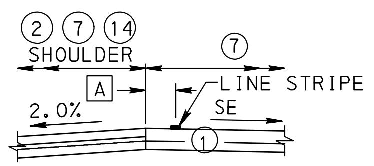
TYPICAL SUPERELEVATED SECTION
(URBAN AND RURAL)
(METRIC)




TYPICAL TANGENT SECTION

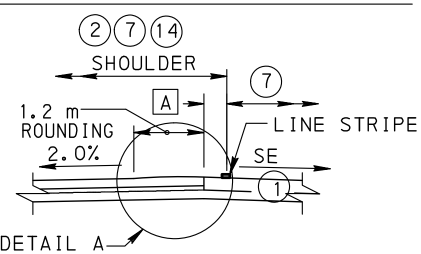



TYPICAL SECTION--SHOULDERS ≤ 1.8 m




TYPICAL SUPERELEVATION SECTION
SE 2.0% TO 6.0%

○ SEE TYPICAL SECTION NOTES ON PAGE 1-62.




D SEE DETAIL A PAGE 1-58.

TYPICAL SUPERELEVATION SECTION
SE > 6.0%

## NOTES

PAVEMENT WIDENING ON THE LOW SIDE OF SUPER-ELEVATIONS SHALL BE CONSTRUCTED AS SHOWN ON THE "TYPICAL TANGENT SECTION" DETAIL ON THIS PAGE WITH THE RATE OF PAVEMENT WIDENING THE SAME AS SUPER-ELEVATION RATE.

A SEE SHOULDER CRITERIA ON PAGES 1-30 AND 1-36 FOR EXTENSION OF WIDENING STRUCTURE INTO THE SHOULDER AREA.

B PROVIDE SUFFICIENT WIDTH TO MAINTAIN 0.6 m MINIMUM CLEARANCE BEHIND GUIDE RAIL AND TO PREVENT GUIDE RAIL ENCROACHMENT ON THE USEABLE SHOULDER AREA.

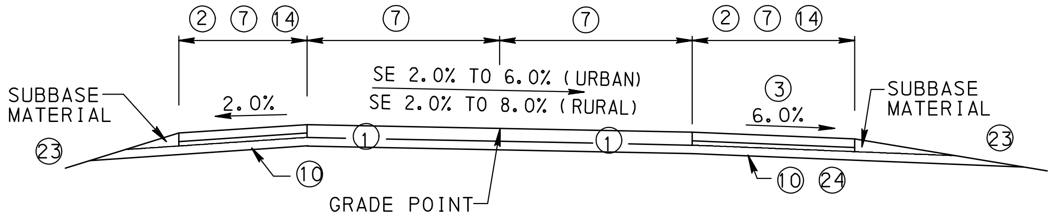
C PROVIDE 1V:6H MAXIMUM TO SHOULDER SLOPE MINIMUM.

D 1.2 m ROUNDING TREATMENT NOT REQUIRED ON 3R PROJECTS.

**INTERSTATE, LIMITED ACCESS FREEWAYS, ARTERIALS, COLLECTORS AND LOCAL ROADS**

TYPICAL PAVEMENT WIDENING
(URBAN AND RURAL)
(METRIC)

DM2_CH1.2009.DGN

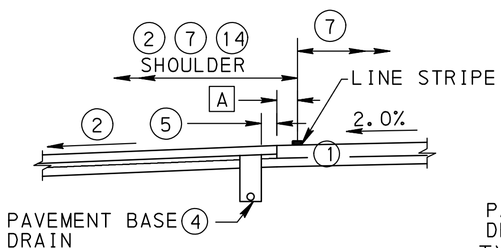



TYPICAL SUPERELEVATED SECTION

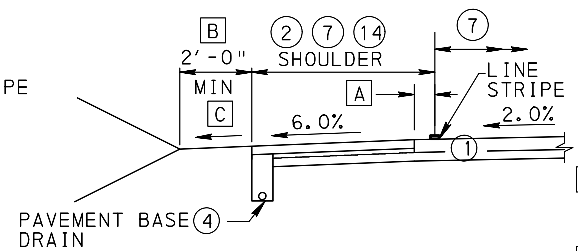
○ SEE TYPICAL SECTION NOTES ON PAGE 1-62.

**COLLECTORS AND LOCAL ROADS**

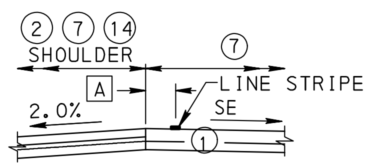
TYPICAL SUPERELEVATED SECTION
(URBAN AND RURAL)
(ENGLISH)



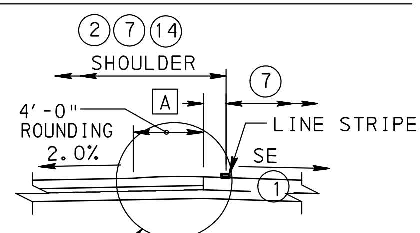

TYPICAL TANGENT SECTION




TYPICAL SECTION--SHOULDERS ≤ 6′-0"




TYPICAL SUPERELEVATION SECTION
SE 2.0% TO 6.0%




D SEE DETAIL A
PAGE 1-59.

TYPICAL SUPERELEVATION SECTION
SE > 6.0%

○ SEE TYPICAL SECTION NOTES ON PAGE 1-62.

## NOTES

PAVEMENT WIDENING ON THE LOW SIDE OF SUPER-ELEVATIONS SHALL BE CONSTRUCTED AS SHOWN ON THE "TYPICAL TANGENT SECTION" DETAIL ON THIS PAGE WITH THE RATE OF PAVEMENT WIDENING THE SAME AS SUPER-ELEVATION RATE.

[A] SEE SHOULDER CRITERIA ON PAGES 1-30 AND 1-36 FOR EXTENSION OF WIDENING STRUCTURE INTO THE SHOULDER AREA.

[B] PROVIDE SUFFICIENT WIDTH TO MAINTAIN 2′-0" MINIMUM CLEARANCE BEHIND GUIDE RAIL AND TO PREVENT GUIDE RAIL ENCROACHMENT ON THE USEABLE SHOULDER AREA.

[C] PROVIDE 1V:6H MAXIMUM TO SHOULDER SLOPE MINIMUM.

[D] 4′-0" ROUNDING TREATMENT NOT REQUIRED ON 3R PROJECTS.

**INTERSTATE, LIMITED ACCESS FREEWAYS, ARTERIALS, COLLECTORS AND LOCAL ROADS**

TYPICAL PAVEMENT WIDENING
(URBAN AND RURAL)
(ENGLISH)

DM2_CH1_2009.DGN

## TYPICAL ROADWAY CROSS SECTION NOTES

① See Publication 242, *Pavement Policy Manual*, for pavement design.

② See Design Criteria Notes for type of shoulder. For all new construction or reconstruction projects, refer to Publication 72M, *Roadway Construction Standards*, RC-25M, for shoulder cross sections.

③ The shoulder on the low side of a superelevated section shall be sloped at the same rate as the travel lane when the rate of travel lane slope exceeds the required shoulder slope of 4.0% or 6.0%. The shoulder cross slope may match the cross slope of the travel lane when the shoulder width is less than or equal to 3.0 ft.

④ Provide Pavement Base Drain in cuts and fills on all Interstate and Other Limited Access Freeways and Arterials. On Collectors and Local Roads, Pavement Base Drains shall be used only where subbase cannot be outletted. Where subsurface water is a potential problem, Underdrain or Combination Storm Sewer shall be used. Where the subbase cannot be outletted, the subgrade slope shall be in the direction of, and at the same rate as, the shoulder slope and the "ALTERNATE SUBSURFACE DRAINAGE TREATMENT" on Pages 1 - 40 and 1 - 41 shall be used.

⑤ The distance from the edge of the pavement shall be equal to the subbase depth.

⑥ Special consideration shall be given to the median treatment on the approach to structures to insure the elevation of the edges of the structure division are the same. This shall apply to medians up to 9.0 m (30 ft) on superelevated sections. Adequate length for shoulder slope transition between the roadway cross section and structure cross section should be provided.

⑦ See Design Criteria for widths of travel lanes and shoulders.

⑧ Slope shoulder at 6.0% for shoulder widths less than or equal to 2.4 m (8 ft). Slope shoulder at 4.0% for shoulder widths greater than 2.4 m (8 ft). The shoulder cross slope may match the cross slope of the travel lane when the shoulder width is less than or equal to 3.0 ft. When the roadway shoulder cross slope is different than the bridge shoulder slope, transition the roadway shoulder slope (7.5 m (25 ft) minimum) approaching the structure, to meet the slope of the bridge water table.

⑨ A 1V:12H slope may be adjusted to a 1V:6H slope to provide 150 mm (6 in) minimum clearance from bottom of swale to subgrade.

⑩ Subgrade slope shall be 1.0% minimum to shoulder slope maximum. For ease of construction, the subgrade slope under the shoulder area shall generally be the same as the pavement slope. A minimum subbase depth of 150 mm (6 in) shall be maintained under the outside of the shoulder, as shown on the "TYPICAL CUT SECTION" detail on Pages 1 - 40 and 1 - 41, or as shown on the "TYPICAL FILL SECTION - 4.5 m (15'-0") AND UNDER" detail on Pages 1 - 42 and 1 - 43.

⑪ Subgrade slope shall be in the direction of, and at the same rate as, the pavement slope. The depth of the subbase under the outside edge of the shoulder shall be as shown on the "TYPICAL MEDIAN TREATMENT" detail on Pages 1 - 40 and 1 - 41.

⑫ A curb or a combination curb and gutter section may be installed at the outside edge of a parking lane, although an offset of 0.3 m to 0.6 m (1 ft to 2 ft) is preferable. If a curb is to be installed where no parking lane is specified, provide a curb offset of 0.6 m (2 ft) desirable, 0.3 m (1 ft) minimum; it may be desirable to provide full width of shoulder as per Design Criteria in Tables 1.3 through 1.8, Matrix of Design Values.

## TYPICAL ROADWAY CROSS SECTION NOTES (Continued)

⑬ Maintain a minimum depth of 0.75 m (2 ft, 6 in) below the outside edge of shoulder or 150 mm (6 in) below top of subgrade, whichever is lower. Where it is not practical to construct a sufficiently deep swale, a Combination Storm Sewer and Underdrain should be constructed along the ditch line. The minimum depth of the Combination Storm Sewer and Underdrain will be either 300 mm (12 in) below the ditch line invert measured to the top of the pipe's bell or 150 mm (6 in) below the grade of the immediately adjacent subgrade, also measured to the top of the pipe's bell, whichever is lower. Provide a minimum of 150 mm (6 in) of tamped soil with appropriate Seeding and Soil Supplements placed over the Combination Storm Sewer and Underdrain.

Where subbase cannot be outletted, the pavement base drain shall be installed as indicated on the "ALTERNATE SUBSURFACE DRAINAGE TREATMENT" detail on Pages 1 - 40 and 1 - 41.

⑭ For new construction or reconstruction projects having a flexible pavement, see Pages 1 - 60 and 1 - 61 for typical pavement widening into the shoulder area.

⑮ For shoulder treatment in superelevated sections, see TYPICAL SUPERELEVATED SECTIONS detail on Pages 1 - 50 and 1 - 51.

⑯ Pavement widening on the low side of superelevations shall be constructed as shown on the "TYPICAL TANGENT SECTION" detail on Pages 1 - 60 and 1 - 61 with the rate of pavement widening the same as the superelevation rate.

⑰ Cut slope shall be 1V:2H unless otherwise indicated in the soil survey report.

⑱ For median treatment, see "TYPICAL MEDIAN TREATMENT" detail on Pages 1 - 40 and 1 - 41.

⑲ For shoulder treatment when the DDHV is equal to or greater than 250 Trucks, see Pages 1 - 46 and 1 - 47.

⑳ For guide rail type and clear zone criteria, refer to Chapter 12.

㉑ For slope treatment in cut and fill sections, see Pages 1 - 40, 1 - 41, 1 - 42 and 1 - 43.

㉒ For shoulder rounding details when superelevation is greater than 6.0%, see Pages 1 - 50 and 1 - 51.

㉓ For slope treatment, see Pages 1 - 56 and 1 - 57 for ARTERIALS and Pages 1 - 60 and 1 - 61 for COLLECTORS AND LOCAL ROADS.

㉔ Where subbase cannot be outletted, the pavement base drain shall be installed as indicated on the "ALTERNATE SUBSURFACE DRAINAGE TREATMENT" detail on Pages 1 - 40 and 1 - 41.

㉕ When there are roadside barriers, walls, or other vertical elements, it is desirable to provide a graded shoulder wide enough that the vertical elements will be offset a minimum of 0.6 m (2 ft) from the edge of the usable shoulder.

## 1.6 ACCELERATION AND DECELERATION (SPEED-CHANGE) LANES

The term speed-change lane, acceleration lane or deceleration lane, as used herein, applies broadly to the added pavement joining the traveled way of the highway with that of the turning roadway and does not necessarily imply a definite lane of uniform width.

The warrants for the use of speed-change lanes cannot be stated definitely. However, based on observations and past experience, the following general conclusions have been made:

**1.** Speed-change lanes are warranted on high-speed and on high-volume highways where a change in speed is necessary for vehicles entering or leaving the through-traffic lanes.

**2.** All drivers do not use speed-change lanes in the same manner.

**3.** Use of speed-change lanes varies with volume, the majority of drivers using them at high volumes.

**4.** The directional type of speed-change lane consisting of a long taper fits the behavior of most drivers and does not require maneuvering on a reverse-curve path.

**5.** Deceleration lanes on the approaches to intersections that also function as storage lanes for turning traffic are particularly advantageous and experience with them generally has been favorable.

For additional information on speed-change lanes as applicable to intersections and interchanges, refer to Chapter 3 and Chapter 4 and to the 2004 AASHTO Green Book, Chapter 9 and Chapter 10.

## 1.7 CONTROL OF ACCESS

Regulating access is called access control and is achieved through full control of access, partial control of access, access management, and driveway/entrance regulations of public access rights to and from properties abutting the highway facilities. The principal advantages of controlling access are the preservation or improvement of service and safety.

The functional advantage providing access control on a street or highway is the management of the interference with through traffic by vehicles or pedestrians entering, leaving and crossing the highway. Where access to a highway is managed, entrances and exits are located at points best suited to fit traffic and land-use needs and are designed to enable vehicles to enter and leave safely with minimum interference from through traffic. On streets or highways where there is no access management and roadside businesses are allowed to develop haphazardly, interference from the roadside can become a major factor in reducing the capacity, increasing the crash potential and eroding the mobility function of the facility. Full control of access is the most important single safety factor that may be designed into new highways. The extent and degree of access control that is feasible or ultimately possible are significant factors in defining the type of street or highway.

The following principles define access management techniques:

**1.** Classify the road system by the primary function of each roadway. Freeways emphasize movement and provide complete control of access. Local streets emphasize property access rather than traffic movement. Arterial and collector roads must serve a combination of both property access and traffic movement.

**2.** Limit direct access to roads with higher functional classifications. Direct property access should be denied or limited along higher class roadways, whenever reasonable access can be provided to a lower class roadway.

**3.** Locate traffic signals to emphasize through traffic movements. Signalized access points should fit into the overall signal coordination plan for traffic progression.

**4.** Locate driveways and major entrances to minimize interference with traffic operations. Driveways and entrances should be located away from other intersections to minimize crashes, to reduce traffic interference, and to provide for adequate storage lengths for vehicles turning into entrances.

**5.** Use curbed medians and locate median openings to manage access movements and minimize conflicts.

The extent of access management depends upon the location, type and density of development, and the nature of the highway system. Access management actions involve both the planning and design of new roads and the retrofitting of existing roads and driveways.

Access control on collector roads and streets should allow access to abutting properties consistent with the Level of Service desired. The control of access on urban collectors should be used primarily to ensure that access points conform to the adopted criteria for safety, location, design, construction and maintenance.

An important consideration in arterial development is the amount of access control, full or partial, that can be acquired. Although adequate access can normally be provided without interference to traffic operations, unique problems may be encountered in the form of slow-moving pieces of machinery. Therefore, access points should be situated to minimize their detrimental effects while the appropriate degree of access control or access management depends on the type and importance of an arterial. Provision of access management is vital to the concept of an arterial route if it is to provide the service life for which it is designed. Adequate and uniform spacing between access points should be considered in relationship to intersection sight distance restrictions and other intersections. This may help eliminate many conditions where a large vehicle at an intersection hides another vehicle on a nearby approach. High-volume access points can lead to particular operational problems if not properly situated.

Access control and access management on urban arterials should be carefully regulated to limit the number of points and their locations. Access control may be exercised (1) by statutory control which limits access to the cross streets or to other major traffic generators, (2) by zoning regulations which effectively control the type of property development along an arterial and influence the type and volume of traffic generated, (3) by driveway regulations to effectively preserve the functional character of the arterial and (4) by geometric highway design through the use of frontage roads; grade separations; limiting, prohibiting, or relocating left turns in and out of adjacent properties; and right-turn-in and right-turn-out arrangements. These geometric highway design measures effectively control access to the through lanes on the arterial street, provide access to adjoining property, separate local from through traffic and permit circulation of traffic along each side of the arterial.

For Interstate and Other Limited Access Freeways, with full control access, preference is given to through traffic by providing access connections with selected public roads only and by prohibiting crossings at-grade and direct private driveway connections. The principal advantages of access control include preservation of highway capacity, higher speeds, and improved safety for highway users.

Access to the interstate system shall be fully controlled. The interstate highway shall be grade separated at all railroad crossings and selected public crossroads. At-grade intersections shall not be allowed. To accomplish this, the intersecting roads are to be grade separated, terminated, rerouted, and/or intercepted by frontage roads. Access is to be achieved by interchanges at selected public roads.

On all sections of the Interstate System, access shall be controlled by acquiring access rights outright prior to construction or by the construction of frontage roads or both. Control of access is required for all sections of the Interstate System, including the full length of ramps and terminals on the crossroad. Control for connections to the crossroad should be affected beyond the ramp terminals by purchasing of access rights, providing frontage roads to control access, controlling added corner right-of-way areas or denying driveway permits. Such control should extend along the crossroads beyond the ramp terminal at least 30 m (100 ft) or more in urban areas and at least 90 m (300 ft) or more in rural areas. These distances usually should satisfy any congestion concerns. However, in areas where the potential for development exists which would create operational or safety problems, longer lengths of access control should be provided. New or revised access points on completed sections of Interstate and Other Limited Access highway facilities shall be achieved as indicated in Publication 10X, Design Manual, Part 1X, *Appendices to Design Manuals 1, 1A, 1B, and 1C,* Appendix Q.

The Interstate highway is to be grade separated at all railroad crossings and selected public crossroads. At-grade intersections are not allowed. To accomplish this, the connecting roads are to be terminated, rerouted or intercepted by frontage roads.

## 1.8 STAGE CONSTRUCTION

Stage construction may be implemented on highway projects in order to maximize total benefits from highway monies. It may be possible to maintain an acceptable Level of Service on a facility by constructing additional lanes or climbing lanes at a later date. The additional stages of construction would be required when the initial stage of construction falls into a lower, below desirable standard, Level of Service. For information concerning the Levels of Service concept, refer to the *HCM*.

Various factors should be taken into consideration when stage construction is considered. These include investment rates, long term inflationary construction rates, accuracy of the traffic growth rate projections, higher construction costs to perform stages of construction separately, lower maintenance costs for the initial stage, additional engineering expenditures for stage construction, additional safety on the ultimate facility versus the initial facility (particularly two lanes on four-lane right-of-way), etc. Many of the above items are highly intangible or sensitive to wide fluctuation which would make a detailed, analytical analysis (assuming quantifiable figures for the above factors are available) useless and in many cases erroneous.

For two-lane facilities which shall be ultimately four-lane divided, adequate provisions should include the following:

**1.** Right-of-way acquisition for the ultimate facility.

**2.** Possible grading of future lanes initially to obtain an earthwork balance. This could include all earthwork required for the ultimate or be limited to selected grading areas.

**3.** Grading of entire roadway width in massive rock cut areas requiring extensive blasting.

**4.** In areas of structures, where rock is encountered, the necessary blasting for structure footers should be performed.

**5.** Overpassing structures should be designed and constructed for the ultimate facility.

**6.** Medians in cut should be graded to provide for ultimate median drainage facilities. This may require slope flattening beyond the inlet to retain an inlet not requiring a backwall.

**7.** The initial shoulders shall be full width on both the left and the right side.

**8.** In the ultimate development of a four-lane divided facility, the initial two-lane surfacing should be constructed to form one of the two-lane one-way surfaces.

In designing ultimate six or eight lane facilities, provisions should be made to include the additional lanes in the median area with a 9.0 m (30 ft) desirable recovery area provided for the ultimate construction. The vertical clearances and span length requirements of overpass structures should be determined based on the ultimate facility.

The demand volume breakpoint, when an initial stage falls below the required Level of Service, may be determined from linearly interpolating between present day traffic and design year traffic.

# CHAPTER 1, APPENDIX A

## REDUCED BRIDGE WIDTH CRITERIA DOCUMENTATION

County ______________________________________ S.R. _______________ Section _______________
Local Route Number/Name _________________________________________________________________
Roadway Classification _____________________ Required Min. Reduced Bridge Width _________ ft
Construction Year ADT _____________________ Proposed Bridge Width______________________ ft
Design Year ADT ________________________ Proposed Traveled Way Width_______________ft
Truck Percentage __________________________ Proposed Shoulder Width ___________________ft

**All of the following conditions must be true in order to use the Reduced Bridge Widths as provided in Table 1.12, *Reduced Bridge Widths*, of this Chapter. (Indicate Yes or No for each item.)**

_____ The proposed bridge is on a roadway functionally classified as a Local, Collector, or Arterial, and is not on the NHS system.

_____ The proposed bridge width is not narrower than the existing approach roadway width, excluding any tapers to the existing bridge.

_____ The roadway within the vicinity of the subject bridge is not anticipated to be reconstructed to meet new construction criteria within the next 20 years.

_____ There is no approved planning at the local, county, regional, or state level to suggest future development pressures will make the proposed bridge width incompatible with future land use in the project corridor.

_____ The proposed bridge width will not restrict sight distance or turning movements adjacent to the bridge.

_____ Winter maintenance and drainage needs are met by the proposed bridge width.

_____ An analysis of crash data has been conducted and the subject location has no history of crashes related to the existing bridge width, or crash potential will be mitigated by the proposed bridge width.

_____ The subject roadway does not service a sufficient percentage of heavy trucks, buses, large farm equipment, or emergency vehicles such that these vehicles should govern design.

_____ The proposed bridge will provide adequate accommodation for pedestrians and bicyclists, in accordance with Publication 10X, Design Manual, Part 1X, *Appendices to Design Manuals 1, 1A, 1B, and 1C*, Appendix S.

_____ Appropriate safety features and/or advisory signing will be included in final construction plans.

_____ The proposed bridge width is compatible with the geometry of the adjacent roadway sections.

**Other conditions supporting the use of Reduced Bridge Width:**

________________________________________
________________________________________
________________________________________
________________________________________
________________________________________
________________________________________
________________________________________
________________________________________

**List the safety features that will be included in the final construction plans:**

________________________________________
________________________________________
________________________________________
________________________________________
________________________________________
________________________________________
________________________________________
________________________________________

Recommended By: ______________________________ Date:__________________
Design Plans Engineer/Portfolio Manager

Recommended By: ______________________________ Date:__________________
Design Bridge Engineer

Recommended By: ______________________________ Date:__________________
Design Safety Engineer

Approved By: ______________________________ Date:__________________
Assistant District Executive – Design

# CHAPTER 2

## DESIGN ELEMENTS AND DESIGN CONTROLS

### 2.0 INTRODUCTION

There are many factors that contribute to the decisions required for the geometric design elements and controls utilized in the location and the design of the various types of highways. Without some type of basic framework of design controls, the judgment of the individual designers may vary considerably. This Chapter presents the guidelines required to tailor the highway to the terrain, to the controls of the land usage and to the type of traffic anticipated. In applying these guidelines, it is important to follow the basic principle that consistency in design is of major importance on any section of highway.

Additional sources of information and criteria to supplement the design elements and related concepts presented in this Chapter are contained in the 2004 AASHTO Green Book, the *HCM* and the *MUTCD*.

### 2.1 HORIZONTAL ALIGNMENT

To obtain balance in highway design, all geometric elements should be designed to provide safe, continuous operation, as far as economically practical, through the use of design speed as an overall design control. Where curvature in the highway alignment is required, it should be based on an appropriate relationship between design speed and curvature and their joint relationships with superelevation and side friction. These factors shall be properly balanced to produce an alignment that is safe, in harmony with the topography and adequate for the design classification of the roadway or highway. These factors are discussed at length in subsequent Sections. To avoid poor design practices, the following general controls for horizontal alignment should be used:

**1.** Alignment should be as directional as practical but should be consistent with the topography and with preserving developed properties and community values.

**2.** In alignment developed for a given design speed, the minimum radius of curvature for that speed should be avoided wherever practical.

**3.** Consistent alignment should always be sought.

**4.** For small deflection angles, curves should be sufficiently long enough to avoid the appearance of a kink.

**5.** Avoid sharp curvature on long, high fills.

**6.** Caution should be exercised in the use of compound circular curves.

**7.** Abrupt reversals in alignment should be avoided.

**8.** The "broken-back" or "flat-back" arrangement of curves (with a short tangent between two curves in the same direction) should be avoided except where very unusual topographical or right-of-way conditions make other alternatives impractical.

**9.** To avoid the appearance of inconsistent distortion, the horizontal alignment should be coordinated carefully with the profile design as presented in Section 2.3. Such coordination is especially important at railroad-highway grade crossings.

For additional information concerning general and design considerations for horizontal alignment and additional presentations on the practical application of the relevant criteria, refer to the section "General Controls for Horizontal Alignment" in the 2004 AASHTO Green Book, Chapter 3.

## 2.2 VERTICAL ALIGNMENT

As with other design elements, the characteristics of vertical alignment are influenced greatly by basic controls related to design speed, highway functional classifications and the terrain conditions. Within these basic controls, there are several general controls for vertical alignment that should be considered that include:

**1.** A smooth gradeline with gradual changes, as consistent with the type of highways, roads or streets and the character of terrain, should be sought for in preference to a line with numerous breaks and short lengths of grades.

**2.** The "roller-coaster" or the "hidden-dip" type of profile should be avoided.

**3.** Undulating gradelines involving substantial lengths of momentum grades should be evaluated for their effect on traffic operation.

**4.** A broken-back gradeline (two vertical curves in the same direction separated by short sections of tangent grade) generally should be avoided, particularly in sags where the full view of both vertical curves is not pleasing.

**5.** It may be preferable, on long grades, to place the steepest grades at the bottom and flatten the grades near the top of the ascent or to break the sustained grade by short intervals of flatter grade.

**6.** Where at-grade intersections or railroad-highway grade crossings occur on roadway sections with moderate to steep grades, it is desirable to reduce the grade through the intersection or railroad-highway grade crossing.

**7.** Sag vertical curves should be avoided in cuts unless adequate drainage can be provided.

For additional information concerning general and design considerations for vertical alignment and additional presentations on the practical application of the relevant criteria, refer to the section "General Controls for Vertical Alignment" in the 2004 AASHTO Green Book, Chapter 3.

## 2.3 CONTROLS FOR COMBINATION HORIZONTAL AND VERTICAL ALIGNMENTS

Horizontal and vertical alignments represent permanent design elements which warrant thorough examination and study. They should not be designed independently, but should complement each other to avoid alignment deficiencies. Excellence in the design of each and the integration of their interrelated concepts results in a completed highway that provides increased safety, usefulness, uniform speeds and improved appearances on which to travel.

The proper combination of horizontal and vertical alignment is obtained through engineering studies with consideration given to the following general guidelines:

**1.** Curvature and grades should be in proper balance. Tangent alignment or flat curvature at the expense of steep or long grades and excessive curvature with flat grades both represent poor design. A logical design that offers the best combination of safety, capacity, ease and uniformity of operation and pleasing appearance within the practical limits of terrain and area traversed is a compromise between these two extremes.

**2.** Vertical curvature superimposed on horizontal curvature, or vice versa, generally results in a more pleasing facility, but such combinations should be analyzed for their effect on traffic. Successive changes in profile not in combination with horizontal curvature may result in a series of humps visible to the driver for some distance which represents an undesirable condition.

**3.** Sharp horizontal curvature should not be introduced at or near the top of a pronounced crest vertical curve. This condition is undesirable because the driver may not perceive the horizontal change in alignment, especially at night. The disadvantages of this arrangement are avoided if the horizontal curvature leads the vertical curvature, i.e., the horizontal curve is made longer than the vertical curve. Suitable designs can also be developed by using design values well above the appropriate minimum values for the design speed.

**4.** Sharp horizontal curvature should not be introduced near the bottom of a steep grade approaching or near the low point of a pronounced sag vertical curve. Because the view of the road ahead is foreshortened, any horizontal curvature other than a very flat curve assumes an undesirable, distorted appearance. Further, vehicle speeds, particularly for trucks, are often high at the bottom of grades and erratic operations may result, especially at night.

**5.** On two-lane roads and streets, the need for passing sections at frequent intervals and including an appreciable percentage of the length of the roadway often supersedes the general guidelines for combinations of horizontal and vertical alignment. In such cases, it is appropriate to work toward long tangent sections to assure sufficient passing sight distance in design.

**6.** Horizontal curvature and profile should be made as flat as practical at intersections and at railroad-highway grade crossings where sight distance along both roads or streets is important and vehicles may have to slow or stop.

**7.** On divided highways and streets, variation in width of median and the use of independent profiles and horizontal alignments for the separate one-way roadways are desirable. Where traffic justifies provision of four lanes, a superior design without additional cost generally results from such practices.

**8.** In residential areas, the alignment should be designed to minimize nuisance to the neighborhood. Generally, a depressed facility makes a highway less visible and less noisy to adjacent residents. Minor horizontal adjustments can sometimes be made to increase the buffer zone between the highway and clusters of homes.

**9.** The alignment should be designed to enhance scenic views of the natural and manmade environment, such as rivers, rock formations, parks and outstanding structures. The highway should head into, rather than away from, those views that are outstanding; it should fall toward those features of interest at a low elevation and it should rise toward those features best seen from below or in silhouette against the sky.

Coordination of horizontal and vertical alignment should begin with preliminary design, at which time adjustments in either or both can be made jointly to obtain the desired coordination. The design criteria contained in Chapter 1 and the elements of design covered in this Chapter should be kept in mind. Design speed may require adjustment during the process to conform to variations in speeds of operation due to changes in alignment characteristics needed to accommodate unusual terrain, railroad-highway grade crossings or right-of-way controls. All aspects of terrain, traffic operation and appearance should be considered and the horizontal and vertical lines should be adjusted and coordinated before the calculations and the preparation of construction plans to large scale are started.

For highways with gutters, the effects of superelevation transitions on gutter line profiles should be examined. This can be particularly significant when flat grades are involved and can result in local depressions. Slight shifts in profile in relation to horizontal curves can sometimes eliminate the problem.

For additional information on the controls and general considerations for the combination of horizontal and vertical alignment, refer to the section "Combinations of Horizontal and Vertical Alignment" in the 2004 AASHTO Green Book, Chapter 3.

## 2.4 SIMPLE CURVE COMPUTATIONS

The changes in direction along a highway are basically accounted for by curves consisting of portions of a circle. The simple curve computation method shall be used for all curve computations as indicated in Figure 2.1.

## 2.5 SURVEY AND CONSTRUCTION BASELINES

**1.** Where spiralled curves are utilized as indicated in Section 2.15, all surveying and design computations on Survey and Construction Baselines (or Centerlines) shall be achieved utilizing spiralled curves except as indicated in item 3.a below. Referencing right-of-way in spiralled areas shall be as illustrated in Figure 2.2.

**2.** For parallel roadways with median widths of 25 m (84 ft) or less:

**a.** One Survey and Construction Centerline, located in the center of the median, shall be used for surveying of the cross sections and the design of the roadway.

**b.** One grade profile shall be required for sections of roadway that have the same grade elevations at the "Grade Points" or a constant difference between the "Grade Points" of the two pavements.

**3.** For transition areas with variable width medians of 25 m (84 ft) or less:

**a.** One Survey Centerline located in the center of the median shall be used for surveying the cross sections and the referencing of the right-of-way. The surveying on the survey Centerline shall be done utilizing simple curves.

**b.** Two Construction Baselines located: on the median edges of four-lane pavements, on the pavements 3.6 m (12 ft) from the median edges of the pavements of six-lane pavements, on the pavements 7.2 m (24 ft) from the median edges of the pavements of eight-lane pavements, shall be used for the design of the roadways.

**c.** Two Grade Profiles shall be developed at the same location as the Construction Baselines.

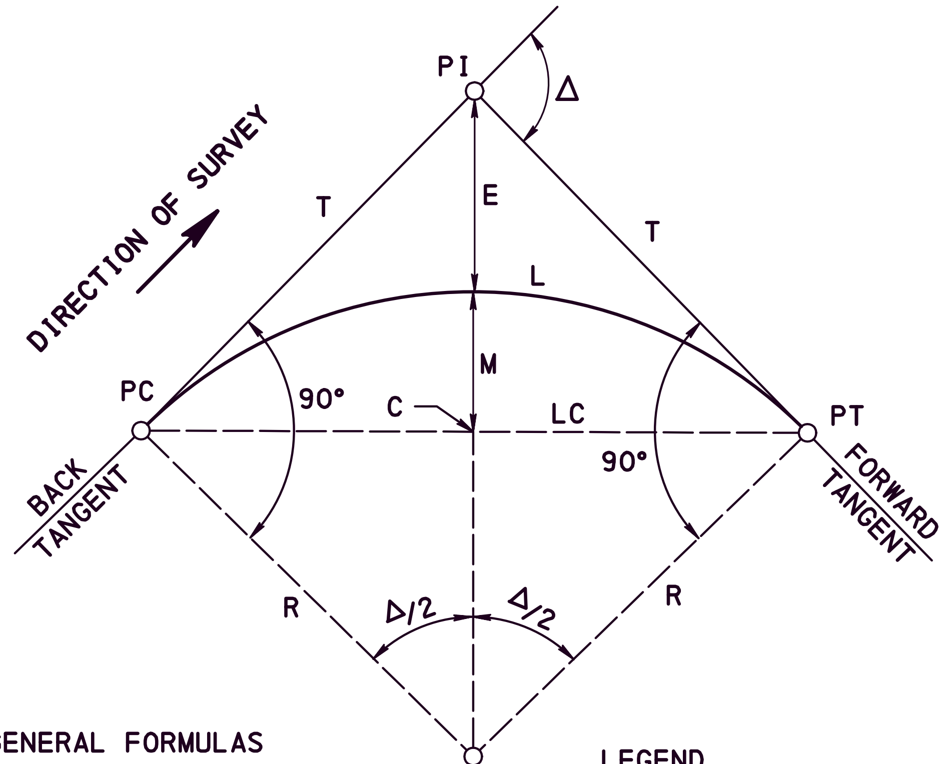
**4.** For roadways with medians in excess of 25 m (84 ft):

**a.** Two Survey and Construction Baselines located: on the median edges of four-lane pavements, on the pavements 3.6 m (12 ft) from the median edges of the pavements of six-lane pavements, on the pavements 7.2 m (24 ft) from the median edges of the pavements of eight-lane pavements shall be used for surveying the cross sections, for the design of the roadways and for the referencing of the right-of-way.

**b.** Two grade profiles shall be developed at the same locations as the Survey and Construction Baselines.

**5.** Survey Baseline shall be established and staked for all side roads. For information on the placing of Fine Grade Stakes, see Publication 122M, *Surveying and Mapping Manual*.

**6.** All Survey Baselines shall be monumented as stated in Publication 122M, *Surveying and Mapping Manual*, Chapter 4, Section 4.3.




**GENERAL FORMULAS FOR ARC DEFINITION**

$T = R \text{ Tangent } \frac{\Delta}{2}$

$LC = 2 R \sin \frac{\Delta}{2}$

$E = T \tan \frac{\Delta}{4}$

WHEN 'R' IS KNOWN, $E = R \sec \frac{\Delta}{2} - R$

$= R \text{ EXSEC } \frac{\Delta}{2}$

$M = E \cos \frac{\Delta}{2}$

WHEN 'R' IS KNOWN, $M = R\left(1 - \cos \frac{\Delta}{2}\right)$

$= R \text{ VERS } \frac{\Delta}{2}$

$L = \frac{\pi R \Delta}{180}$

ENGLISH: $L = \frac{100\Delta}{D}$ WHEN Δ AND 'D' ARE IN MINUTES

ENGLISH: $D = \frac{5729.578}{R}$

LOCATING THE PC AND PT

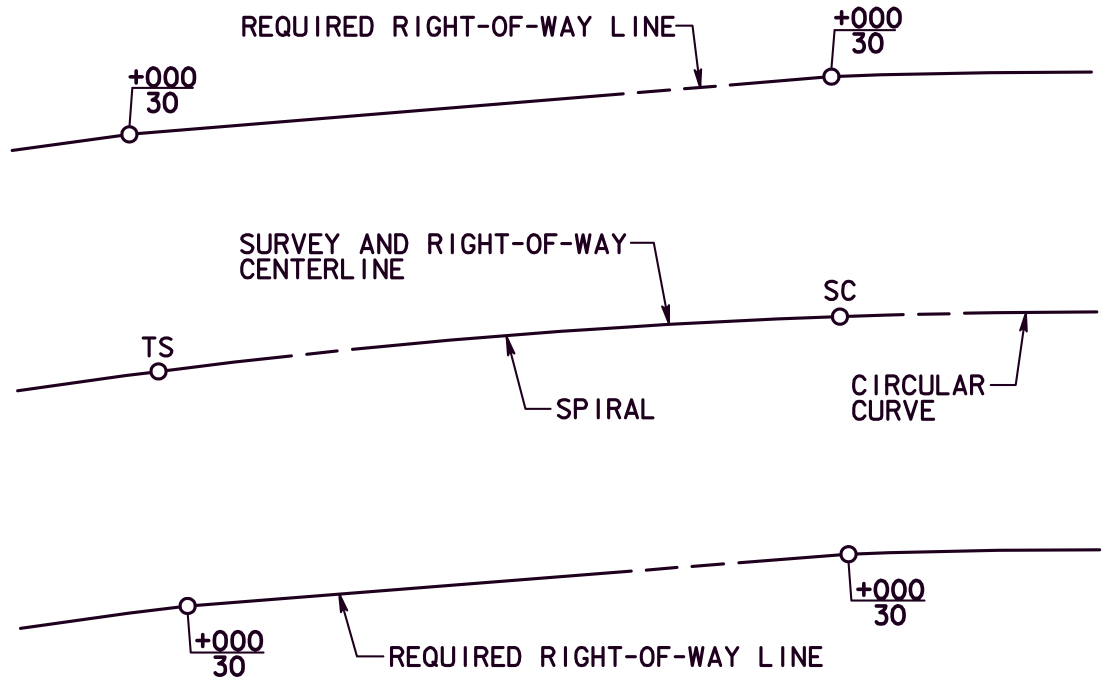
STA PC = STA PI − T

STA PT = STA PC + L

**LEGEND**

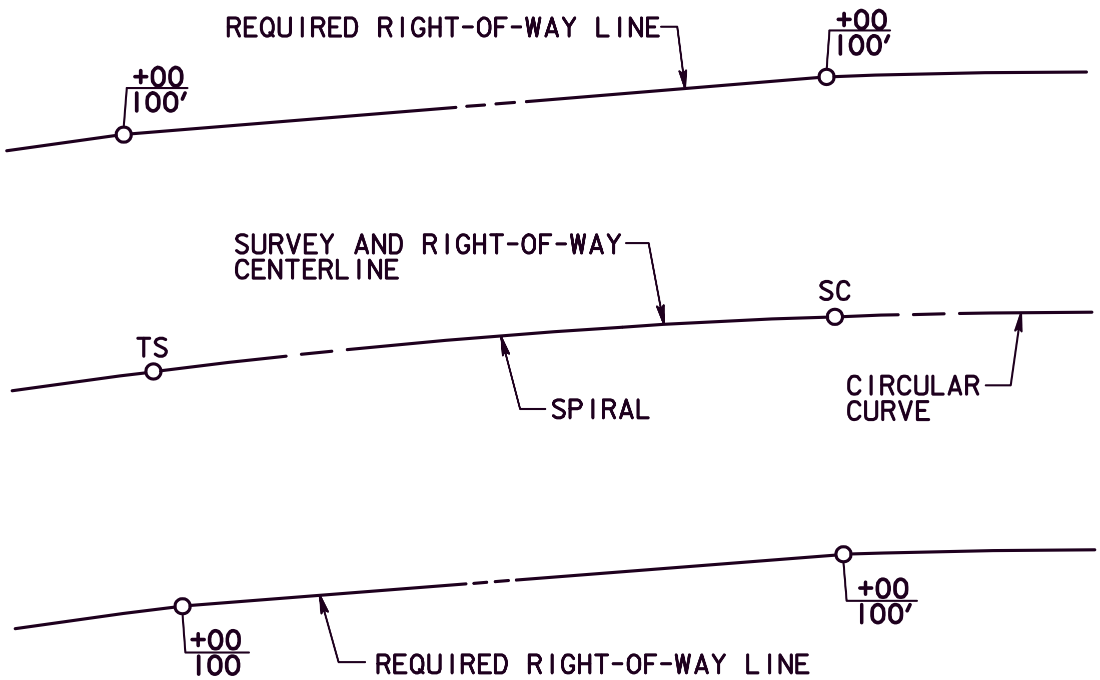
PI = POINT OF INTERSECTION
PC = POINT OF CURVATURE
PT = POINT OF TANGENCY
Δ = DEFLECTION ANGLE BETWEEN THE TANGENTS
T = TANGENT DISTANCE
E = EXTERNAL DISTANCE
R = RADIUS OF THE CIRCULAR ARC
M = MIDDLE ORDINATE
LC = LONG CHORD (DISTANCE BETWEEN PC AND PT)
C = MIDPOINT OF LONG CHORD
L = LENGTH OF CURVE
π = PI (CONSTANT)
D = DEGREE OF CURVATURE

FIGURE 2.1
SIMPLE CURVE COMPUTATION METHOD




NOTE : THE RIGHT-OF-WAY LINE THROUGH THE SPIRAL AREA IS A STRAIGHT LINE. IF NECESSARY, TO CONSERVE RIGHT-OF-WAY, A SERIES OF STRAIGHT LINES MAY BE USED.

FIGURE 2.2 (METRIC)
REFERENCING RIGHT-OF-WAY IN SPIRALLED AREAS




<u>NOTE</u> : THE RIGHT-OF-WAY LINE THROUGH THE SPIRAL AREA IS A STRAIGHT LINE. IF NECESSARY, TO CONSERVE RIGHT-OF-WAY, A SERIES OF STRAIGHT LINES MAY BE USED.

FIGURE 2.2 (ENGLISH)
REFERENCING RIGHT-OF-WAY IN SPIRALLED AREAS

## 2.6 MINIMUM RADIUS

**A. Definition.** The minimum radius is a limiting value of curvature for a given design speed and is determined from the maximum rate of superelevation and the maximum allowable side friction factor. Thus, the minimum radius is a significant value in alignment design and is an important control value for the determination of superelevation rates for flatter curves.

In metric units, the minimum radius ($R_{Min}$) can be calculated from the following curve formula:

$$R_{Min} = \frac{V^2}{127(0.01e_{max} + f_{max})}$$

where: $e_{max}$ = Rate of roadway superelevation (%)
$f_{max}$ = Side friction factor
$R_{Min}$ = Minimum radius (m)
$V$ = Design speed (km/h)

In English units, the minimum radius ($R_{Min}$) can be calculated from the following curve formulas:

$$R_{Min} = \frac{V^2}{15(0.01e_{max} + f_{max})}$$

where: $e_{max}$ = Rate of roadway superelevation (%)
$f_{max}$ = Side friction factor
$R_{Min}$ = Minimum radius (ft)
$V$ = Design speed (mph)

**B. Design for Rural Highways, Urban Freeways and High-Speed Urban Streets.** The minimum radius determined for limiting values of superelevation, side friction factor and design speed is presented in the 2004 AASHTO Green Book, Chapter 3, Exhibit 3-15. The values for minimum radius shown in Exhibit 3-15 are based on maximum side friction factors recommended for rural highways (maximum superelevation rate of 8.0%) and urban highways and streets (maximum superelevation rate of 6.0%). In recognition of safety considerations, use of a maximum superelevation rate of 4.0% should be limited to urban conditions.

Utilizing less than the minimum radius results in a reduction in safety if a corresponding increase in superelevation or a reduction in design speed does not occur. When it is necessary to use less than the minimum radius, approval from the Director, Bureau of Project Delivery shall be obtained before proceeding with the design.

**C. Design for Low-Speed Urban Streets.** On low-speed urban streets where speed is relatively low and variable, the use of superelevation for horizontal curves can be minimized. Where side friction demand exceeds the assumed available side friction factor for the design speed, superelevation, within the range from the normal cross slope to maximum superelevation, is provided.

The 2004 AASHTO Green Book, Chapter 3, Exhibit 3-12 shows the recommended side friction factors for low-speed streets and highways as a dashed-line. These recommended side friction factors provide a reasonable margin of safety at low-speeds and lead to somewhat lower superelevation rates as compared to the high-speed friction factors. The side friction factors vary with the design speed from 0.40 at 15 km/h (0.38 at 10 mph) to 0.15 at 70 km/h (45 mph). Based on the maximum allowable side friction factors from the 2004 AASHTO Green Book, Chapter 3, Exhibit 3-12, the 2004 AASHTO Green Book, Chapter 3, Exhibit 3-15 gives the minimum radius for the maximum superelevation rates of 4.0%, 6.0%, and 8.0%.

For the design of horizontal curves on low-speed urban streets, drivers have developed a higher threshold of discomfort. By this design method, it is assumed that none of the lateral force is counteracted by superelevation so long as the side friction factor is less than the specified maximum for the radius of the curve and the design speed.

The equation defined in Section 2.6.A would also apply for determining the maximum comfortable speed on horizontal curves.

Although superelevation is advantageous for traffic operations, various factors often combine to make its use impractical in many low-speed urban areas. These factors include wide pavement areas, the need to meet the grade of adjacent property, surface drainage considerations, the desire to maintain low-speed operation, and frequency of cross streets, alleys, and driveways. Therefore, horizontal curves on low-speed urban streets are frequently designed without superelevation, sustaining the force solely with side friction. On these curves for traffic entering a curve to the left, the normal cross slope is an adverse or negative superelevation, but with flat curves the resultant friction needed to sustain the lateral force, even given the negative superelevation, is small.

For further guidance on design for low-speed urban streets, refer to the section "Design for Low-Speed Urban Streets" in the 2004 AASHTO Green Book, Chapter 3, and Exhibits 3-12, 3-16, and 3-17.

## 2.7 GRADES

Roadways should be designed to encourage uniform operation through the selection of a design speed in correlation with various geometric features of the road or street. To date, definite conclusions concerning the appropriate relationship of roadway grades to design speed have not been reached. The material presented in this section presents the vehicle-operating characteristics on grades and the control grades for design.

The effect of grades on passenger cars varies greatly due to the practices of passenger car drivers. It is generally accepted that nearly all passenger cars can readily negotiate grades as steep as four to five percent without an appreciable loss in speed below that normally maintained on level roadways. Operation on a three percent upgrade has only a slight effect on passenger car speeds compared to operations on the level. On steeper upgrades, speeds decrease progressively with increases in the grade. On downgrades, passenger car speeds are generally slightly higher than on level sections.

The effect of grades on truck speeds is more pronounced than on speeds of passenger cars. On upgrades, trucks generally decrease speed by seven percent or more that is dependent primarily on the length and steepness of the grade and the trucks weight/power ratio. On downgrades, trucks generally increase speed by up to about five percent. The effect of rate and length of grade on the speed of a typical heavy truck is illustrated in the 2004 AASHTO Green Book, Chapter 3, Exhibits 3-55 and 3-56, respectively. The data presented in these figures can serve as a valuable design guide to appraise the effect of trucks on traffic operations for a given set of profile conditions. The travel time and speed of trucks on grades is directly related to the weight/power ratio which is expressed in terms of gross weight and net power in units of kilograms/kilowatt (weight/horsepower). It has been found that trucks with weight/power ratios of about 120 kg/kW (200 lb/hp) provide acceptable operating characteristics and assures a minimum speed of about 60 km/h (35 mph) on a three percent upgrade.

Consideration of recreational vehicles (RV's) on grades is not as critical as consideration of trucks. However, on certain routes, such as designated recreational routes, where a low percentage of trucks may not warrant a truck climbing lane, sufficient recreational vehicle traffic may indicate a need for an additional lane.

The maximum and minimum grade controls for design are dependent on the topography and the functional classification of the highway and street and are presented in the Matrices of Design Values in Chapter 1, Table 1.3 through Table 1.8. The maximum design grade should be used only infrequently; in most cases, grades should be less than the maximum design grade. A minimum grade of 0.5% may be used. Particular attention should be given to the design of storm water inlets and their spacing to keep the spread of water on the traveled way within tolerable limits.

For additional information on vehicle-operating characteristics on grades and control grades (maximum and minimum) for design, refer to the section "Grades" in the 2004 AASHTO Green Book, Chapter 3.

## 2.8 CRITICAL LENGTH OF GRADE

The term "critical length of grade" is used to indicate the maximum length of a designated upgrade on which a loaded truck can operate without an unreasonable reduction in speed. If the desired freedom of operation is to be maintained on grades longer than critical, design adjustments such as a change in location to reduce grades or the addition of extra lanes should be considered.

To establish design values for critical lengths of grade where gradeability of trucks is the determining factor, the following data are required:

**1.** The size and power of a representative truck or truck combination for use as a design vehicle including gradeability data. A representative vehicle would be a loaded truck with a weight/power ratio of 120 kg/kW (200 lb/hp) with the gradeability data based on the 2004 AASHTO Green Book, Chapter 3, Exhibits 3-55 and 3-56.

**2.** Speed at entrance to critical length of grade. The average running speed, as related to design speed, can be used to approximate vehicle speed beginning an uphill climb subject to adjustments as approach conditions may determine.

**3.** Minimum speed on the grade below in which interference to following vehicles is considered unreasonable. Although no specific data are available for minimum tolerable speeds of trucks on upgrades, such minimum speeds should be in direct relation to the design speed. Minimum truck speeds of about 40 km/h to 60 km/h (25 mph to 40 mph) for the majority of highways (on which design speeds are about 60 km/h to 100 km/h (40 mph to 60 mph)) are not unreasonably annoying to following vehicles if the time interval during which they are unable to pass is not too long.

A common basis for determining critical length of grade is based on a reduction in speed of trucks below the average running speed of traffic. It is recommended that a 15 km/h (10 mph) reduction criterion be used as the general guide to determine critical lengths of grade. Identification of the critical length of grade for various percents of grade are discussed in the section "Critical Lengths of Grade for Design" in the 2004 AASHTO Green Book, Chapter 3 and may be determined from the 2004 AASHTO Green Book, Chapter 3, Exhibit 3-59. Where recreational vehicles could be a control to determine critical length of grade, the control shall be determined from the 2004 AASHTO Green Book, Chapter 3, Exhibit 3-60.

Steep downhill grades can also have a detrimental effect on the capacity and safety of facilities with high traffic volumes and numerous heavy trucks. Some downgrades are long and steep enough that some heavy vehicles travel at crawl speeds to avoid loss of control on the grade. Therefore, there are instances where consideration should be given to providing a truck lane for downhill traffic. Procedures have been developed in the *HCM* to analyze this situation.

The suggested design criterion to determine the critical length of grade is offered as a guideline. In some instances, the terrain or other physical controls may preclude shortening or flattening grades to meet these controls. Where the length of critical grade is exceeded, consideration should be given to providing an added uphill lane or climbing lane for slow-moving vehicles as presented in Section 2.11.

## 2.9 DESIGN SPEED

Design speed is a selected speed used to determine the various geometric features of the roadway. The assumed design speed should be a logical one with respect to the topography, anticipated operating speed, the adjacent land use, and the functional classification of the highway.

The selected design speed should be consistent with the speeds that drivers are likely to expect on a given highway facility. Where a reason for limiting speed is obvious, drivers are more apt to accept lower speed operation than where there is no apparent reason. A highway of higher functional classification may justify a higher design speed than a lesser classified facility in similar topography, particularly where the savings in vehicle operation and other operating costs are sufficient to offset the increased costs of right-of-way and construction. A low design speed, however, should not be selected where the topography is such that drivers are likely to travel at high speeds. Drivers do not adjust their speeds to the importance of the highway, but to their perception of the physical limitations of the highway and its traffic.

**A. Projects with New or Modified Speed Posting.** For projects on new location, or projects where the desired operating speed differs from the current posted speed on the roadway, the design speed should be selected with respect to the topography, anticipated operating speed, the adjacent land use, and the functional classification of the highway. The geometric features of the roadway should be designed appropriately, consistent with the established design speed, to encourage the appropriate operating speed.

Every effort should be made to use the most practical design speed to attain a desired degree of safety, mobility, and efficiency within the constraints of environmental quality, economics, aesthetics, and social or political impacts. Once the design speed is selected, all of the pertinent highway features should be related to it to obtain a balanced design.

**B. Projects Maintaining Existing Speed Posting.** For resurfacing, rehabilitation, and restoration (3R), and reconstruction projects, it may be appropriate to establish the design speed based on the existing posted speed limit upon analysis of safety, mobility, and efficiency. On expressways and Interstate facilities, it may be appropriate to set the design speed 10 km/h (5 mph) greater than the posted speed limit. On all other facilities, the selected design speed should equal the posted speed limit unless the aforementioned analysis of safety, mobility and efficiency warrants setting the design speed 10 km/h (5 mph) greater than the posted speed limit. The geometric features of the roadway should be designed consistent with the established design speed and the posted speed limit installed during construction should reflect the established design speed.

**C. Existing Roadways with No Posted Regulatory Speed Limit.** If a roadway does not have a posted regulatory speed limit, a 55 mph speed limit applies, except for the following:

- 35 mph in urban districts.
- 25 mph on non-numbered roads in residence districts which have the "local" roadway classification. Note that locally owned roads may not all have a "local" functional classification. Numbered traffic routes refer to Interstate routes, US routes and PA routes.

The Vehicle Code defines the following terms:

"Residence district" - The territory contiguous to and including a highway not comprising a business district when the property on the highway for a distance of 300 ft or more is in the main improved with residences or residences and buildings in use for business.

"Urban district" - The territory contiguous to and including any street which is built up with structures devoted to business, industry or dwelling houses situated at intervals of less than 100 ft for a distance of a quarter of a mile or more.

Refer to Publication 46, *Traffic Engineering Manual* for further clarification on "residence district" and "urban district". See also the Title 75, Vehicle Code § 3362 for more information:

http://www.dmv.state.pa.us/pdotforms/vehicle_code/chapter33.pdf

**D. Non-Applicable Design Speeds.** Design speed may not be applicable to certain features of roundabouts, stop controlled and T-intersections since slow or stop conditions preclude attainment.

## 2.10 TERRAIN

The topography of the land traversed has an influence on the vertical and horizontal alignments of roadways and streets. To characterize variations, topography is separated into three classifications according to terrain which include: (1) level terrain, (2) rolling terrain and (3) mountainous terrain.

In level terrain, highway sight distances, as governed by both horizontal and vertical restrictions, are generally long or can be made to be so without construction difficulty or major expense.

In rolling terrain, natural slopes consistently rise above and fall below the road or street grade, and occasional steep slopes offer some restriction to normal horizontal and vertical roadway alignment.

In mountainous terrain, longitudinal and transverse changes in the elevation of the ground with respect to the road or street are abrupt, and benching and side hill excavations are frequently needed to obtain acceptable horizontal and vertical roadway alignment.

Terrain classifications pertain to the general character of a specific route corridor. Routes in valleys, passes, or mountainous areas that have all the characteristics of roads or streets traversing level or rolling terrain should be classified as level or rolling. In general, rolling terrain generates steeper grades, then level terrain, causing trucks to reduce speeds below those of passenger cars; mountainous terrain has even greater effects, causing some trucks to operate at crawl speeds.

## 2.11 CLIMBING LANES

On two-lane highways, a climbing lane can be used as an additional vehicle lane to accommodate slow moving vehicles and to improve operations on upgrades. A highway section with a climbing lane is not considered as a three-lane highway, but a two-lane highway with an added lane for vehicles moving slowly uphill so that other vehicles using the normal lane to the right of the centerline are not delayed.

A climbing lane is normally provided, as an added lane, for the upgrade direction of a two-lane highway where the grade, traffic volume and heavy vehicle volume combine to degrade traffic operations from those on the approach to the grade. On highways with low volumes, only an occasional vehicle is delayed and climbing lanes, although desirable, may not be justified economically even where the critical length of grade is exceeded.
The following three criteria, reflecting economic considerations, should be satisfied to justify a climbing lane:

**1.** Upgrade traffic flow rate in excess of 200 vehicles per hour.

**2.** Upgrade truck flow rate in excess of 20 vehicles per hour.

**3.** One of the following conditions exists:

- **a.** A 15 km/h (10 mph) or greater speed reduction is expected for a typical heavy truck.
- **b.** Level-of-Service E or F exists on the grade.
- **c.** A reduction of two or more levels-of-service is experienced when moving from the approach segment to the grade.

The upgrade flow rate is determined by multiplying the predicted or existing design hour volume by the directional distribution factor for the upgrade direction and dividing the result by the peak hour factor. The number of upgrade trucks is obtained by multiplying the upgrade flow rate by the percentage of trucks in the upgrade direction.

On Interstate highways with ascending grades which exceed the critical design length, a climbing lane analysis should be performed and climbing lanes added where appropriate.

In addition to evaluating speed reduction, the Level-of-Service should be considered from the standpoint of highway capacity to justify the inclusion of a climbing lane. Also, safety considerations may justify the addition of a climbing lane regardless of grade or traffic volumes. For additional information on the principal determinants of need and the applicable criteria and detailed methodology for the inclusion of climbing lanes, refer to the section "Climbing Lanes" in the 2004 AASHTO Green Book, Chapter 3 and the *HCM*.

## 2.12 VERTICAL CURVES

**A. General Considerations.** Vertical curves are used to effect gradual changes between tangent grades at their point of intersection. Vertical curves that are offset below the tangent are crest vertical curves and those offset above the tangent are sag vertical curves as shown in Figure 2.3. These curves should be simple in application and should result in a design that is safe (ample sight distance), comfortable in operation (proper rate of change of grade), adequate for drainage and exhibit a pleasing appearance. The major control for safe operation on crest vertical curves is the provision of ample sight distances for the design speed. Minimum stopping sight distances should be provided in all cases. Wherever practical, more liberal stopping sight distances should be used.

For simplicity, a parabolic curve with an equivalent vertical axis centered on the point of vertical intersection (PVI) is usually used in roadway profile design. On certain occasions, because of critical clearance or other controls, the use of asymmetrical vertical curves may be appropriate. The derivation and use of the relevant equations for computing symmetrical and asymmetrical vertical curves can be found in numerous highway engineering texts.

**B. Crest Vertical Curves.** Minimum lengths of crest vertical curves based on sight distance criteria generally are satisfactory from the standpoint of safety, comfort and appearance. An exception may be at decision areas, such as sight distance to ramp exit gores, where longer lengths are needed. For additional information concerning decision sight distance, refer to Section 2.17.

The major control for safe operation on crest vertical curves is the provision of ample sight distances for the design speed. Minimum stopping sight distance should be provided in all cases as indicated in the 2004 AASHTO Green Book, Chapter 3, Exhibit 3-72. When the design speed is less than 30 km/h (20 mph), the stopping sight distances indicated in the 2004 AASHTO Green Book, Chapter 9, Exhibit 9-70 should be used. The design controls for crest vertical curves based on stopping sight and passing sight distances and the general formulas to determine minimum lengths of crest vertical curves are contained in the section "Crest Vertical Curves" in the 2004 AASHTO Green Book, Chapter 3.

**C. Sag Vertical Curves.** At least four different criteria to establish the lengths of sag vertical curves are recognized that include: (1) headlight sight distance, (2) passenger comfort, (3) drainage control and (4) general appearance. The design controls for these curves differ from those for crest vertical curves and separate design values are required. Sag vertical curves shorter than the lengths computed may be justified for economic reasons in cases where an existing feature, such as a structure not ready for replacement, controls the vertical profile. For formulas and general design consideration for sag vertical curves refer to the section "Sag Vertical Curves" in the 2004 AASHTO Green Book, Chapter 3.

## 2.13 SUPERELEVATION

**A. General.** When a vehicle moves in a circular path, it undergoes a centripetal acceleration that acts toward the center of curvature. This acceleration is sustained by a component of the vehicle's weight related to the roadway superelevation, by the side friction developed between the vehicle's tires and the pavement surface, or by a combination of the two. The factor, known as superelevation, consists of tilting the roadway to provide safe and continuous vehicle operation. When a vehicle travels at a constant speed on a curve superelevated for that specific speed, the side friction value is zero and the centripetal acceleration is sustained by the vehicle's weight resulting in no steering effort on the part of the vehicle operator. The curves on a given facility are designed for a certain running speed and vehicles traveling at that speed should be able to negotiate the turns with ease. Vehicles, however, travel at a wide range of speeds and therefore the drivers must exert themselves to successfully negotiate these curves. They are aided by side friction on the tires.

From the above, it is evident that superelevation is predicated on design speed; therefore, the classes of highways shall be superelevated according to their speed rather than using a superelevation for a single radius for all design speeds.

$G_1$ AND $G_2$ = TANGENT GRADES (%)
A = ALGEBRAIC DIFFERENCE IN GRADES
L = LENGTH OF VERTICAL CURVES (m (ft))
M = MIDDLE ORDINATE (m (ft))

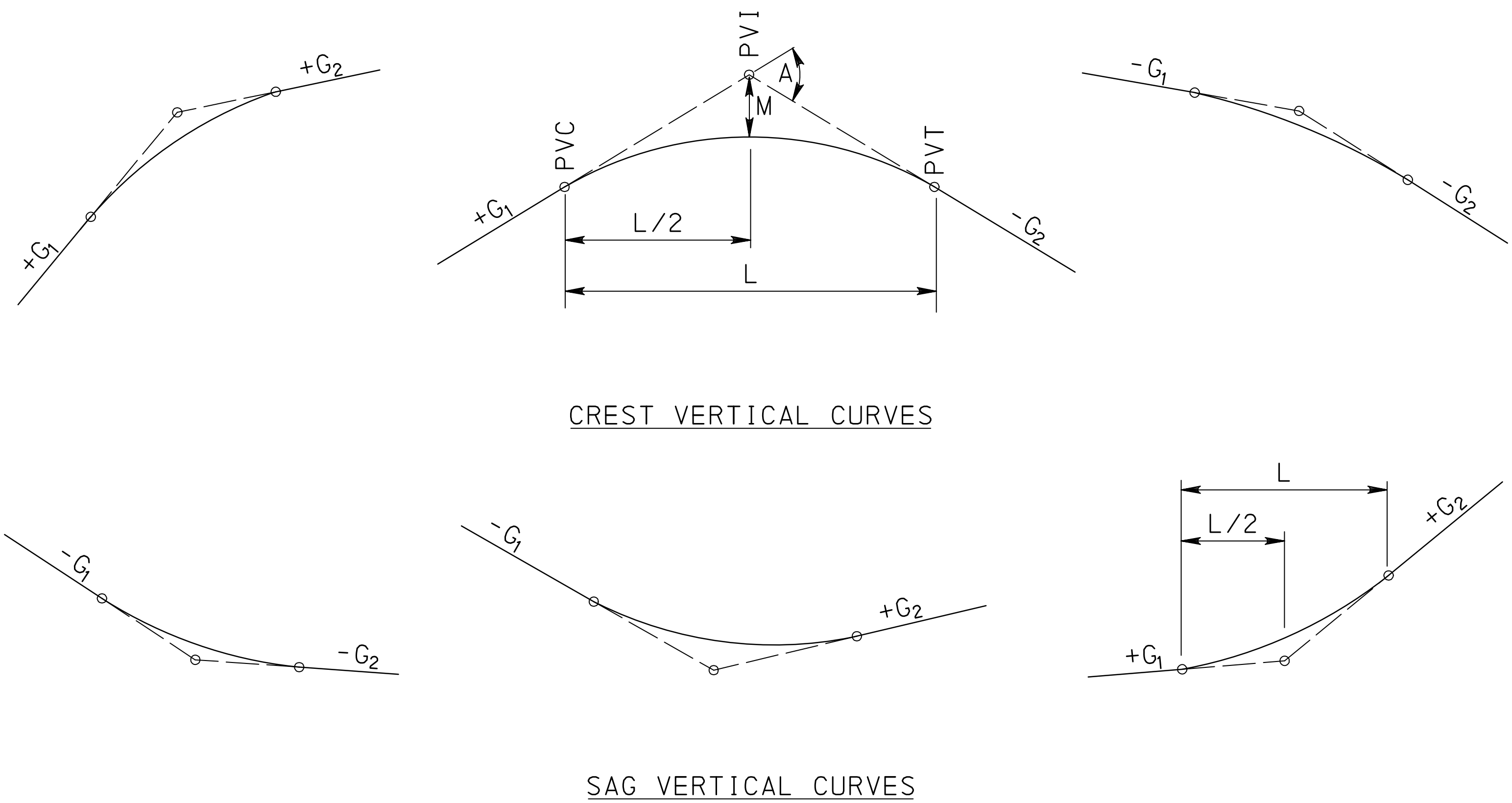



FIGURE 2.3
TYPES OF VERTICAL CURVES

**B. Rates of Superelevation.** The minimum and maximum cross slopes for the various functional classes of roadways are presented in the Matrices of Design Values found in Chapter 1, Table 1.3 through Table 1.8. The rates of superelevation are based on specific design speeds as identified in the Matrices of Design Values. To determine the rates of superelevation for various combinations of radii and design speeds, refer to Section 2.13.D.4 and to the section "Design Superelevation Tables" in the 2004 AASHTO Green Book, Chapter 3.

**C. Maximum Superelevation.** The maximum rates of superelevation used on highways are controlled by climate conditions, terrain conditions, type of area and frequency of very slow-moving vehicles. Consistent with current practice, the maximum rate of superelevation is 8.0%. This rate is based upon consideration of ice and snow factors and is adopted to minimize slipping across the highway by stopped vehicles or vehicles attempting to start slowly from a stopped position. A maximum rate of superelevation of 6.0% may be used in urban areas where traffic congestion or extensive marginal development acts to restrict top speeds. Where traffic congestion or extensive marginal development acts to restrict top speeds, it is common practice to utilize a low maximum rate of superelevation, usually 4.0% to 6.0%. Similarly, either a low maximum rate of superelevation or no superelevation is employed within important intersection areas or where there is a tendency to drive slowly because of turning and crossing movements, warning devices and signals. In these areas, it is difficult to warp crossing pavements for drainage without providing negative superelevation for some turning movements.

**D. Superelevation Transition (T).** When a motor vehicle enters or leaves a circular horizontal curve, the vehicle generally follows a suitable transition path within the limits of normal lane width. However, combinations of high speed and sharp curvature lead to longer transition paths, which can result in shifts in lateral position and encroachment on adjoining lanes. To meet the requirements of comfort and safety, incorporation of transition curves between tangents and sharp circular curves and between circular curves of substantially different radii may be appropriate in order to make it easier for a driver to keep his or her vehicle within its own lane. Superelevation transition (T) represents the progression of the roadway from a normal section to a fully superelevated section or vice versa (see Figures 2.4, 2.5 and 2.6).

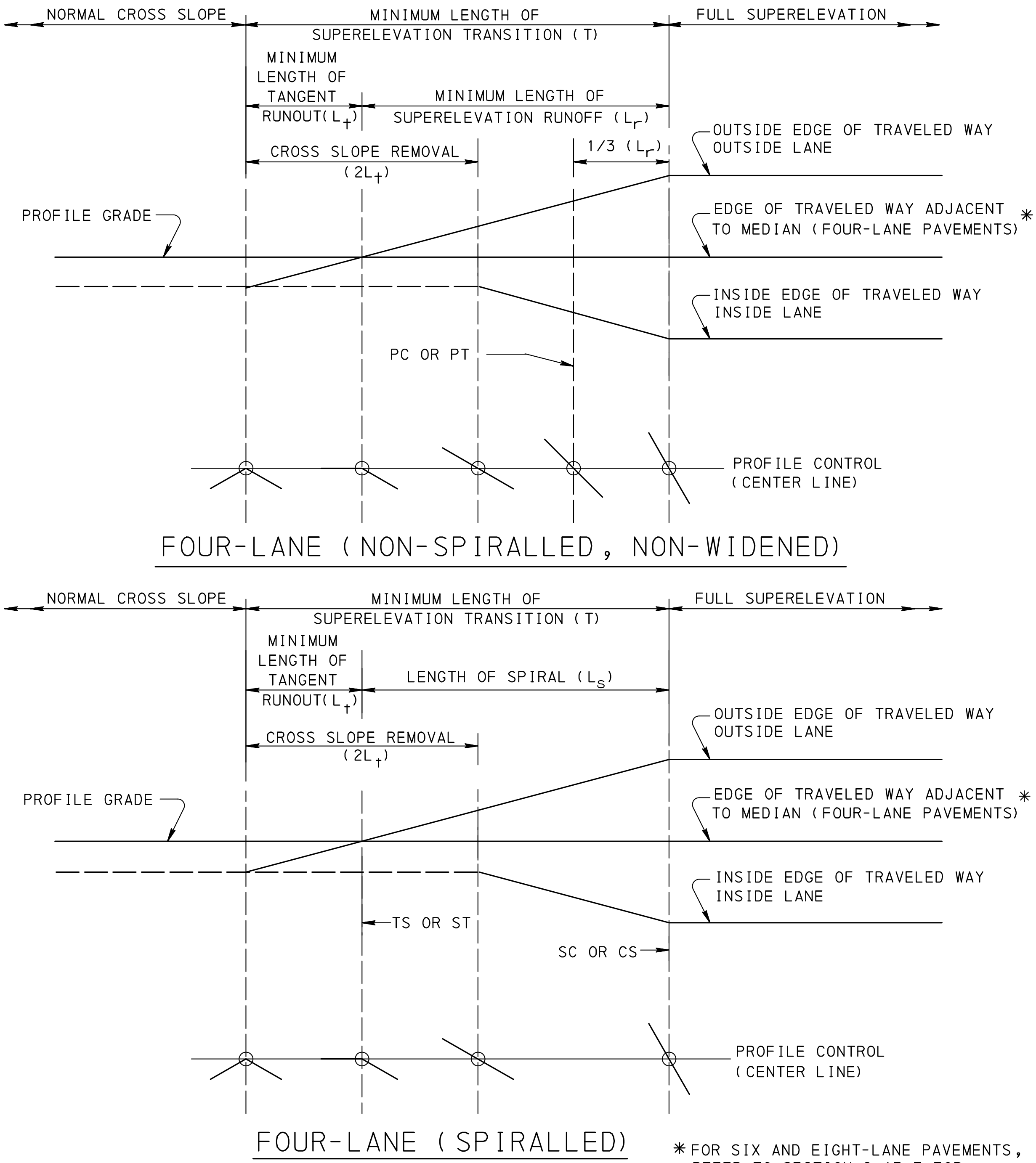
The principal advantages to the application of superelevation transition (T) in horizontal alignment are as follows:

- Provides a natural, easy-to-follow path for drivers such that the lateral force increases and decreases gradually as the vehicle enters and leaves a circular curve, minimizing encroachment on adjacent lanes and promoting uniformity in speed.
- Provides a suitable location for the superelevation runoff.
- Facilitates the transition in width where the traveled way is widened on a circular curve. Superelevation transitions provide flexibility in accomplishing the widening of sharp curves.
- Enhances the appearance of the highway or street by reducing or eliminating the noticeable breaks in the alignment as perceived by drivers at the beginning and ending of circular curves.

Two terms are related to superelevation transition (T):

- Minimum Length of Tangent Runout ($L_t$). The minimum length of tangent runout ($L_t$) represents the general term denoting the length of highway section needed to accomplish the change in cross slope from a normal cross slope section to a section with the adverse cross slope removed or vice versa. The minimum length of tangent runout ($L_t$) is determined by the amount of adverse cross slope to be removed and the rate at which it is removed. This rate of removal should preferably be the same as the rate used to effect the minimum length of superelevation runoff ($L_r$).
- Minimum Length of Superelevation Runoff ($L_r$). The minimum length of superelevation runoff ($L_r$) represents the general term denoting the length of highway section needed to accomplish the change in cross slope from a section with adverse cross slope removed to a fully superelevated section or vice versa.

The specific methods of profile design for attaining the required superelevation for the various functional classification systems are diagrammatically illustrated in Figure 2.4, Figure 2.5 and Figure 2.6.

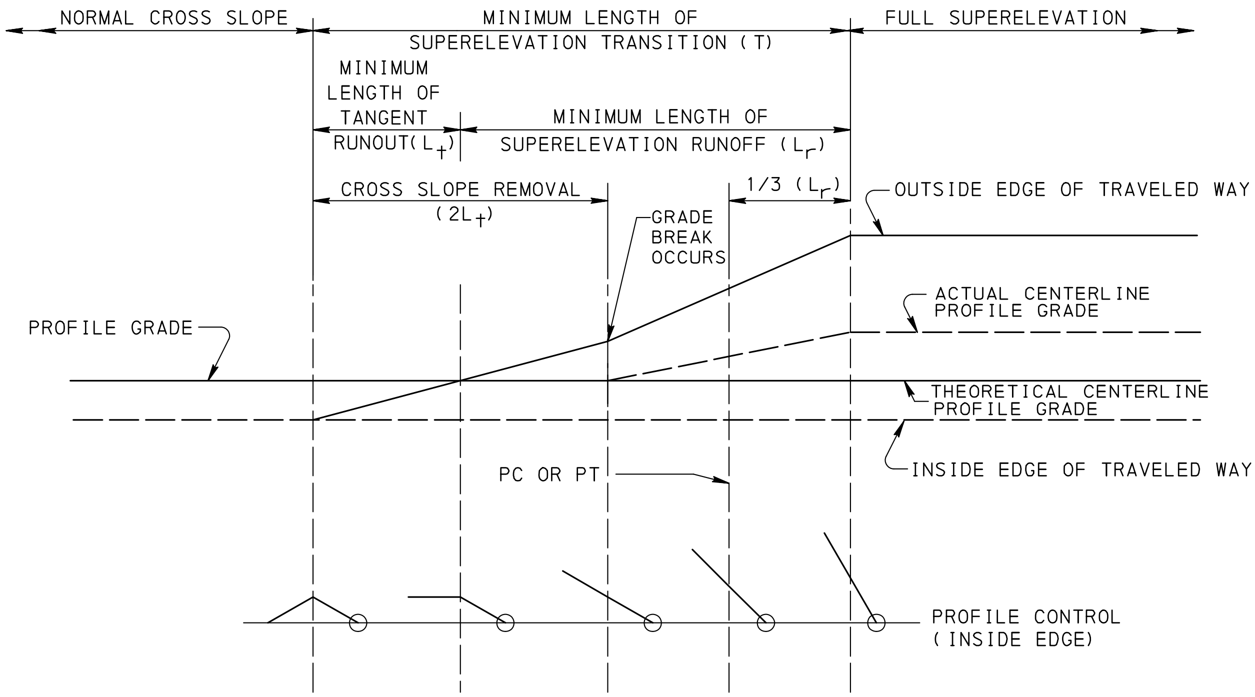



* FOR SIX AND EIGHT-LANE PAVEMENTS, REFER TO SECTION 2.13.E FOR LOCATION OF THIS LINE.

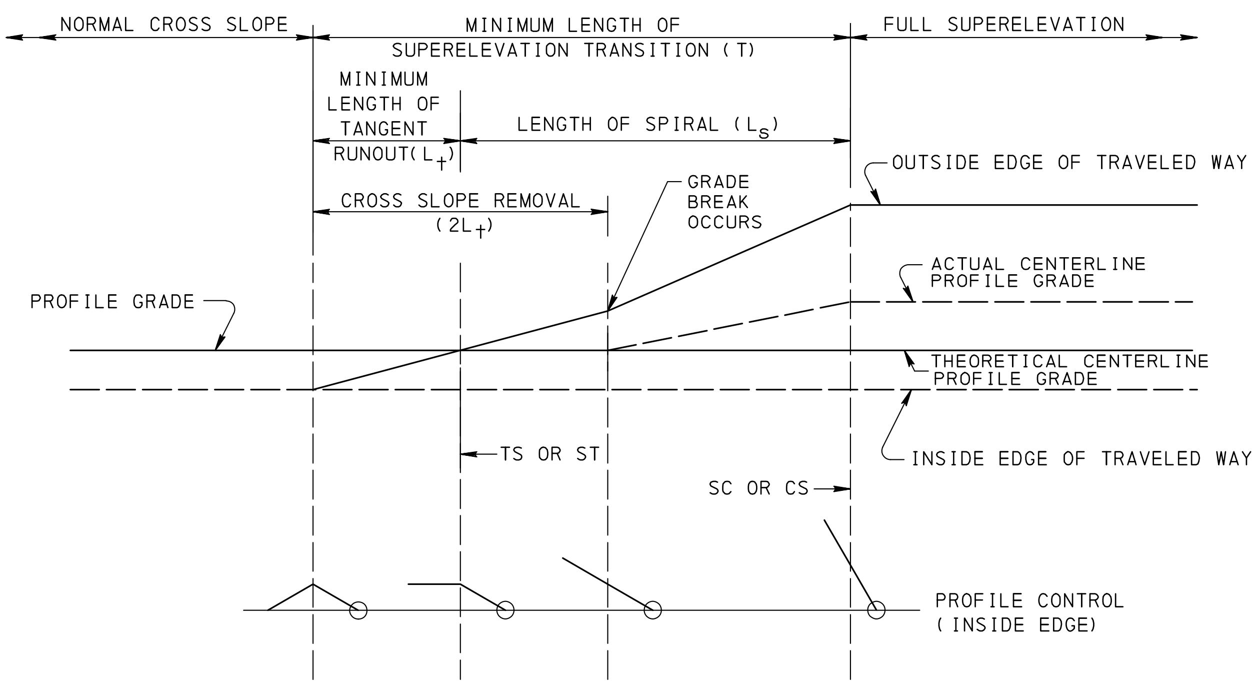
** WHEN ONLY TWO LANES ARE TO BE BUILT INITIALLY.

FIGURE 2.4

PROFILES SHOWING METHOD OF ATTAINING SUPERELEVATION FOR INTERSTATE AND NON-INTERSTATE LIMITED ACCESS FREEWAYS (NOTE: ALSO SEE 2004 AASHTO GREEN BOOK, EXHIBIT 3-40B FOR PROFILE CONTROL AT INSIDE EDGE OF TRAVELED WAY)

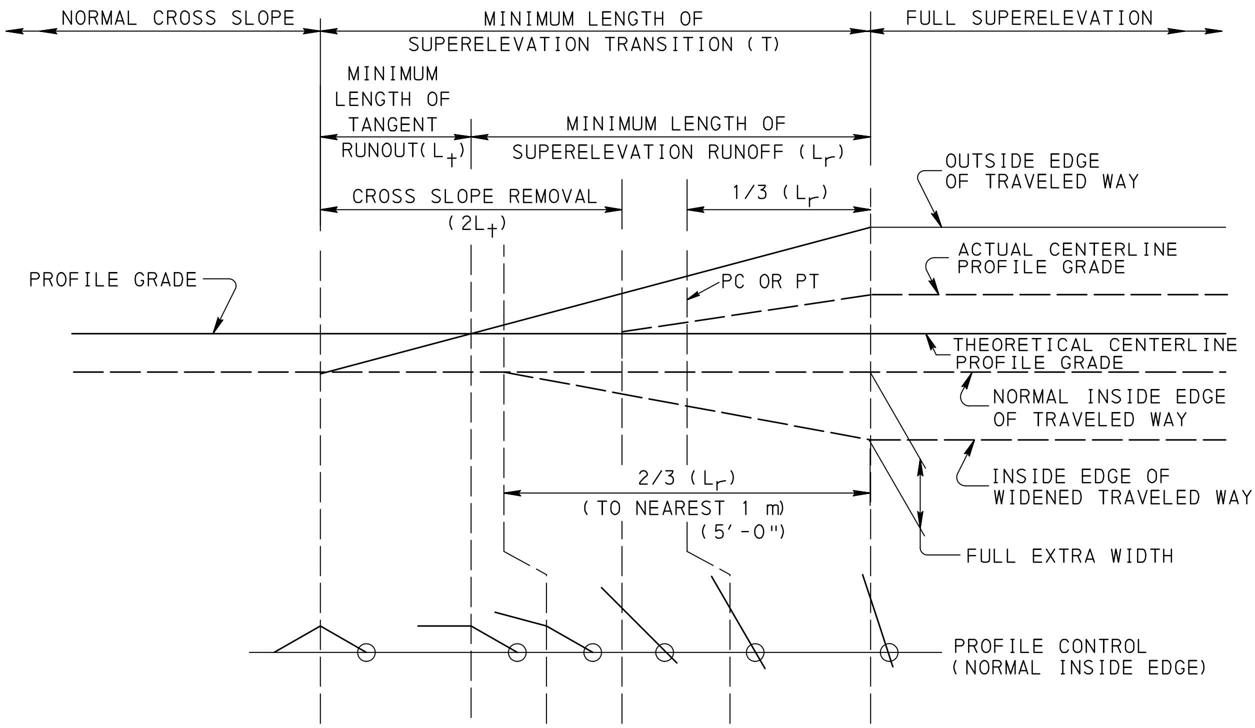



TWO-LANE (NON-SPIRALLED)




TWO-LANE (SPIRALLED)

FIGURE 2.5
PROFILES SHOWING METHOD
OF ATTAINING SUPERELEVATION
FOR ARTERIALS




TWO-LANE (NON-SPIRALLED, WIDENED)

USE ARTERIAL METHOD OF ATTAINING SUPERELEVATION AS INDICATED IN FIGURE 2.5.

TWO-LANE (NON-SPIRALLED, NON-WIDENED)

FIGURE 2.6
PROFILES SHOWING METHOD
OF ATTAINING SUPERELEVATION
FOR COLLECTORS AND LOCAL ROADS

Where curves of different radii join, the superelevation transition (T) shall be located entirely within the curve of the larger radius. The difference in the radii of the curves (R) shall be the radius used to determine the length of this transition.

For superelevation transitions between reverse curves (i.e., two closely spaced simple curves with deflections in opposite directions), a sufficient length of tangent must be provided. Along this tangent, a normal crown section does not need to be achieved; rather, the roadway may be continuously rotated in a plane about its axis. In this situation, the minimum length of tangent will be that needed to meet the superelevation requirements for the two curves.

The minimum length of spiral ($L_s$) indicated in Figures 2.4 and 2.5 may be greater or less than the minimum length of superelevation runoff ($L_r$) depending on the formula and factors used. The minimum length of superelevation runoff ($L_r$) is applicable to all superelevated curves and the values for $L_r$ may be used for the minimum lengths of spiral required.

**1.** Minimum Length of Superelevation Runoff. For appearance and comfort, the length of superelevation runoff should be based on a maximum acceptable difference between the longitudinal grades of the axis of rotation and the edge of traveled way. This relationship is defined as the maximum relative gradient. The axis of rotation is generally represented by the alignment centerline for undivided roadways (see Figure 2.4); however, other pavement reference lines can be used (see Figures 2.5 and 2.6).

The maximum relative gradient is varied with design speed to provide longer runoff lengths at higher speeds and shorter lengths at lower speeds. The 2004 AASHTO Green Book, Chapter 3, Exhibit 3-30 provides the values for the maximum relative gradients. Runoff lengths determined on this basis are directly proportional to the total superelevation, which is the product of the lane width and superelevation rate.

On the basis of the preceding discussion, the minimum length of superelevation runoff should be determined as:

$$L_r = \frac{(wn_1)\, e_d}{\Delta}(b_w)$$

where:

| | | |
|---|---|---|
| $L_r$ | = | minimum length of superelevation runoff (m (ft)) |
| $w$ | = | width of one traffic lane (typically 3.6 m (12 ft)) |
| $n_1$ | = | number of lanes rotated |
| $e_d$ | = | design superelevation rate (percent) |
| $b_w$ | = | adjustment factor for number of lanes rotated |
| $\Delta$ | = | maximum relative gradient (percent) |

This equation can be used directly for undivided streets or highways where the cross section is rotated about the highway centerline and $n_1$ is equal to one-half the number of lanes in the cross section. More generally, this equation can be used for rotation about any pavement reference line provided that the rotated width ($wn_1$) has a common superelevation rate and is rotated as a plane.

A strict application of the maximum relative gradient criterion provides runoff lengths for four-lane undivided roadways that are double those for two-lane roadways; those for six-lane undivided roadways would be tripled. While lengths of this order may be considered desirable, it is often not practical to provide such lengths in design. On a purely empirical basis, the minimum superelevation runoff lengths should be adjusted downward to avoid excessive lengths for multilane roadways. The recommended adjustment factors are presented in the 2004 AASHTO Green Book, Chapter 3, Exhibit 3-31.

The adjustment factors listed in the 2004 AASHTO Green Book, Chapter 3, Exhibit 3-31 are directly applicable to undivided streets and highways. Development of runoff for divided highways is discussed in more detail in the section "Axis of Rotation with a Median" in the 2004 AASHTO Green Book, Chapter 3.

Values for the minimum length of superelevation runoff ($L_r$) are presented in the 2004 AASHTO Green Book, Chapter 3, Exhibit 3-32. The values for the minimum length of superelevation runoff ($L_r$) may be increased to provide smoother transitions. If the minimum length of superelevation runoff ($L_r$) is increased, a revised length of tangent runout ($L_t$) is required to maintain a smooth edge-of-traveled way profile.

The superelevation runoff lengths given in Exhibit 3-32 are based on 3.6 m (12 ft) lanes. For other lane widths, the appropriate runoff length should vary in proportion to the ratio of the actual lane width to 3.6 m (12 ft). Shorter lengths could be applied for designs with 3.0 m (10 ft) and 3.3 m (11 ft) lanes, but considerations of consistency and practicality suggest that the runoff lengths for 3.6 m (12 ft) lanes should be used in all cases.

**2.** Minimum Length of Tangent Runout. The minimum length of tangent runout is determined by the amount of adverse cross slope to be removed and the rate at which it is removed. To effect a smooth edge of traveled way profile, the rate of removal should equal the relative gradient used to define the superelevation runoff length. Based on this rationale, the following equation should be used to compute the minimum length of tangent runout:

$$L_t = \frac{e_{NC}}{e_d} L_r$$

where: $L_t$ = minimum length of tangent runout (m (ft))
$e_{NC}$ = normal cross slope rate (percent)
$e_d$ = design superelevation rate (percent)
$L_r$ = minimum length of superelevation runoff (m (ft))

**3.** Minimum Length of Superelevation Transition. The minimum length of superelevation transition is determined by the following equation:

$$T = L_r + L_t$$

where: $T$ = minimum length of superelevation transition (m (ft))
$L_r$ = minimum length of superelevation runoff (m (ft))
$L_t$ = minimum length of tangent runout (m (ft))

The 2004 AASHTO Green Book, Chapter 3, Exhibit 3-32 indicates the values to be applied for the minimum length of superelevation runoff ($L_r$). The values for the minimum length of superelevation runoff ($L_r$) may be increased to provide smoother transitions. If the minimum length of superelevation runoff ($L_r$) is increased, a revised length of tangent runout ($L_t$) is required to maintain a smooth edge-of-traveled way profile.

**4.** Design Superelevation Tables. The 2004 AASHTO Green Book, Chapter 3, Exhibits 3-25, 3-26 and 3-27 show minimum values of radius (R) for various combinations of superelevation and design speeds for each of three values of maximum superelevation rate (i.e., for a full range of common design conditions). The maximum superelevation rates are $e_{Max}$ = 4.0% (Exhibit 3-25), $e_{Max}$ = 6.0% (Exhibit 3-26), and $e_{Max}$ = 8.0% (Exhibit 3-27).

Spirals are seldom used when the design superelevation rate is less than 3.0%.

When using one of the Exhibits for a given radius, interpolation is not necessary as the superelevation rate should be determined from a radius equal to, or slightly smaller than, the radius provided in the Exhibit. The result is a superelevation rate that is rounded up to the nearest 0.2%.

Found below are two examples that demonstrate how to obtain the superelevation rate for a given horizontal curve:

**a.** Example 1 (Metric): Design Speed of Horizontal Curve, $V_d$ = 80 km/h
Maximum Superelevation Rate, $e_{Max}$ = 8.0%
Radius of Horizontal Curve, R = 436.595 m

Solution: From Exhibit 3-27, e = 6.2% when R = 445 m
e = 6.4% when R = 422 m
Determine the superelevation rate of the actual horizontal curve from the radius in Exhibit 3-27 that is equal to or slightly smaller. Since 422 m < 436.595 m, specify a design superelevation rate ($e_d$) of 6.4%.

Example 1 (English): Design Speed of Horizontal Curve, $V_d$ = 50 mph
Maximum Superelevation Rate, $e_{Max}$ = 8.0%
Radius of Horizontal Curve, R = 1432.39 ft

Solution: From Exhibit 3-27, e = 6.2% when R = 1480 ft
e = 6.4% when R = 1400 ft
Determine the superelevation rate of the actual horizontal curve from the radius in Exhibit 3-27 that is equal to or slightly smaller. Since 1400 ft < 1432.39 ft, specify a design superelevation rate ($e_d$) of 6.4%.

**b.** Example 2 (Metric): Design Speed of Horizontal Curve, $V_d$ = 100 km/h
Maximum Superelevation Rate, $e_{Max}$ = 6.0%
Radius of Horizontal Curve, R = 1164.253 m

Solution: From Exhibit 3-26, e = 3.8% when R = 1170 m
e = 4.0% when R = 1090 m
Determine the superelevation rate of the actual horizontal curve from the radius in Exhibit 3-26 that is equal to or slightly smaller. Since 1090 m < 1164.253 m, specify a design superelevation rate ($e_d$) of 4.0%.

Example 2 (English): Design Speed of Horizontal Curve, $V_d$ = 60 mph
Maximum Superelevation Rate, $e_{Max}$ = 6.0%
Radius of Horizontal Curve, R = 3819.72 ft

Solution: From Exhibit 3-26, e = 3.6% when R = 3940 ft
e = 3.8% when R = 3650 ft
Determine the superelevation rate of the actual horizontal curve from the radius in Exhibit 3-26 that is equal to or slightly smaller. Since 3650 ft < 3819.72 ft, specify a design superelevation rate ($e_d$) of 3.8%.

**INTENTIONALLY BLANK**

**5.** Example Superelevation Problem. Found below is a superelevation problem that demonstrates how to obtain the minimum length of superelevation runoff ($L_r$), the minimum length of tangent runout ($L_t$), and the resulting length of superelevation transition (T). The data to be used in this superelevation problem comes from Example 2 in the previous subsection.

EXAMPLE SUPERELEVATION PROBLEM (METRIC)

Given: Normal Cross Slope, $e_{NC}$ = 2.0%
$V_d$ = 100 km/h
R = 1164.253 m
$e_d$ = 4.0%
$e_{Max}$ = 6.0%
Two 3.6 m Lanes (Non-Spiralled, Non-Widened)

Find: (a) Minimum Length of Superelevation Runoff ($L_r$)
(b) Minimum Length of Tangent Runout ($L_t$)
(c) Superelevation Transition (T)

Solution: (a) From Exhibit 3-32, $L_r$ = 33 m (assuming one lane is rotated)
(b) From equation,

$$L_t = \frac{e_{NC}}{e_d} L_r = \left(\frac{0.02}{0.04}\right)(33) = 16.5 \text{ m}$$

(c) From equation,

$$T = L_r + L_t = 33 \text{ m} + 16.5 \text{ m} = 49.5 \text{ m}$$

EXAMPLE SUPERELEVATION PROBLEM (ENGLISH)

Given: Normal Cross Slope, $e_{NC}$ = 2.0%
$V_d$ = 60 mph
R = 3819.72 ft
$e_d$ = 3.8%
$e_{Max}$ = 6.0%
Two 12 ft Lanes (Non-Spiralled, Non-Widened)

Find: (a) Minimum Length of Superelevation Runoff ($L_r$)
(b) Minimum Length of Tangent Runout ($L_t$)
(c) Superelevation Transition (T)

Solution: (a) From Exhibit 3-32, $L_r$ = 101 ft (assuming one lane is rotated)
(b) From equation,

$$L_t = \frac{e_{NC}}{e_d} L_r = \left(\frac{0.02}{0.038}\right)(101) = 53.16 \text{ ft}$$

(c) From equation,

$$T = L_r + L_t = 101 \text{ ft} + 53.16 \text{ ft} = 154.16 \text{ ft}$$

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**E. Application of Superelevation.**

**1.** Methods of Attaining Superelevation. On spiral curves, the superelevation shall be applied by removing the adverse cross slope through the minimum length of tangent runout ($L_t$) distance to the tangent to spiral (TS). Total superelevation shall be attained along the length of spiral and held from the spiral to curve (SC) to the curve to spiral (CS).

On non-spiralled, non-widened curves, the superelevation shall be applied by using the method shown in Figure 2.5. Total superelevation shall be reached at a point beyond the point of curvature (PC) at a distance equal to one-third (1/3) of the minimum length of superelevation runoff ($L_r$). The same procedure shall be followed at the point of tangency (PT).

On non-spiralled, widened curves, the superelevation shall be applied by using the method shown in Figure 2.6. Curve widening shall be placed on the inside edge of curve and shall be attained in a distance equivalent to two-thirds (2/3) of the length of superelevation runoff (L) to the nearest 1 m (5 ft). Total superelevation and full extra width shall be reached at a point beyond the point of curvature (PC) at a distance equivalent to one-third (1/3) of the length of superelevation runoff (L). The same procedure shall be followed at the point of tangency (PT).

**2.** Location of Profile Grade. The profile grade line controls the roadway's vertical alignment through the horizontal curve. Although shown as a horizontal line in Figures 2.4, 2.5 and 2.6, the profile grade line may correspond to a tangent, a vertical curve, or a combination of the two. In Figure 2.4, the profile grade line corresponds to the centerline profile. In Figures 2.5 and 2.6, the profile grade line is represented as a "theoretical" centerline profile as it does not coincide with the axis of rotation.

For four-lane pavement with paved or unpaved divisor areas, hold profile grade on the edge of traveled way adjacent to the divisor area, as shown in Figure 2.4. See the 2004 AASHTO Green Book, Exhibit 3-40B for profile control at the inside edge of traveled way.

For six-lane pavement with paved or unpaved divisors, hold profile grade on the traveled way 3.6 m (12 ft) from the median edges of the traveled way. For eight-lane pavements with paved or unpaved divisors, hold profile grade on the traveled way 7.2 m (24 ft) from the median edges of the traveled way.

**3.** Additional Design Considerations. In the design of divided highways, the inclusion of a median in the cross section influences the superelevation transition design. This influence stems from the several possible locations for the axis of rotation. The most appropriate location for this axis depends on the width of the median and its cross section. For a discussion of common combinations of these factors and the appropriate corresponding axis location, refer to the section "Axis of Rotation with a Median" in the 2004 AASHTO Green Book, Chapter 3.

For narrow medians less than 6.0 m (20 ft) wide with concrete median barrier, special attention is needed to assure that the centerline elevations are equal elevations along curved roadway sections. Depending on the superelevation and shoulder slopes, it may be necessary to define the profile grade along the high side of the superelevation, At the same location, the low side of the superelevation would be defined as a graphic grade lower than and relative to the high side of the superelevation. For this design situation, the goal would be to install a standard concrete median barrier because it would: (1) provide the same elevations for the gutter lines on either side of the barrier; and (2) be less costly and time consuming than developing a specially-designed and constructed bifurcated concrete median barrier to accommodate differences in elevations on either side of the barrier.

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Special superelevation design shall be applied in areas involving crossover pavements to prevent flat areas and provide adequate drainage. Narrow medians may present a special problem on superelevated curves. In order to provide required shoulder slopes, it may be necessary to adjust the profile grade lines.

**F. Superelevation of City Streets.** Local city streets on the highway system are not generally superelevated. In built-up areas, it is desirable to discourage speed and the elimination of superelevation contributes to this objective. Also, established street grades, intersections, curbs, effect on adjacent properties and drainage conditions may inhibit the application of superelevation. There are, however, many occasions when it is desirable to provide superelevation on state highways in urban areas. For example, limited access freeways are superelevated.

**G. Superelevation for Curves on Ramps.** The section "General Ramp Design Considerations" in the 2004 AASHTO Green Book, Chapter 10 provides guidelines for the design of superelevation and cross-slope on ramps. Guidelines for the development of superelevation at free-flow ramp terminals are found in the 2004 AASHTO Green Book, Chapter 10, Exhibit 10-58.

## 2.14 TRAVELED WAY WIDENING ON HORIZONTAL CURVES

Vehicles negotiating horizontal curves may require increased traveled way width to make operating conditions on curves comparable to those on tangent sections. The reasons are twofold:

**1.** The design vehicle occupies a greater width because the rear wheels generally track inside front wheels (offtracking) in negotiating curves.

**2.** Drivers experience difficulty in steering their vehicles in the center of the lane.

Widening should transition gradually on the approaches to the curve to ensure a reasonably smooth alignment of the edge of the traveled way and to fit the paths of vehicles entering or leaving the curve. The principal points of concern in the design of curve widening which apply to both ends of highway curves are presented below:

**1.** On simple (unspiralled) curves, widening should be applied on the inside edge of the traveled way only. On curves designed with spirals, widening may be applied on the inside edge or divided equally on either side of the centerline. The final marked centerline, and desirably any central longitudinal joint, should be placed midway between the edges of the widened traveled way.

**2.** Curve widening should transition gradually over a length sufficient to make the whole of the traveled way fully usable. Preferably, widening should transition over the superelevation runoff length, but shorter lengths are sometimes used. Changes in width normally should be effected over a distance of 30 m to 60 m (100 ft to 200 ft).

**3.** The edge of the traveled way through the widening transition should be a smooth, graceful curve and a tangent transition edge should be avoided. The transition ends should avoid an angular break at the pavement edge.

**4.** On highway alignment without spirals, smooth and fitting alignment results from attaining widening with one-half to two-thirds of the transition length along the tangent and the balance along the curve. The inside edge of the traveled way may be designed as a modified spiral, with control points determined by the width/length ratio of a triangular wedge, by calculated values based on a parabolic or cubic curve, or by a larger radius (compound) curve. On highway alignment with spiral curves, the increase in width is usually distributed along the length of the spiral.

Traveled way widening on curves for the main roadway shall be undertaken in accordance with the details in Figure 2.6. Widening is not required under the following conditions:

1. Traveled ways that are 7.2 m (24 ft) wide.
2. Interstate and Other Limited Access Freeways and Arterials.
3. Collectors and Local Roads when the radius is greater than 350 m (degree of curve is less than 5° 00').

Traveled way widening on ramps is discussed in Chapter 4, Section 4.7. For additional information concerning traveled way widening on curves, refer to the section "Traveled Way Widening on Horizontal Curves" in the 2004 AASHTO Green Book, Chapter 3.

## 2.15 TRANSITION (SPIRAL) CURVES AND COMPUTATIONS

Transition spirals are curves which provide a gradual change in curvature from a straight to a circular path. Such an alignment is desirable because it permits vehicle operational comfort, gradually introduces superelevation, provides a transitional path to reduce the tendency to deviate from the traffic lane and enhances the appearance of the highway. On Interstate and Non-Interstate Limited Access Freeways, spirals are applicable to curves with radii of 1746.38 m (5729.58 ft) and less (with degree of curves of 1° and greater) and on Arterial roadways, spirals are applicable to curves with radii of 873.19 m (2864.79 ft) and less (with degree of curves of 2° and greater). Superelevation controls spiral lengths, tangent runouts and lengths of superelevation runoff for various radii and are presented in Section 2.13. These are minimum values that may be exceeded.

The reference books for spiral curve computations are "Transition Curves for Highways" by Joseph Barnett and "Route Location and Design" by Thomas F. Hickerson, published by the United States Printing Office and McGraw-Hill Book Company, respectively. The minimum data shown for the spiral alignment shall be in accordance with Publication 14M, Design Manual, Part 3, *Plans Presentation,* Chapter 2.

The following example problem illustrates transition (spiral) curve computations using data from Barnett's book (Table II) and the spiral curve formulas contained in Figure 2.7.

**EXAMPLE PROBLEM (METRIC)**

Given: PI Sta = 13 + 200.000
$\Delta$ = 56° 00' 00" RT
$R_c$ = 1000.000 m
$L_s$ = 92.000 m

Spiral Curve Data:

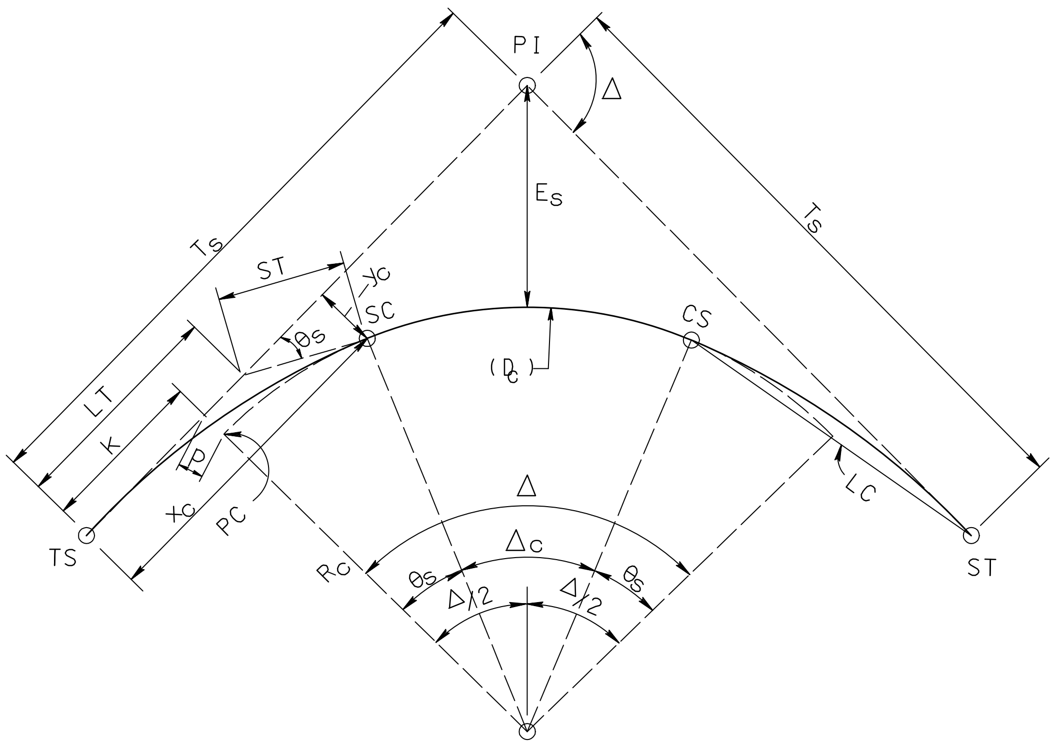
PI Sta = 13 + 200.000
$\Delta$ = 56° 00' 00"
$\Delta_c$ = 50° 43' 43.64"
$R_c$ = 1000.000 m
$L_c$ = 885.384 m
$\theta_s$ = 2° 38' 08.18"
$L_s$ = 92.000 m
$T_s$ = 577.892 m
$E_s$ = 132.968 m
k = 45.996 m
p = 0.351 m
$x_c$ = 91.981 m
$y_c$ = 1.410 m
LT = 61.340 m
ST = 30.673 m
LC = 91.992 m

**EXAMPLE PROBLEM (ENGLISH)**

Given: PI Sta = 436 + 89.20
$\Delta$ = 56° 00' 00" RT
$D_c$ = 9° 00'
$R_c$ = 636.62'
$L_s$ = 300.00'

Spiral Curve Data:

PI Sta = 436 + 89.20
$\Delta$ = 56° 00' 00"
$\Delta_c$ = 29° 00' 00"
$D_c$ = 9° 00' 00"
$R_c$ = 636.62'
$L_c$ = 322.22'
$\theta_s$ = 13° 30' 00"
$L_s$ = 300.00'
$T_s$ = 491.35'
$E_s$ = 91.06'
k = 149.72'
p = 5.88'
$x_c$ = 298.34'
$y_c$ = 23.47'
LT = 200.58'
ST = 100.53'
LC = 299.26'




$R_C$ = Radius of Circular Curve
($D_C$) = Degree of Curvature of the Circular Curve)
$T_S$ = Tangent Distance
$\Delta$ = Delta – External Angle
$\theta_S$ = Spiral Angle
$\Delta_C$ = Central Angle Between the SC and CS
$E_S$ = External Distance
LC = Long Chord
LT = Long Tangent

ST = Short Tangent
$x_C$ = Tangent Distance for SC
$y_C$ = Tangent Offset of the SC
k = Simple Curve Co-ordinate (Abscissa)
p = Simple Curve Co-ordinate (Ordinate)
TS = Tangent to Spiral Point
SC = Spiral to Curve Point
CS = Curve to Spiral Point
ST = Spiral to Tangent Point

FIGURE 2.7
TRANSITION SPIRAL CURVES

**EXAMPLE PROBLEM (METRIC):**

$\theta_s$ = $(L_s / 60.96012192) \times (1746.378852 / R_c)$
= $(92.000 / 60.96012192) \times (1746.378852 / 1000.000)$
$\theta_s$ = 2° 38' 08.18"

p = ("p" constant, Table II) × $L_s$
= 0.00382 × 92.000
p = 0.351 m

k = ("k" constant, Table II) × $L_s$
= 0.49996 × 92.000
k = 45.996 m

$$T_s = (R_c + p)\tan\left(\frac{\Delta}{2}\right) + k$$

= (1000.000 + 0.351) × tan (28° 00' 00") + 45.996
$T_s$ = 577.892 m

$\Delta_c$ = $\Delta - 2\theta_s$
= 56° 00' 00" - 2 × (2° 38' 08.18")
$\Delta_c$ = 50° 43' 43.64"

$L_c$ = $(30.48006096 \times \Delta_c) / (1746.378852 / R_c)$
= (30.48006096 × (50° 43' 43.64")) / (1746.378852 / 1000.000)
$L_c$ = 885.384 m

$$\text{exsec}\,\frac{\Delta}{2} = \frac{1}{\cos\frac{\Delta}{2}} - 1$$

= (1 / cos (28° 00' 00")) - 1
= 0.132570

$$E_s = (R_c + p)(\text{exsec}\,\frac{\Delta}{2}) + p$$

= (1000.000 + 0.351)(0.132570) + 0.351
$E_s$ = 132.968 m

| | |
|---|---|
| PI Sta | 13+200.000 |
| - $T_s$ | -577.892 |
| TS Sta | 12+622.108 |
| + $L_s$ | +92.000 |
| SC Sta | 12+714.108 |

| | |
|---|---|
| SC Sta | 12+714.108 |
| + $L_c$ | +885.384 |
| CS Sta | 13+599.492 |
| + $L_s$ | +92.000 |
| ST Sta | 13+691.492 |

**EXAMPLE PROBLEM (METRIC) (CONTINUED):**

$x_c$ = ("x" constant, Table II) × $L_s$
= 0.99979 × 92.000
$x_c$ = 91.981 m

$y_c$ = ("y" constant, Table II) × $L_s$
= 0.01533 × 92.000
$y_c$ = 1.410 m

LT = ("LT" constant, Table II) × $L_s$
= 0.66674 × 92.000
LT = 61.340 m

ST = ("ST" constant, Table II) × $L_s$
= 0.33340 × 92.000
ST = 30.673 m

LC = ("LC" constant, Table II) × $L_s$
= 0.99991 × 92.000
LC = 91.992 m

Suppose a surveyor wanted to locate a point 50.000 m from the TS, measured along the spiral. The intersection angle (θ) between the tangent of the complete curve and the tangent at any other point on the spiral is:

$\theta = (L^2 / L_s^2) \times \theta_s$
$= ((50.000)^2 / (92.000)^2) \times (2° 38' 08.18")$
$\theta = 0° 46' 42.51"$

The values for the tangent distance (x) and tangent offset (y) are:

x = ("x" constant, Table II) × L
= 0.99998 × 50.000
x = 49.999 m

y = ("y" constant, Table II) × L
= 0.00453 × 50.000
y = 0.226 m

**EXAMPLE PROBLEM (ENGLISH):**

$\theta_s = (L_S / 200) \times D_c)$
$= (300 / 200) \times 9$
$\theta_s = 13° 30' 00"$

$p = ("p" \text{ constant, Table II}) \times L_S$
$= 0.01960 \times 300$
$p = 5.88'$

$k = ("k" \text{ constant, Table II}) \times L_S$
$= 0.49908 \times 300$
$k = 149.72'$

$$T_s = (R_c + p) \tan\left(\frac{\Delta}{2}\right) + k$$

$= (636.62 + 5.88) \times \tan(28° 00' 00") + 149.72$
$T_s = 491.35'$

$\Delta_c = \Delta - 2\theta_s$
$= 56° 00' 00" - (2 \times (13° 30' 00"))$
$\Delta_c = 29° 00' 00"$

$L_c = (\Delta_c \times 100) / D_c$
$= (29.00 \times 100) / 9$
$L_c = 322.22'$

$$\text{exsec}\,\frac{\Delta}{2} = \frac{1}{\cos\frac{\Delta}{2}} - 1$$

$= (1 / \cos(28° 00' 00")) - 1$
$= 0.132570$

$$E_s = (R_c + p)(\text{exsec}\,\frac{\Delta}{2}) + p$$

$= (636.62 + 5.88)(0.132570) + 5.88$
$E_s = 91.06'$

| | | | |
|---|---|---|---|
| PI Sta | 436+89.20 | SC Sta | 434+97.85 |
| $- T_s$ | -491.35 | $+ L_c$ | +322.22 |
| TS Sta | 431+97.85 | CS Sta | 438+20.07 |
| $+ L_s$ | +300.00 | $+ L_s$ | +300.00 |
| SC Sta | 434+97.85 | ST Sta | 441+20.07 |

**EXAMPLE PROBLEM (ENGLISH) (CONTINUED):**

$x_c$ = ("x" constant, Table II) × $L_s$
= 0.99446 × 300
$x_c$ = 298.34'

$y_c$ = ("y" constant, Table II) × $L_s$
= 0.07823 × 300
$y_c$ = 23.47'

LT = ("LT" constant, Table II) × $L_s$
= 0.66862 × 300
LT = 200.58'

ST = ("ST" constant, Table II) × $L_s$
= 0.33511 × 300
ST = 100.53'

LC = ("LC" constant, Table II) × $L_s$
= 0.99753 × 300
LC = 299.26'

Suppose a surveyor wanted to locate a point 152.85 ft from the TS, measured along the spiral. The intersection angle (θ) between the tangent of the complete curve and the tangent at any other point on the spiral is:

$\theta = (L^2 / L_s^2) \times \theta_s$
$= ((152.85)^2 / (300)^2) \times (13° 30' 00")$
$\theta = 3° 30' 16.09"$

The values for the tangent distance (x) and tangent offset (y) are:

x = ("x" constant, Table II) × L
= 0.999605 × 152.85
x = 152.79'

y = ("y" constant, Table II) × L
= 0.020385 × 152.85
y = 3.12'

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## 2.16 AIRPORT - HIGHWAY CLEARANCES

The Administrator for the Federal Aviation Administration has established specific clearance requirements and criteria for highways and other structures adjacent to airports that are identified in *Part 77 of the Federal Aviation Regulations - Federal Aviation Administration*. The document is available from the Federal Aviation Administration, Washington, DC or the Superintendent of Documents, US Government Printing Office, Washington, DC and shall be used as a guide in the preparation of the design of highways adjacent or near airports to provide adequate clearance between the highways and the navigable airspace. For additional guidelines on the preparation of data, plans and other pertinent information relative to airport clearance requirements, refer to Publication 10C, Design Manual, Part 1C, *Transportation Engineering Procedures,* Chapter 4, Section 4.8.F.

## 2.17 SIGHT DISTANCE

**A. General.** For safety on highways, drivers should be provided with sight distance of sufficient length to control the operation of their vehicles to avoid striking an unexpected object in the traveled way. Since the path and speed of these vehicles on highways and streets are subject to the control of drivers whose ability, training and experience are quite varied, proper sight distance shall be provided to enable a vehicle traveling at or near the design speed to stop before reaching a stationary object in its path. Sufficient sight distance should be provided on certain two-lane highways to enable drivers to occupy the opposing traffic lane for passing other vehicles without risk of a crash. Two-lane rural highways should generally provide such passing sight distance at frequent intervals and for substantial portions of their length. Sight distance represents the continuous length ahead along a roadway throughout which an object of specified height is continuously visible to the driver. In design, four sight distances are considered:

1. Passing sight distance.
2. Stopping sight distance.
3. Decision sight distance.
4. Intersection sight distance.

**B. Criteria for Measuring Sight Distance.** The criteria for measuring sight distances are dependent on the height of the driver's eye above the road surface, the specified object height above the road surface and the height and lateral position of sight obstructions within the driver's line of sight:

**1.** Height of Driver's Eye. For calculating sight distances for passenger vehicles, the height of the driver's eye above the road surface shall be considered as 1.080 m (3.5 ft). For large trucks the driver eye height shall be assumed as 2.330 m (7.6 ft) for design.

**2.** Height of Object. For stopping sight distance and decision sight distance calculations, the height of object shall be considered as 0.600 m (2.0 ft) above the road surface. For passing sight distance calculations, the height of object shall be considered as 1.080 m (3.5 ft) above the road surface. For intersection sight distance calculations, the height of object shall be considered as 1.080 m (3.5 ft) above the surface of the intersecting road.

**3.** Sight Obstructions. On a tangent roadway, the obstruction that limits the driver's sight distance is the road surface at some point on a crest vertical curve. On horizontal curves, the obstruction that limits the driver's sight distance may be the road surface at some point on a crest vertical curve, or it may be some physical feature outside of the traveled way, such as a longitudinal barrier, a bridge-approach fill slope, a tree, foliage or the backslope of a cut section. Accordingly, all highway construction plans should be checked in both the vertical and horizontal plane for sight distance obstructions.

**C. Passing Sight Distance for Two-Lane Highways.** Passing sight distance is the minimum sight distance that shall be available to enable the driver of one vehicle to pass another vehicle safely and comfortably, without interfering with the speed of an oncoming vehicle traveling at the design speed should it come into view after the overtaking maneuver is started. The sight distance available for passing at any place is the longest distance at which a driver whose eyes are 1.080 m (3.5 ft) above the road surface can see the top of an object 1.080 m (3.5 ft) above the road surface.

Passing sight distance for use in design should be determined on the basis of the length needed to complete normal passing maneuvers and is determined for a single vehicle passing a single vehicle. When computing minimum passing sight distance on two-lane highways, the following assumptions concerning driver behavior are made:

**1.** The overtaken vehicle travels at uniform speed.

**2.** The passing vehicle has reduced speed and trails the overtaken vehicle as it enters a passing section.

**3.** When the passing section is reached, the passing driver needs a short period of time to perceive the clear passing section and to react to start the maneuver.

**4.** Passing is accomplished under what may be termed a delayed start and a hurried return in the face of opposing traffic. The passing vehicle accelerates during the maneuver and its average speed during the occupancy of the left lane is 15 km/h (10 mph) higher than that of the overtaken vehicle.

**5.** When the passing vehicle returns to its lane, there is a suitable clearance length between it and an oncoming vehicle in the other lane.

The minimum passing sight distance for two-lane highways represents the sum of four elements or distances that include:

**1.** Distance traversed during perception and reaction time and during the initial acceleration to the point of encroachment on the left lane ($d_1$).

**2.** Distance traveled while the passing vehicle occupies the left lane ($d_2$).

**3.** Distance between the passing vehicle at the end of its maneuver and the opposing vehicle ($d_3$).

**4.** Distance traversed by an opposing vehicle for two-thirds of the time the passing vehicle occupies the left lane ($d_4$ or 2/3 of $d_2$ above).

These distances are diagrammatically illustrated in Exhibit 3-4 of the 2004 AASHTO Green Book, Chapter 3. For additional information concerning the components used to compute these distances, refer to the section "Passing Sight Distance for Two-Lane Highways" in the 2004 AASHTO Green Book, Chapter 3.

The values contained in the 2004 AASHTO Green Book, Chapter 3, Exhibit 3-7 represent the design values for minimum passing sight distance. These distances should be exceeded as much as practical and passing sections should be provided as often as can be done at reasonable costs to provide as many passing opportunities as practical.

Appreciable grades affect the sight distance needed for passing. The sight distances needed to permit vehicles traveling upgrade to pass safely are greater than those needed on level roads due to reduced acceleration of the passing vehicle and the likelihood that opposing traffic may speed up. Therefore, if passing maneuvers are to be performed on upgrades, passing sight distances should be greater than the derived design values in the 2004 AASHTO Green Book, Chapter 3, Exhibit 3-7. Although no specific adjustments for design are available, the desirability of exceeding the values shown should be recognized.

The frequency and length of passing sections encountered on two-lane highways depend on the topography, the design speed, the spacing of intersections and the cost. At each passing section, the length of roadway ahead, with adequate sight distance for passing equal to or greater than the passing sight distance, should be as long as practical. It is not practical to directly indicate the frequency with which passing sections should be provided on two-lane highways due to the physical and cost limitations. Where high traffic volumes are expected on a highway and a high level of service is to be maintained, frequent or nearly continuous passing sight distances should be provided.

Passing sight distance is considered only on two-lane roads. At critical locations, a stretch of four-lane construction with stopping sight distance is sometimes more economical than two lanes with passing sight distance. This is particularly practical during stage construction where two lanes of a future four-lane divided highway are being built.

The following is a summary of the design procedure to follow in providing passing sections on two-lane highways:

**1.** Horizontal and vertical alignment should be designed to provide as much of the highway as practical with passing sight distance (see the 2004 AASHTO Green Book, Chapter 3, Exhibit 3-7).

**2.** Where the design volume approaches capacity, the effect of lack of passing opportunities in reducing the Level of Service should be recognized.

**3.** Where the critical length of grade exceeds the physical length of an upgrade, consideration should be given to constructing added climbing lanes. The critical lengths of grade are as shown in the 2004 AASHTO Green Book, Chapter 3, Exhibits 3-55 and 3-56.

**4.** Where the extent and frequency of passing opportunities made available by application of Criteria 1 and 3 are still too few, consideration should be given to the construction of passing lane sections.

**D. Stopping Sight Distance.** Stopping sight distance represents the length needed for a vehicle traveling at a given speed to stop before reaching an object in its path. Stopping sight distance is measured from the driver's eyes which are 1.080 m (3.5 ft) above the road surface to an object 0.600 m (2.0 ft) above the road surface. Stopping sight distance is the sum of the distance traversed by the vehicle from the instant the driver sights an object necessitating a stop (brake reaction distance) and the distance needed to stop the vehicle from the instant brake application begins (braking distance).

The approximate braking distance of a vehicle on a level roadway may be determined from the following equation:

$$\text{METRIC:} \quad d = 0.039\frac{V^2}{a} \qquad\qquad \text{ENGLISH:} \quad d = 1.075\frac{V^2}{a}$$

where: d = braking distance (m)
V = design speed (km/h)
a = deceleration rate ($m/s^2$)

where: d = Braking distance (ft)
V = Initial speed (mph)
a = deceleration rate ($ft/s^2$)

Also, design speed should be used to formulate stopping distance values. The stopping sight distances presented in the 2004 AASHTO Green Book, Chapter 3, Exhibit 3-1 for the various design speeds are developed based on wet pavement conditions. Stopping sight distances exceeding those shown in the 2004 AASHTO Green Book, Chapter 3, Exhibit 3-1 should be used as the basis for design wherever practical thereby increasing the margin of safety.

The recommended stopping sight distances are based on passenger car operation. Although trucks need longer stopping distances than cars, separate stopping sight distances for both vehicles are not generally used in highway design. Because truck operators are able to see substantially farther beyond vertical sight obstructions because of the higher position of the seat in their vehicles, this factor tends to balance the additional braking lengths for trucks with those for passenger cars.

When a highway is on a grade, the equation for braking distance should be modified as follows:

$$\text{METRIC:} \quad d = \frac{V^2}{254\left[\left(\frac{a}{9.81}\right) \pm G\right]} \qquad\qquad \text{ENGLISH:} \quad d = \frac{V^2}{30\left[\left(\frac{a}{32.2}\right) \pm G\right]}$$

In this equation, G is the percent of grade divided by 100, and the other terms are as stated previously above in this section. The stopping distances needed on upgrades are shorter than on level roadways, and those available on downgrades are longer. The extent of the corrections for grade, which are based on wet pavement conditions, is indicated in the 2004 AASHTO Green Book, Chapter 3, Exhibit 3-2. On roadways traversed by traffic in both directions, the sight distance available on downgrades is larger than on upgrades, more or less automatically provides the appropriate corrections for grade.

**E. Decision Sight Distance.** Stopping sight distances are usually sufficient to allow reasonably competent and alert drivers to come to a hurried stop under ordinary circumstances. However, these distances are often inadequate when drivers must make complex or instantaneous decisions, when information is difficult to perceive or when unexpected or unusual maneuvers are required. Since there are many locations where it would be prudent to provide longer sight distances, decision sight distance provides the greater visibility distance that drivers need.

Decision sight distance is the distance needed for a driver to detect an unexpected or otherwise difficult-to-perceive information source or condition in a roadway environment that may be visually cluttered, recognize the condition or its threat potential, select an appropriate speed and path and initiate and complete the maneuver safely and efficiently. Decision sight distance offers drivers additional margin for error and affords them sufficient length to maneuver their vehicles at the same or reduced speed rather than to just stop.

The following are examples of critical locations where these kinds of errors are likely to occur and where it is desirable to provide decision sight distance:

1. Interchanges and intersections.
2. Locations where unusual or unexpected maneuvers are required.
3. Changes in cross section such as toll plazas and lane drops.
4. Areas of concentrated demand where there is apt to be "visual noise".
5. Railroad-highway grade crossings.

Decision sight distance criteria that are applicable to most situations have been developed from empirical data. The decision sight distances vary depending on whether the location is on a rural or urban road, and on the type of avoidance maneuver required. If it is not practical to provide these distances because of horizontal or vertical curvatures, special attention should be given to the use of suitable traffic control devices. The 2004 AASHTO Green Book, Chapter 3, Exhibit 3-3 shows decision sight distance values for various situations rounded for design.

For additional information concerning decision sight distance, refer to the section "Decision Sight Distance" in the 2004 AASHTO Green Book, Chapter 3.

**F. Intersection Sight Distance.** Since each intersection has the potential for several different types of vehicle conflicts, those conflicts can be greatly reduced through provisions for proper sight distances and appropriate traffic controls. The driver of a vehicle approaching an intersection should have an unobstructed view of the entire intersection, including any traffic control devices, and sufficient lengths along the intersecting highway to permit the driver to anticipate and avoid potential collisions.

For procedures to determine sight distances at intersections according to different types of traffic control, refer to the section "Intersection Sight Distance" in the 2004 AASHTO Green Book, Chapter 9. These types include:

1. Case A - Intersections with No Control.
2. Case B - Intersections with Stop Control on the Minor Road
   a. Case B1 - Left Turn from the Minor Road
   b. Case B2 - Right Turn from the Minor Road
   c. Case B3 - Crossing Maneuver from the Minor Road
3. Case C - Intersections with Yield Control on the Minor Road
   a. Case C1 - Crossing Maneuver from the Minor Road
   b. Case C2 - Left or Right Turn from the Minor Road
4. Case D - Intersections with Traffic Signal Control
5. Case E - Intersections with All-Way Stop Control
6. Case F - Left Turns from the Major Road

Sight distance between intersecting traffic flows is not considered a requirement for intersections controlled by traffic signals, since the flows move at separate times. However, due to a variety of operational characteristics, such as violation of signal, right turn on red, malfunction of the signal etc., sight distance should be provided for signalized intersections as well. A basic requirement for all controlled intersections is that drivers must be able to see the control device soon enough to perform the action it indicates.

For additional information concerning sight distance for intersections, refer to the section "Intersection Sight Distance" in the 2004 AASHTO Green Book, Chapter 9.

**G. Sight Distance for Multilane Highways.** It is not necessary to consider passing sight distance on highways or streets that have two or more traffic lanes in each direction of travel. Passing maneuvers on multilane roadways are expected to occur within the limits of the traveled way for each direction of travel. Thus, passing maneuvers that involve crossing the centerline of four-lane undivided roadways or crossing the median of four-lane roadways should be prohibited. Multilane roadways should have continuously adequate stopping sight distance with greater-than-design sight distances preferred.

**H. Sight Distance on Horizontal Curves.** The sight distance needed across the inside of horizontal curves, where there are sight obstructions such as walls, cut slopes, buildings and possibly guide rail or median barrier, may need adjustment in the normal highway cross section or a change in the alignment if removal of the obstruction is impractical to provide adequate sight distance. Because of the many variables in alignment, in cross section and in the number, type and location of potential obstructions, specific study is usually needed for each individual curve. With sight distance for the design speed as a control, check the actual conditions on each curve and make the appropriate adjustments to provide adequate sight distance.

For general use in design of a horizontal curve, the sight line is a chord of the curve, and the stopping sight distance is measured along the centerline of the inside lane around the curve. The 2004 AASHTO Green Book, Chapter 3, Exhibit 3-53 indicates the horizontal sightline offsets for needed clear sight areas that satisfy stopping sight distance criteria presented in the 2004 AASHTO Green Book, Chapter 3, Exhibit 3-1. The horizontal sightline offset values in the 2004 AASHTO Green Book, Chapter 3, Exhibit 3-53 are derived from geometry for the several dimensions, as indicated in the diagrammatic sketch in the 2004 AASHTO Green Book, Chapter 3, Exhibit 3-54 and in the 2004 AASHTO Green Book, Chapter 3, Equation 3-38. Using the height criteria for stopping sight distance of 1.080 m (3.5 ft) for height of eye and 0.600 m (2.0 ft) for height of object, a height of 0.840 m (2.75 ft) may be used as the midpoint of the sight line where the cut slope usually obstructs sight. This assumes there is little or no vertical curvature.

The method presented in the 2004 AASHTO Green Book, Chapter 3, Exhibits 3-53 and 3-54 is only exact when both the vehicle and the sight obstruction are located within the limits of the simple horizontal curve. When either the vehicle or the sight obstruction is located beyond the limits of the simple curve, the values obtained are only approximate. The same is true if either the vehicle or the sight obstruction is located within the limits of a spiral or a compound curve. In these instances, the value obtained would result in horizontal sightline offset values slightly larger than those needed to satisfy the desired stopping sight distance.

The minimum passing sight distance for a two-lane road or street is about four times as great as the minimum stopping sight distance at the same design speed. The equation indicated in the 2004 AASHTO Green Book, Chapter 3 (Equation 3-38) is directly applicable for passing sight distance confined to tangent and very flat alignment conditions and are of limited practical value except on long curves since it is difficult to maintain passing sight distance on other than very flat curves.

## 2.18 OTHER ELEMENTS AFFECTING GEOMETRIC DESIGN

In addition to the design elements presented in previous Sections, there are other elements that affect or are affected by geometric design of a roadway. Each of these additional elements is addressed briefly below only to the extent necessary to indicate its relationship to geometric design.

**A. Traffic Control Devices.** Traffic control devices provide guidance and navigation information and also display additional information that augments some roadway or environmental feature that might otherwise be overlooked or difficult to receive. Traffic control devices include regulatory, warning, route guidance information, markings and delineation measures. Control devices are essential elements for all functional classification systems and their application shall be consistent and uniform especially at intersections where multiphase or actuated traffic signals may be needed. Geometric design should not be considered complete nor should it be implemented until it has been determined that needed traffic control devices will have the desired effect in controlling traffic.

Traffic control signals (including railroad crossing signals) represent devices that control vehicular and pedestrian traffic by assigning the right-of-way to various movements for certain pretimed or traffic-actuated intervals of time. Since they are one of the key elements in the function of many urban streets and rural intersections, the planned signal operation for each intersection of a facility should be integrated with the design so as to achieve optimum operational efficiency. The guidelines for the design and operation of traffic signals on all streets and highways shall conform to Publication 149, *Traffic Signal Design Handbook;* Publication 408, *Specifications;* Publication 111M, *Traffic Control - Pavement Marking and Signing Standards*, TC-8600 and TC-8700 Series; and Publication 148, *Traffic Standards - Signals*, TC-7800 Series. For railroad crossing signals, refer to the *MUTCD*, Part 8.

Signing and marking are directly related to the design of the highway or street and are features of traffic control and operation that should be considered in the geometric layout of such a facility. The signing and marking should be designed concurrently with the geometrics since future operational problems can be reduced significantly if both are treated as an integral part of design. The extent to which signs and markings are used depends on the traffic volume, the type of facility, and the extent of traffic control appropriate for safe and efficient operation.

Although safety and efficiency of operation depend to a considerable degree on the geometric design of the facility, the physical layout should also be supplemented by effective signing as a means of informing, warning and controlling drivers. Signing plans coordinated with horizontal and vertical alignment, sight distance obstructions, operational speeds and maneuvers and other applicable items should be worked out before completion of design.

Markings and markers, like signs, have the function of controlling traffic to encourage safe and efficient operation. Markings or markers either supplement regulatory or warning signs or serve independently to indicate certain regulations or warn of certain conditions present on the highway. The design, location and operation of all traffic signs and markings shall be governed by the regulations contained in 67 PA Code § 212.

Physical obstructions in or near the roadway should be removed in order to provide the appropriate clear zone. Where removal is impractical, such objects should be adequately marked by painting or by use of other high-visibility material. Where the object is in the direct line of traffic, the obstruction and marking thereon preferably should be illuminated at night by floodlighting; where this is not practical, the markings should be effectively reflectorized.

**B. Intelligent Transportation Systems.** Intelligent Transportation Systems (ITS) involve the installation and use of electronic message signs, highway advisory radios, closed circuit television (CCTV) and other electronic devices by PennDOT to provide real-time emergency or congestion information to motorists. Design guidance is found in Publication 646, *Intelligent Transportation Systems Design Guide* and Publication 647M, *Civil and Structural Standards for Intelligent Transportation Systems*. Maintenance guidance is provided in Publication 697, *Intelligent Transportation Systems Maintenance Standards*.

**C. Erosion Control.** Erosion prevention represents one of the major factors in design, construction and maintenance. The most direct application of erosion control occurs in drainage design and in the writing of specifications of landscaping and slope planting. Erosion and maintenance are minimized largely by: (1) the use of flat side slopes, rounded and blended with natural terrain; (2) serrated cut slopes; (3) drainage channels designed with due regard to width, depth, slopes, alignment and protective treatment; (4) inlets located and spaced with erosion control in mind; (5) prevention of erosion at culvert outlets; (6) proper facilities for groundwater interception; (7) dikes, berms and other protective devices; (8) sedimentation devices to trap sediment at strategic locations; and (9) protective ground covers and planting. The procedures and criteria for effecting maximum erosion and sediment control shall follow the guidelines contained in Chapter 13 and shall be constructed in accordance with Publication 72M, *Roadway Construction Standards* and Publication 408, *Specifications,* for all functional classification systems.

**D. Landscape Development.** Landscape development should be provided for aesthetic and erosion control purposes in keeping with the character of the highway and its environment. Programs include the following general areas of improvement: (1) preservation of existing vegetation; (2) transplanting of existing vegetation where practical; (3) planting of new vegetation; (4) selective clearing and thinning; and (5) regeneration of natural plant species and material.

The objectives in planting or the retention and preservation of natural growth on roadsides are closely related. In essence, they are to provide: (1) vegetation that shall be an aid to aesthetics and safety; (2) vegetation that shall aid in lowering construction and maintenance costs; and (3) vegetation that creates interest, usefulness and beauty for the pleasure and satisfaction of the traveling public.

Care should be exercised to ensure that guidelines for sight distances and clearance to obstructions are observed especially at intersections. Landscaping should also consider maintenance problems and cost, future sidewalks, utilities, additional lanes and possible bicycle facilities. All landscape development shall conform to the general principles established in Chapter 8 and the additional sources of reference listed therein for all functional classification systems.

**E. Railroad-Highway Grade Crossings.** All railroad-highway grade crossings come under the jurisdiction of the Public Utility Commission (PUC) and cannot be constructed or altered without their prior approval. Appropriate grade crossing warning devices, as determined by the PUC, shall be installed at all railroad-highway grade crossings. Details of the available devices to be used are given in Publication 212, *Official Traffic Control Devices* and in the *MUTCD*, Part 8.

Sight distance is an important consideration at railroad-highway grade crossings. There shall be sufficient sight distance on the highway for the driver to recognize the crossing, perceive the warning device and stop if necessary.

Another important consideration is the required minimum railroad vertical and/or horizontal clearances between the track and an obstruction. Refer to Publication 371, *Grade Crossing Manual*, Appendix H for these requirements.

Additional design guidance for railroad requirements may be found in Publication 371, *Grade Crossing Manual*.

**F. Drainage.** Highway drainage facilities carry water across the right-of-way and remove storm water from the roadway itself. Drainage facilities include bridges, culverts, channels, curbs, gutters and various types of drains. Hydraulic design procedures, requirements for stream crossing and floodplain encroachments, hydraulic capacities and locations of the above structures should be designed to take into consideration damage to upstream property and reduce traffic interruption by flooding as is consistent with the importance of the roadway, the design traffic service requirements and available funds. The design and criteria for highway drainage facilities shall conform to the guidelines presented in Chapter 10 and shall be constructed in accordance with Publication 72M, *Roadway Construction Standards*; Publication 408, *Specifications*; and other applicable Department directives. Additional design guidance may be found in Publication 584, *PennDOT Drainage Manual*.

**G. Lighting.** Lighting may improve the safety of a highway or street and the ease and comfort of operation thereon. Lighting of rural highways may be desirable, but the need for such fixed-source lighting is much less than on streets and highways in urban areas. Lighting of rural highways is seldom justified except in certain critical areas such as interchanges, intersections, railroad-highway grade crossings, long or narrow bridges, tunnels, sharp curves and other areas where roadside interferences are present. Since highway lighting for freeways is intimately associated with the type and location of highway signs, full effectiveness should include the joint design of these two areas. The design criteria and policies for highway lighting systems shall conform to the procedures presented in Chapter 5 and the additional sources of reference listed therein and shall be constructed in accordance with Publication 72M, *Roadway Construction Standards* and Publication 408, *Specifications*.

**H. Safety Rest Areas, Welcome Centers and Scenic Overlooks.** These areas represent functional and desirable elements of the complete highway facility and are provided for the safety and convenience of highway users. Site selection for safety rest areas, welcome centers and scenic overlooks should consider the scenic quality of the area, accessibility and adaptability to development that includes facilities designed to accommodate the needs of older persons and persons with disabilities. The design procedures associated with these facilities shall be in accordance with the criteria presented in Chapter 9 and the additional sources of reference listed therein.

**I. Utilities.** Highway and street improvements, whether upgraded within the existing right-of-way or entirely on new right-of-way, must be designed to avoid or minimize impacts to utility facilities. This is in accordance with State and Federal regulations (PA One Call, 23 CFR and the Federal Program Guide on Utility Relocation and Accommodation on Federal-Aid Highway Projects) and must be done.

The existing utilities should be placed on the plans early in the development of a project to identify conflicts when designing the new or upgraded highway and street improvements.

The use of Subsurface Utility Engineering (SUE) may be required to determine the exact horizontal and vertical location of all underground utilities (refer to Publication 16, Design Manual, Part 5, *Utility Relocation*, Chapter 6, Subsurface Utility Engineering). The SUE Utility Impact Form (see Publication 16, Design Manual, Part 5, *Utility Relocation*, Appendix A-501) is a tool that was developed to address the legal requirements and to comply with the State and Federal laws. The form provides an analysis based on project criteria to determine if SUE use is "practicable," when SUE should be considered on a project, and what SUE quality levels should be utilized. SUE should be considered for all projects regardless of a project's estimated cost. The SUE Impact form should be completed by the Project Manager in coordination with the District Utility Relocation Unit.

Special construction items should be shown on the utility submissions (see Publication 16, Design Manual, Part 5, *Utility Relocation*, Appendix A-502).

It is important that the Project Manager coordinate plan revisions with the District Utility Administrator to determine the effect they may have on the relocation of utilities. In many cases minor revisions to the highway plan can have major impacts to the relocation of utilities.

Although utilities generally have little effect on the geometric design of the highway or street, full consideration should be given to measures, reflecting sound engineering principles and economic factors, needed to preserve and protect the integrity and visual quality of the highway or street, its maintenance efficiency and the safety of traffic. The various policies and procedures to accomplish utility adjustments made necessary by highway construction projects are contained in Publication 16, Design Manual, Part 5, *Utility Relocation*.

**J. Bicycle Facilities.** The bicycle has become an element for consideration in the highway design process. Most of the distance required for bicycle travel is comprised of the current street and highway system. However, at certain locations or in certain corridors, a designated bikeway (for either exclusive or nonexclusive bicycle use) may be provided to supplement the existing street or highway system. The design of bikeway facilities shall adhere to the guidelines presented in Chapter 16 and Chapter 19.

**K. Noise Control and Noise Barriers.** Since motor vehicles generate traffic noise, the design of highways may require the establishment of measures to minimize the radiation of noise into noise-sensitive areas by evaluating existing or potential noise levels and estimate the effectiveness of reducing highway traffic noise through location and design considerations. The actual noise level is not, in itself, a good predictor of annoyance since human reactions to noise are usually less if the noise source is hidden from view. The type of development in a particular area can affect the annoyance level since high traffic noise levels are usually more tolerable in industrial than in residential areas. Other factors that influence human reactions to noise are pitch and intermittency because the higher the pitch or the more pronounced the intermittency of the noise, the greater the degree of annoyance.

To combat the adverse effect noise can have on people living on, working on or otherwise using land adjacent to highways, noise barriers may be constructed on both new and existing highways. Careful consideration shall be exercised to ensure the location and construction of noise barriers shall not compromise the safety of the highway by providing proper horizontal clearances and adequate sight distances particularly where the location of the noise barrier is along the inside of a curve. An effective method of reducing traffic noise from adjacent areas is to design the highway so that some form of solid material such as earth or concrete blocks the line of sight between the noise source and the receptors. Buffer plantings such as shrubs, trees or ground covers offer some noise reduction while exceptionally wide and dense plantings may result in substantial reductions in noise levels. In terms of noise considerations, a depressed highway section is the most desirable noise reduction design. For additional information and general considerations for noise barriers including design procedures, noise reduction designs and the assessment of noise impacts on highway projects, refer to Publication 10C, Design Manual, Part 1C, *Transportation Engineering Procedures,* Chapter 4, Section 4.9.G.12 and the section "Noise Control" in the 2004 AASHTO Green Book, Chapter 4.

**L. Structures.** The established standard policies, procedures and specifications for the design and construction of highway structures shall be governed by Publication 15M, Design Manual, Part 4, *Structures* and the additional sources of reference listed therein.

**M. Pedestrian Facilities.** Since pedestrians represent a part of every roadway environment, attention should be paid to their presence in rural as well as in urban areas. The urban pedestrian, being more prevalent, influences roadway design features more often than the rural pedestrian does. Pedestrian facilities may include sidewalks, crosswalks, traffic control features and curb ramps for persons with disabilities. When designing urban highways with substantial pedestrian-vehicle conflicts, the following are some measures that could be considered to help reduce these conflicts and may increase the efficient operation of the roadway: (1) eliminate left and/or right turns; (2) prohibit free-flow right-turn movements; (3) prohibit right turn on red; (4) convert from two-way to one-way street operation; (5) provide separate signal phases for pedestrians; (6) eliminate selected crosswalks; and (7) provide for pedestrian grade separations. Pedestrian accommodation and pedestrian facilities shall follow the design criteria and guidelines presented in Chapter 6. For additional information concerning general considerations, physical characteristics of pedestrians and characteristics of pedestrians with disabilities, refer to the section "The Pedestrian" in the 2004 AASHTO Green Book, Chapter 2 and Chapter 19.

**N. Highway Capacity Analysis.** The term "capacity" is used to express the maximum number of vehicles that have a reasonable expectation of passing over a given section of a lane or a roadway during a given time period under prevailing roadway and traffic conditions. The principles and major factors concerning highway design capacity analysis are presented in the *HCM*.

**O. Mass Transit Facilities.** Wherever there is a demand for highways to serve automobile traffic, there is likewise a demand for public transportation. The requirements for public transit and their compatibility with other highway traffic shall be considered in the development and design of highways to insure the forms of interference between the two are minimized through careful planning, design and traffic control measures. Mass transit facilities may include bus stops and bus turnouts, park and ride facilities, rail transit and high-occupancy vehicle (HOV) facilities. For additional information concerning the location and design of these mass transit facilities, refer to the sections "Bus Turnouts", "Public Transit Facilities", and "Accommodation of Transit and High-Occupancy Vehicle Facilities" in the 2004 AASHTO Green Book, Chapters 4, 7, and 8, respectively and Chapter 19.

**P. Special Purpose Roads.** For the purpose of design, highways are classified by function with specific design criteria given for each functional classification (see Chapter 1, Section 1.2). However, certain roads do not fit into any of the current functional classifications due to their purpose and are referred to as special purpose roads. These roads include: (1) recreational roads; (2) resource recovery roads; and (3) local service roads and, because of their uniqueness, separate design criteria are provided as presented in the section "Special-Purpose Roads" in the 2004 AASHTO Green Book, Chapter 5. Recreation roads, as the name implies, serve recreation sites and areas through the use of primary access roads, circulation roads and area roads. Resource recovery roads include mining and logging roads that are primarily composed of large, slow-moving, heavily loaded vehicles. Local service roads represent roads serving isolated areas that have little or no potential for further development with traffic that is very low and generally consists of drivers who are familiar with the road.

Although not classified as special purpose roads, frontage roads, cul-de-sacs, turnarounds and alleys are presented herein since their functions apply to special areas of accessibility. Frontage roads serve numerous functions depending on the type of roadway they serve and the character of the surrounding area. Frontage roads can be used on all types of highways to: (1) control access to an arterial; (2) function as a street facility serving adjoining properties; (3) maintain circulation of traffic on each side of an arterial; (4) segregate local traffic from higher-speed, through traffic; and (5) intercept driveways of residences and commercial establishments along the highway. For information on data and features of frontage roads, refer to the section "Frontage Roads" in the 2004 AASHTO

Green Book, Chapter 4. Cul-de-sacs and turnarounds are normally employed for use on a local street system that is open at one end. A special turning area at the closed end is used to enable passenger vehicles and local delivery trucks to U-turn or at least turn around by backing once. Alleys are also associated with local street systems. They provide access to the side or rear individual land parcels with connections to streets or to other alleys. The geometric features and design guidelines for cul-de-sacs, turnarounds and alleys are presented in the sections "Cul-de-Sacs and Turnarounds" and "Alleys" in the 2004 AASHTO Green Book, Chapter 5.

**Q. Traffic Barriers.** Traffic barriers are used to prevent vehicles that leave the traveled way from hitting an object that has greater crash severity potential than the barrier itself. Because barriers are a source of crash potential themselves, their use should be carefully considered. The criteria and guidelines for the design, placement and installation of longitudinal barrier systems (roadside barriers and median barriers) and impact attenuators are presented in Chapter 12.

**R. Curbs and Driveways.** The type and location of curbs affects driver behavior and, in turn, the safety and utility of a highway. Curbs serve any or all of the following purposes: (1) drainage control; (2) roadway edge delineation; (3) right-of-way reduction; (4) aesthetics; (5) delineation of pedestrian walkways; (6) reduction of maintenance operations; and (7) assistance in orderly roadside development. Curb configurations include both vertical and sloping curves. The design and construction of curbs shall be in accordance with Publication 72M, *Roadway Construction Standards*; Publication 408, *Specifications*; and Chapters 6, 7, and 9. For further information refer to the sections "Curbs" and "Driveways" in the 2004 AASHTO Green Book, Chapter 4. Vertical curbs should not be used along freeways or other high-speed roadways because an out-of-control vehicle may overturn or become airborne as a result of an impact with such a curb. Since curbs are not adequate to prevent a vehicle from leaving the roadway, a suitable traffic barrier should be provided where redirection of vehicles is needed. Sloping curbs can be used at median edges to outline channelizing islands in intersection areas or at the outer edge of the shoulder. Sloping curbs are designed so vehicles can cross them readily when the need arises.

**S. Maintenance of Traffic Through Construction Areas.** Maintaining a safe flow of traffic during construction shall be carefully planned in the development of construction plans, and the designs for traffic control shall minimize the effect on traffic operations by minimizing the frequency or duration of interference with normal traffic flow. The development of traffic control plans is an essential part of the overall project design and depends on the nature and scope of the improvement, volumes of traffic, highway or street pattern and capacities of available highways or streets. A well-thought-out and carefully developed traffic control plan through a construction work zone can contribute significantly to the safe and efficient flow of traffic as well as the safety of the construction forces.

The goal of any traffic control plan should be to safely route traffic at a controlled speed through or around construction areas with geometrics and traffic control devices as nearly comparable to those utilized for normal operating situations as practical while providing room for construction operations. The maintenance of traffic through construction areas shall adhere to the guidelines presented in Publication 212, *Official Traffic Control Devices* and Publication 213, *Temporary Traffic Control Guidelines.*

**T. Outer Separations and Border Areas.** The area between the traveled way of a roadway for through traffic and a frontage road (see Section O above) or a street for local traffic is referred to as the outer separation. These function as buffers for noise abatement in sensitive areas and provide space for shoulders, sideslopes, drainage, access-control fencing and possibly retaining walls and ramps in urban areas. The outer separation should be as wide as economically possible so local traffic will have less influence on through traffic and should lend itself to landscape treatment that can enhance the appearance of both the highway and adjoining property. Where ramp connections are provided between the through roadway and the frontage road, the outer separation should be wider than normal with the needed width dependent on the design requirements of the ramp termini. Where two-way frontage roads are provided, desirably the outer separation should be sufficiently wide to minimize the effects of the approaching traffic particularly the nuisance of headlight glare at night.

The cross section and treatment of an outer separation depends largely upon its width and the type of arterial and frontage road. Preferably, the strip should drain away from the through roadway either to a curb and gutter at the frontage road or to a swale within the strip. Typical cross sections for outer separations are presented in the 2004 AASHTO Green Book, Chapter 4, Exhibit 4-13.

Where there are no frontage roads or local streets functioning as frontage roads, the area between the traveled way of the main lanes and the right-of-way line is referred to as the border area. The border area between the roadway and the right-of-way line should be wide enough to serve several purposes including provision of a buffer space between pedestrians and vehicular traffic, sidewalk space, snow storage, an area for placement of underground and above ground utilities such as traffic signals, parking meters and fire hydrants and an area for maintainable aesthetic features such as grass or other landscaping features. The border width should be 2.4 m (8 ft) wide and preferably 3.6 m (12 ft) wide or more. Every effort should be made to provide wide borders not only to serve functional needs but also as a matter of aesthetics, safety and reducing the nuisance of traffic to adjacent development.

**U. Median Crossovers.** Consideration shall be given to providing openings in medians on Interstate and other Limited Access Freeways for use by emergency and other authorized vehicles. Median crossovers are also intended to be used where operation of snow and ice removal equipment to clear interchange ramps would be expedited. The need for such openings shall be determined by the District Executive and their use shall conform to the guidelines presented below. Median barrier and end treatments, if required at these locations, shall be constructed as indicated on the Standard Drawings. Crossovers should never be provided unless justified. Median crossovers constructed on Interstate Highways shall be approved by the Federal Highway Administration (FHWA). A submission shall be made to the Central Office, Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section for this purpose.

Median crossovers can be used on Interstate and Non-Interstate Limited Access Freeways when the median width is greater than 10 m (33 ft). If crossovers are required in a median where the width is not greater than 10 m (33 ft), coordination with the Central Office, Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section is required. Median crossovers can be located as follows:

**1.** Where the distance between the ends of speed-change tapers for adjacent interchanges is less than 6 km (4 mi), one median crossover may be provided. This crossover should be constructed at a suitable location midway between the interchanges, but not closer than 450 m (1,500 ft) from the end of any speed-change taper or structure. Crossovers should be located only where above-minimum stopping sight distance is provided and preferably should not be located on superelevated curves.

**2.** Where the distance between the ends of speed-change tapers for adjacent interchanges is greater than 6 km (4 mi), two or more median crossovers may be provided. These crossovers shall be provided at no less than 5 km (3 mi) intervals, and shall not be constructed closer than 450 m (1,500 ft) from the end of any speed-change taper or structure.

**3.** One set of dual crossovers may be located at or near a State or County line if the proximity of the nearest interchange or median crossover is greater than 1.6 km (1 mi). The intent of the dual crossovers is to allow for the safe operation of winter maintenance activities, eliminating the need for winter maintenance vehicles to back up to a crossover after plowing or spreading materials beyond the crossover. If an acceptable location for dual crossovers cannot be established at the State or County line, the pair may be shifted to the nearest acceptable location that has adequate sight distance. If dual crossovers are required, coordination with the Central Office, Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section is required.

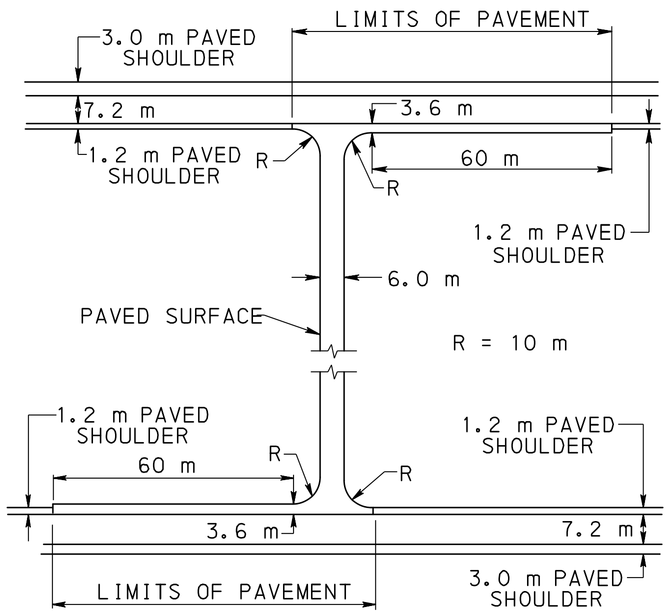
All median crossovers shall conform to the typical detail shown in Figure 2.8. They shall be constructed with a paved surface, paved shoulders, and deceleration lanes as shown. A typical detail for dual crossovers at or near a State or County line is shown in Figure 2.9.

The location of median crossovers should be coordinated with proposed or existing median drainage systems to eliminate exposed pipe end sections that could present an obstacle to errant vehicles. Where cross pipes are deemed necessary, careful thought should be given to providing a safe, hydraulically-efficient drainage system that uses proper drainage appurtenances to eliminate undesirable conditions. The kind, size, and location of the drainage system required is dependent on actual field conditions.

All exposed culvert end sections shall be designed to ensure they can be safely negotiated by errant vehicles. The ends of the pipe should be sloped to match the side slopes of the crossover. All pipe openings greater than 450 mm (18 in) in diameter should be designed to provide safe traversability by using a grate, longitudinal or transverse bars or a combination thereof. Embankment slopes in the crossover area should be 1V:6H minimum, longitudinally and 1V:12H minimum, transversely (1V:20H desirable), with respect to the crossover pavement.

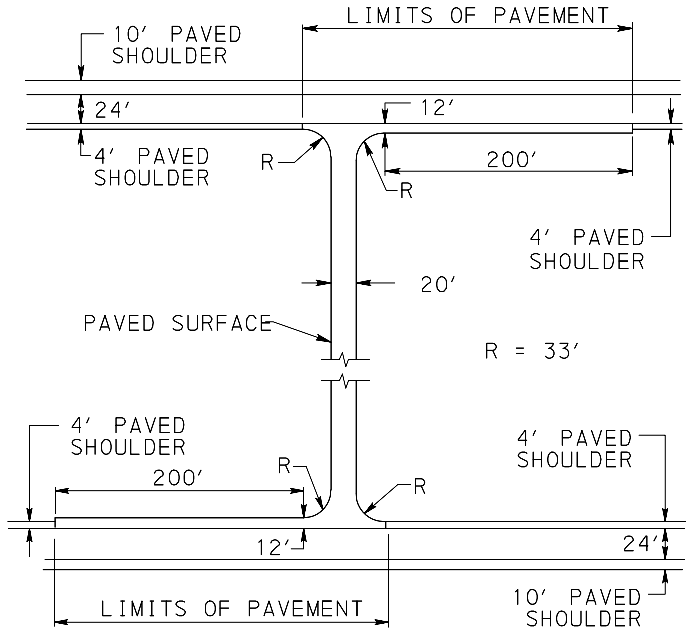
In order to limit usage to emergency and other authorized vehicles, appropriate signing and delineation shall be used (see Traffic Standard TC-8604).

When eliminating existing crossovers, proper coordination should be conducted with local emergency management officials to ensure their operations are not significantly impacted.




1. TRANSVERSE SLOPES SHOULD BE A MINIMUM 1V:12H WITH RESPECT TO THE CROSSOVER PAVEMENT, FLAT AND FREE OF ROADSIDE OBSTRUCTIONS.
2. LONGITUDINAL SLOPES SHOULD BE A MINIMUM 1V:6H WITH RESPECT TO THE CROSSOVER PAVEMENT, UNLESS PROTECTED BY A GUIDE RAIL.
3. PAVED SURFACE SHALL CONSIST OF: 40 mm HMA WEARING COURSE, 100 mm HMA BASE COURSE, 150 mm SUBBASE OR 40 mm HMA WEARING COURSE, 150 mm AGG-BIT, 150 mm SUBBASE.
4. WHEN CONCRETE SHOULDERS ARE PROVIDED ON THE MAINLINE, THE 1.2 m CONCRETE SHOULDER SHALL BE CONTINUED THROUGH THE DECELERATION LANE AND CROSSOVER AREA. THE ADDITIONAL 2.4 m WIDENING FOR THE DECELERATION LANE AND THE CROSSOVER PAVEMENT SHALL BE A PAVED SURFACE CONSISTING OF: 40 mm HMA WEARING COURSE, 100 mm HMA BASE COURSE, 150 MM SUBBASE OR 40 MM HMA WEARING COURSE, 150 MM AGG-BIT, 150 mm SUBBASE.

FIGURE 2.8 (METRIC)
TYPICAL PERMANENT
MEDIAN CROSSOVER



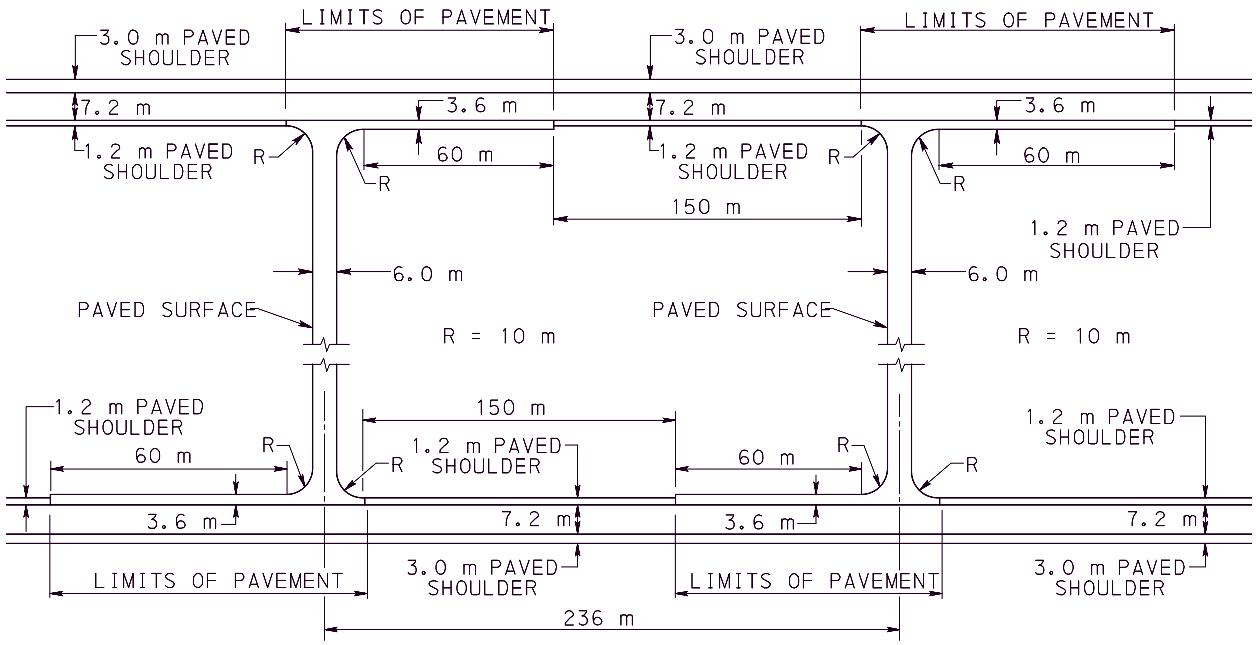

1. TRANSVERSE SLOPES SHOULD BE A MINIMUM 1V:12H WITH RESPECT TO THE CROSSOVER PAVEMENT, FLAT AND FREE OF ROADSIDE OBSTRUCTIONS.

2. LONGITUDINAL SLOPES SHOULD BE A MINIMUM 1V:6H WITH RESPECT TO THE CROSSOVER PAVEMENT, UNLESS PROTECTED BY A GUIDE RAIL.

3. PAVED SURFACE SHALL CONSIST OF: 1½" HMA WEARING COURSE, 4" HMA BASE COURSE, 6" SUBBASE OR 1½" HMA WEARING COURSE, 6" AGG-BIT, 6" SUBBASE.

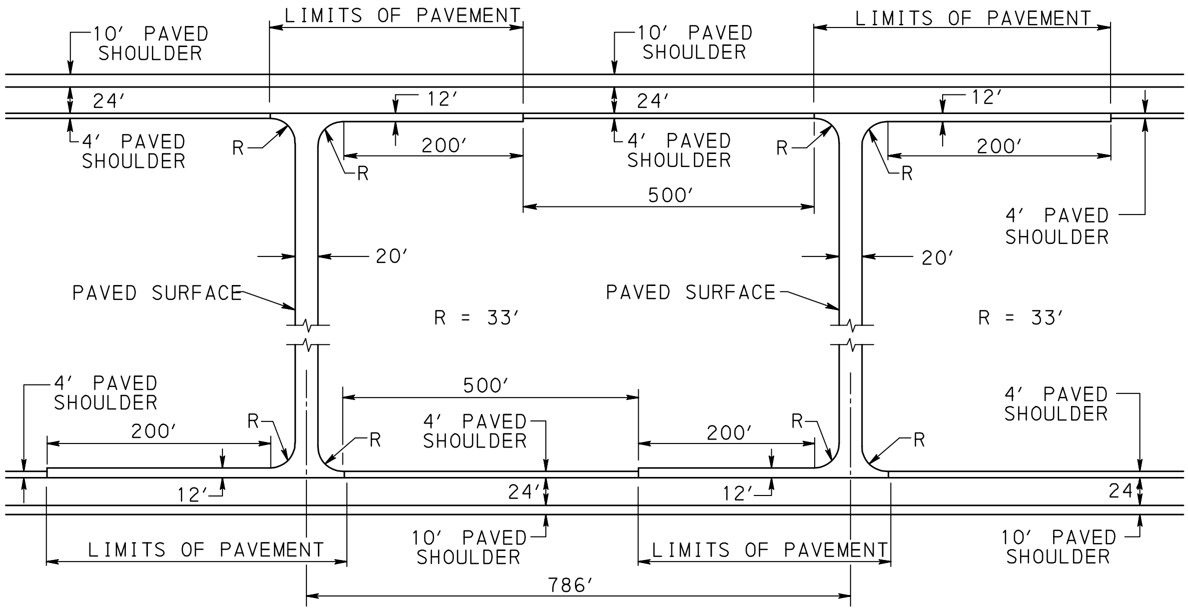
4. WHEN CONCRETE SHOULDERS ARE PROVIDED ON THE MAINLINE, THE 4′ CONCRETE SHOULDER SHALL BE CONTINUED THROUGH THE DECELERATION LANE AND CROSSOVER AREA. THE ADDITIONAL 8′ WIDENING FOR THE DECELERATION LANE AND THE CROSSOVER PAVEMENT SHALL BE A PAVED SURFACE CONSISTING OF: 1½" HMA WEARING COURSE, 4" HMA BASE COURSE, 6" SUBBASE OR 1½" HMA WEARING COURSE, 6" AGG-BIT, 6" SUBBASE.

FIGURE 2.8 (ENGLISH)
TYPICAL PERMANENT
MEDIAN CROSSOVER




1. TRANSVERSE SLOPES SHOULD BE A MINIMUM 1V:12H WITH RESPECT TO THE CROSSOVER PAVEMENT, FLAT AND FREE OF ROADSIDE OBSTRUCTIONS.
2. LONGITUDINAL SLOPES SHOULD BE A MINIMUM 1V:6H WITH RESPECT TO THE CROSSOVER PAVEMENT, UNLESS PROTECTED BY A GUIDE RAIL.
3. PAVED SURFACE SHALL CONSIST OF: 40 mm HMA WEARING COURSE, 100 mm HMA BASE COURSE, 150 mm SUBBASE OR 40 mm HMA WEARING COURSE, 150 mm AGG-BIT, 150 mm SUBBASE.
4. WHEN CONCRETE SHOULDERS ARE PROVIDED ON THE MAINLINE, THE 1.2 m CONCRETE SHOULDER SHALL BE CONTINUED THROUGH THE DECELERATION LANE AND CROSSOVER AREA. THE ADDITIONAL 2.4 m WIDENING FOR THE DECELERATION LANE AND THE CROSSOVER PAVEMENT SHALL BE A PAVED SURFACE CONSISTING OF: 40 mm HMA WEARING COURSE, 100 mm HMA BASE COURSE, 150 mm SUBBASE OR 40 mm HMA WEARING COURSE, 150 mm AGG-BIT, 150 mm SUBBASE.

FIGURE 2.9 (METRIC)
TYPICAL DUAL MEDIAN
CROSSOVERS AT STATE
OR COUNTY LINES




1. TRANSVERSE SLOPES SHOULD BE A MINIMUM 1V:12H WITH RESPECT TO THE CROSSOVER PAVEMENT, FLAT AND FREE OF ROADSIDE OBSTRUCTIONS.
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3. PAVED SURFACE SHALL CONSIST OF: 1½" HMA WEARING COURSE, 4" HMA BASE COURSE, 6" SUBBASE OR 1½" HMA WEARING COURSE, 6" AGG-BIT, 6" SUBBASE.
4. WHEN CONCRETE SHOULDERS ARE PROVIDED ON THE MAINLINE, THE 4′ CONCRETE SHOULDER SHALL BE CONTINUED THROUGH THE DECELERATION LANE AND CROSSOVER AREA. THE ADDITIONAL 8′ WIDENING FOR THE DECELERATION LANE AND THE CROSSOVER PAVEMENT SHALL BE A PAVED SURFACE CONSISTING OF: 1½" HMA WEARING COURSE, 4" HMA BASE COURSE, 6" SUBBASE OR 1½" HMA WEARING COURSE, 6" AGG-BIT, 6" SUBBASE.

FIGURE 2.9 (ENGLISH)
TYPICAL DUAL MEDIAN
CROSSOVERS AT STATE
OR COUNTY LINES

## 2.19 DESIGN CONTROLS

This section presents the characteristics of design vehicles, driver performance and traffic data that are necessary for the optimization or improvement in the design of the various highways that comprise the functional classification system. Additional sources of information and criteria to supplement the general characteristics presented are contained in the 2004 AASHTO Green Book, Chapter 2, "Design Controls and Criteria".

**A. Design Vehicles.** Design vehicles represent selected motor vehicles with the weight, dimensions and operating characteristics used to establish highway design controls for accommodating vehicles of designated classes. Nineteen design vehicles are used in design that comprise four general classes, including passenger cars, buses, trucks and recreational vehicles. In the design of any highway facility, the largest design vehicle likely to use that facility with considerable frequency or a design vehicle with special characteristics appropriate to a particular intersection is used to determine the design of such critical features as radii at intersections and radii of turning roadways. The dimensions for the 19 design vehicles and their associated symbols are presented in the 2004 AASHTO Green Book, Chapter 2, Exhibit 2-1.

**1.** Minimum Turning Paths. The minimum turning paths for the 19 design vehicles are presented in the 2004 AASHTO Green Book, Chapter 2, Exhibits 2-3 through 2-23. The boundaries of the minimum turning paths are established by the outer trace of the front overhang and the path of the inner rear wheel. The 2004 AASHTO Green Book, Chapter 2, Exhibit 2-2 indicates the minimum turning radius and the minimum inside radius for the 19 design vehicles.

**2.** Vehicle Performance. Acceleration and deceleration rates of vehicles represent critical parameters in determining highway design and these rates often govern the dimensions of such design features as intersections, freeway ramps, climbing or passing lanes and turnout bays for buses.

**3.** Vehicular Pollution. Pollutants emitted from motor vehicles and pollutants in the form of noise transmitted to the surrounding area are factors that shall be recognized during the highway design process. Factors including vehicle mix, vehicle speed, ambient air temperature, vehicle age distribution and the percentage of vehicles operating in a cold mode affect the rate of pollutant emission from vehicles. For passenger cars, noise produced under normal operating conditions is primarily from the engine exhaust system and the tire-roadway interaction. Truck noise has several principal components originating from such sources as exhaust, engine gears, fans and air intake.

The quality of noise varies with the number and operating conditions of the vehicles while the directionality and amplitude of the noise vary with highway design features. The highway designer shall therefore be concerned with how highway location and design influence the vehicle noise perceived by persons residing or working nearby. The perceived noise level decreases as the distance to the highway from a residence or workplace increases.

**B. Driver Performance.** An appreciation of driver performance is essential to proper highway design and operation. When drivers use a highway designed to be compatible with their capabilities and limitations, their performance is aided. Where positive guidance is applied to design, competent drivers, using well-designed highways with appropriate information displays, can perform safely and efficiently.

The section "Driver Performance" in the 2004 AASHTO Green Book, Chapter 2 provides additional information that is useful in designing and operating highways. It describes drivers in terms of their performance---how they interact with the highway and its information system and why they make errors. Specifically, this section discusses:

**1.** Older Drivers.
**2.** The Driving Task.
**3.** The Guidance Task.
**4.** The Information System.
**5.** Information Handling.
**6.** Driver Error.
**7.** Speed and Design.
**8.** Design Assessment.

**C. Traffic Characteristics.** The design of a highway and its features should be based upon explicit consideration of the traffic volume information which serves to establish the loads for the geometric highway design. The data collected include traffic volumes for days of the year and times of the day, the distribution of vehicles by types and weights and information on trends from which the designer may estimate the traffic expected in the future.

The section "Traffic Characteristics" in the 2004 AASHTO Green Book, Chapter 2 provides additional information about the following:

**1.** Traffic Volumes.

**a.** Average Daily Traffic (ADT) Volume. Defined as the total volume during a given time period (in whole days), greater than one day and less than one year, divided by the number of days in that time period.

**b.** Hourly Traffic Volume. Knowledge of the ADT volume is important for many purposes; however, the direct use of ADT volume in the geometric design of highways is not appropriate since it does not indicate traffic volume variations occurring during the various months of the year, days of the week and hours of the day. Traffic volumes for an interval of time shorter than a day more appropriately reflect operating conditions to be used for design. The hourly traffic volume used in design should not be exceeded very often or by very much nor should it be so high that traffic would rarely be sufficient to make full use of the resulting facility. One guide to determine the hourly traffic volume that is best suited for use in design is a curve showing variation in hourly traffic volumes during the year as indicated in the 2004 AASHTO Green Book, Chapter 2, Exhibit 2-28. The hourly traffic best suited for use in design is the 30th highest hourly volume of the year (30 HV). The design hourly volume (DHV), therefore, should be 30 HV of the future year chosen for design. In rural areas with average fluctuation in traffic flow, 30 HV is approximately 15 percent of the ADT while for urban areas 30 HV is approximately 10 percent of the ADT. For the design of a highway improvement, the variation in hourly traffic volumes should be measured and the percentage of ADT during the 30th highest hour determined. Where such measurement cannot be made and the ADT only is known, use should be made of 30 HV percentage factors for similar highways in the same locality, operated under similar conditions.

**2.** Directional Distribution. The directional distribution of traffic on multilane facilities during the design hour (DDHV) may be computed by multiplying the ADT by the percentage that 30 HV is of the ADT and then by the percentage of traffic in the peak direction during the design hour.

**3.** Composition of Traffic. Truck traffic should be expressed as a percentage of total traffic during the design hour (in the case of a two-lane highway, as a percentage of total two-way traffic, and in the case of a multilane highway, as a percentage of total traffic in the peak direction of travel).

**4.** Projection of Future Traffic Demands. New highways or improvements to existing highways should not usually be based on current traffic volumes alone, but should consider future traffic volumes expected to use the facility. A period of 20 years should be used as the basis for design. For reconstruction or rehabilitation projects, estimating traffic volumes for a 20-year design period may not be appropriate because of the uncertainties of predicting traffic and funding constraints. A shorter design period (5 to 10 years) may be developed for such projects.

**5.** Speed.

**a.** Operating Speed. Operating speed is the speed at which drivers are observed operating their vehicles during free-flow conditions. The 85th percentile of the distribution of observed speeds is the most frequently used measure of the operating speed associated with a particular location or geometric feature.

**b.** Design Speed. Design speed is a selected speed used to determine the various geometric design features of the roadway.

**c.** Running Speed. The speed at which an individual vehicle travels over a highway section, defined as the length of the highway section divided by the running time required for the vehicle to travel through the section.

**6.** Traffic Flow Relationships. Traffic flow conditions on roadways can be characterized by the volume flow rate expressed in vehicles per hour, the average speed in kilometers per hour (miles per hour) and the traffic density in vehicles per kilometer (vehicles per mile). Generalized speed-volume-density relationships are shown in the 2004 AASHTO Green Book, Chapter 2, Exhibit 2-30.

**D. Safety.** The section "Safety" in the 2004 AASHTO Green Book, Chapter 2 discusses how a viable safety evaluation and improvement program is a vital part of the overall highway improvement program. Areas of primary importance include the identification of potential safety problems, the evaluation of the effectiveness of alternative solutions, and the programming of available funds for the most effective improvements.

**E. Environment.** The section "Environment" in the 2004 AASHTO Green Book, Chapter 2 discusses how a highway should be considered as an element of the total environment. Because highway location and design decisions have an effect on the development of adjacent areas, it is important that environmental variables be given full consideration. Also, care should be exercised to ensure that applicable local, state, and federal environmental requirements are met.

**F. Economic Analysis.** Highway economics is concerned with the cost of a proposed improvement and the benefits resulting from it. The AASHTO publication, "User Benefit Analysis for Highways", may be used to perform economic analysis of proposed highway improvements.

## 2.20 VERTICAL CLEARANCE REQUIREMENTS

Vertical clearance represents one of the key highway elements or features as the controlling criteria for developing geometric design for both highway and bridge projects.

As such, the clearances presented in this Section represent the minimum acceptable criteria and shall be used as the required vertical control based on the functional classification of the facility and type of project. Vertical clearance shall apply to the required clearance over the entire roadway width and the usable width of the shoulders and shall also include auxiliary lanes, when applicable, to structures passing over the highway facility. The minimum vertical clearance required shall preferably be maintained within the recovery area. See Table 2.1 for a summary of required vertical clearances over roadways.

All structures having a vertical clearance below the minimum acceptable criteria should ultimately be considered for improvement of clearance. When the vertical clearance requirements cannot be achieved, justification to support a design exception submission request shall be provided.

**A. Strategic Highway Network (STRAHNET).** The Surface Deployment and Distribution Command Transportation Engineering Agency (SDDCTEA) of the Department of Defense has developed and continues to refine the Strategic Highway Network (STRAHNET). The STRAHNET is a system of highways that provides defense access, continuity and emergency capabilities for movements of personnel and equipment in both peacetime and wartime. STRAHNET routes are included on the National Highway System. STRAHNET routes include all interstate highways in Pennsylvania (including the Pennsylvania Turnpike interstate highways), strategic highway network routes and major strategic highway network connectors. For a map of the STRAHNET see: ftp://ftp.dot.state.pa.us/public/pdf/BPR_PDF_FILES/MAPS/Statewide/STRAHNET_web_map.pdf.

All highway facilities on the STRAHNET require the vertical clearances as noted on Table 2.1.

When a vertical clearance of less than 4.9 m (16 ft, 0 in) is created as a result of a highway construction project on the STRAHNET, it is considered an exception. All exceptions to the 4.9 m (16 ft, 0 in) vertical clearance standard on rural Interstate routes or on a single Interstate route through urban areas require coordination with the SDDCTEA. Coordination should occur whether it is a new construction project, a project that does not provide for correction of an existing substandard condition, or a project which creates a substandard vertical clearance. This applies to the full roadway width including shoulders for the through lanes, as well as ramps and collector-distributor roadways for Interstate-to-Interstate interchanges.

A request for coordination may be forwarded by FHWA to the SDDCTEA at any time during project development prior to taking any action on the design exception. It should include a time period of 10 working days (after receipt) for action on the request. The FHWA office initiating a request for coordination to the SDDCTEA should verify receipt of the request by telephone or fax. If the SDDCTEA does not respond within the time frame, the FHWA should conclude that the SDDCTEA does not have any concerns with the proposed exception. If comments are forthcoming, the FHWA and the Department will consider mitigation to the extent feasible.

Chapter 2, Appendix A provides a form and instructions that should be used when requesting vertical clearance design exception coordination with the SDDCTEA. FHWA submits this form to the SDDCTEA.

**B. Bridges over Railroads.** The vertical clearance requirements for all bridges over railroads shall conform with the criteria presented in Publication 15M, Design Manual, Part 4, *Structures*, Section D2.3.3.4 and Publication 10C, Design Manual, Part 1C, *Transportation Engineering Procedures*, Section 4.11.D.

**C. Pedestrian Overpasses.**

**1.** New Construction, Reconstruction and Superstructure Replacement Projects. Because of their lesser resistance to impacts, the vertical clearance requirements for all pedestrian overpass structures shall be 0.30 m (1 ft) greater than the vertical clearance required for the highway over which the structure is located.

**2.** 3R Projects. Because of their lesser resistance to impacts, the vertical clearance requirements for all pedestrian overpass structures shall be 0.30 m (1 ft) greater than the 3R vertical clearance required for the highway over which the structure is located. Pedestrian overpasses over arterials may remain in place for vertical clearance down to 4.6 m (15 ft, 0 in), but the vertical clearance may not be further reduced.

**3.** Pavement Preservation Projects. Because of their lesser resistance to impacts, the vertical clearance requirements for all pedestrian overpass structures shall be at least 0.30 m (1 ft) greater than the 3R vertical clearance required for the highway over which the structure is located. The vertical clearances presently below minimum requirements shall not be further reduced by a Pavement Preservation project as per Pavement Preservation Guidelines presented in Publication 242, *Pavement Policy Manual*, Appendix G.

**4.** Bridge Preservation Projects. Because of their lesser resistance to impacts, the vertical clearance requirements for all pedestrian overpass structures shall be at least 0.30 m (1 ft) greater than the 3R vertical clearance required for the highway over which the structure is located. The vertical clearances presently below minimum requirements shall not be further reduced by a Bridge Preservation project. Refer to Publication 15M, Design Manual, Part 4, *Structures*, for work eligible for Bridge Preservation projects.

**D. Traffic Signals.** The vertical clearance requirements shall conform with the criteria presented in Publication 149, *Traffic Signal Design Handbook*.

**E. Utility Lines.** The vertical clearance requirements shall conform with the criteria presented in Publication 16, Design Manual, Part 5, *Utility Relocation*, Appendix A.

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## TABLE 2.1 (METRIC)
## REQUIRED VERTICAL CLEARANCES FOR STRUCTURES OVER HIGHWAYS

| **Type of Project[1]** | **STRAHNET** | **Freeways** | **Arterials** | **Collectors and Local Roads** | **Overhead Sign Structures[2]** |
|---|---|---|---|---|---|
| New Construction, Reconstruction & Superstructure Replacements | 5.05 m | 5.05 m | 5.05 m | 4.45 m | 5.33 m |
| 3R | 4.9 m[3] | Not Applicable | 4.9 m[5] | 4.3 m | 5.18 m |
| Deck Replacement, Pavement Preservation & Bridge Preservation [4] | 4.9 m | 4.9 m | 4.9 m | 4.3 m | 5.18 m |

(1) For vertical clearance under pedestrian bridges, see Section 2.20.C.

(2) Details regarding the vertical clearance requirements are presented in Publication 218M, *Standards for Bridge Design*, BD-600 (Dual Unit).

(3) 3R criteria is not applicable for freeways.

(4) Existing vertical clearances below minimum requirements shall not be further reduced by a Deck Replacement, a Pavement Preservation or a Bridge Preservation project. Refer to Publication 15M, Design Manual, Part 4, *Structures*, for work eligible for Bridge Preservation projects. For Pavement Preservation Guidelines, see Publication 242, *Pavement Policy Manual*, Appendix G.

(5) Existing vertical clearances below 4.9 m, but over 4.3 m can remain for arterials, but are not to be further reduced.

## TABLE 2.1 (ENGLISH)
## REQUIRED VERTICAL CLEARANCES FOR STRUCTURES OVER HIGHWAYS

| Type of Project[1] | STRAHNET | Freeways | Arterials | Collectors and Local Roads | Overhead Sign Structures[2] |
|---|---|---|---|---|---|
| New Construction, Reconstruction & Superstructure Replacements | 16'-6" | 16'-6" | 16'-6" | 14'-6" | 17'-6" |
| 3R | 16'-0"[3] | Not Applicable | 16'-0"[5] | 14'-0" | 17'-0" |
| Deck Replacement, Pavement Preservation & Bridge Preservation [4] | 16'-0" | 16'-0" | 16'-0" | 14'-0" | 17'-0" |

(1) For vertical clearance under pedestrian bridges, see Section 2.20.C.

(2) Details regarding the vertical clearance requirements are presented in Publication 218M, *Standards for Bridge Design*, BD-600 (Dual Unit).

(3) 3R criteria is not applicable for freeways.

(4) Existing vertical clearances below minimum requirements shall not be further reduced by a Deck Replacement, a Pavement Preservation or a Bridge Preservation project. Refer to Publication 15M, Design Manual, Part 4, *Structures*, for work eligible for Bridge Preservation projects. For Pavement Preservation Guidelines, see Publication 242, *Pavement Policy Manual*, Appendix G.

(5) Existing vertical clearances below 16'-0", but over 14'-0" can remain for arterials, but are not to be further reduced.

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# CHAPTER 2, APPENDIX A

## VERTICAL CLEARANCE DESIGN EXCEPTION COORDINATION WITH SURFACE DEPLOYMENT AND DISTRIBUTION COMMAND TRANSPORTATION ENGINEERING AGENCY (SDDCTEA)

To: **Surface Deployment and Distribution Command (SDDCTEA)**
ATTN: SDTE-SA
Contact: Mr. Jason Cowin, P.E.
Telephone: (618) 220-5229
Fax: (618) 220-5125
**E-mail:** jason.cowin@us.army.mil

From: **Federal Highway Administration**
**_____ (State) Division** or **______ DOT**
Contact/Title:
Telephone:
Fax:
E-mail Address:
**Date to SDDCTEA:**
Date response is requested by:
*--Above information is to be completed by the FHWA or State DOT--*

## Interstate Vertical Clearance Exception Coordination

**1. Structure Location:**
State: _____ County: _____
Route I-_____ Direction _____ Milepost _____
(mark an "x" on the appropriate line) ___Rural ____Urban Single Routing
Overpass Route:
*Include a map showing the general vicinity.*

**2. Structure NBI number:**

**3. Project Description:**

**Estimated Total Project Cost:** $

**4. Location** (e.g., driving lane, passing lane, shoulder, ramp, C-D Road, etc.) **and description of the substandard clearance:**

| | Through Lane(s) | Shoulder(s) | Aux./Ramp (Interstate to Interstate) |
|---|---|---|---|
| Existing: | ____ m ( ft) | ____ m ( ft) | ____ m ( ft) |
| Proposed: | ____ m ( ft) | ____ m ( ft) | ____ m ( ft) |

**5. Description of work required to achieve the 4.9m (16.0 ft) clearance:**

Estimated **additional cost** to obtain 4.9m (16.0ft) clearance: $

**6. Reason why 4.9m (16.0ft) vertical clearance cannot be attained:**

7. **Alternate route** with 4.9m (16.0ft) vertical clearance:

8. **Anticipated schedule for future project(s)** which will correct or improve the substandard clearance:
☐ Future Project Year : _____ Anticipated Clearance: ____ m ( ft)
☐ Future project not programmed

**9. Names of nearby military installations or ports:**

**Remarks**

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**INFORMATION REQUIRED FOR VERTICAL CLEARANCE DESIGN EXCEPTION COORDINATION WITH SDDCTEA (FOR FHWA or STATE DOT USE)**

**E-MAIL COORDINATION FORM (INCLUDING VICINITY MAP) TO:**
**jason.cowin@us.army.mil**

1. STRUCTURE LOCATION –
Direction – EB, WB, NB, or SB
Overpass Route – include route name and number

2. STRUCTURE NBI NUMBER – National Bridge Inventory reference number

3. PROJECT DESCRIPTION - pavement rehabilitation, pavement preservation, etc.
ESTIMATED TOTAL PROJECT COST – self-explanatory

4. LOCATION AND DESCRIPTION OF THE SUBSTANDARD CLEARANCE - dual units of the existing and proposed clearance are preferred – Metric (meters in decimals) and English (feet and inches).

5. DESCRIPTION OF WORK REQUIRED TO ACHIEVE THE 4.9m (16.0ft) CLEARANCE – self-explanatory
ESTIMATED ADDITIONAL COST TO OBTAIN 4.9m (16.0ft) CLEARANCE – self-explanatory

6. REASON WHY 4.9m (16.0ft) VERTICAL CLEARANCE CANNOT BE ATTAINED – high cost, environmental issues, etc.

7. ALTERNATE ROUTE WITH 4.9m (16.0ft) VERTICAL CLEARANCE - alternate route around each substandard-vertical-clearance substructure. The alternate route should have standard vertical clearances. If at least one standard vertical clearance through-lane exists (in both directions), this can be considered an alternate route. A diamond interchange can provide an alternate route.

8. ANTICIPATED SCHEDULE FOR FUTURE PROJECTS WHICH WILL CORRECT OR IMPROVE THE SUBSTANDARD VERTICAL CLEARANCE – include type of project (bridge replacement, etc) and year programmed

9. NAMES OF NEARBY MILITARY INSTALLATIONS OR PORTS – self-explanatory

10. REMARKS – self-explanatory

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# CHAPTER 3

## INTERSECTIONS

### 3.0 INTRODUCTION

By definition, an intersection is the general area where two or more highways join or cross including the roadway and roadside facilities for traffic movements within the area. The efficiency, safety, speed, cost of operation and capacity of an intersection depends upon its design. Since each intersection involves innumerable vehicle movements, these movements may be facilitated by various geometric design and traffic control depending on the type of intersection. The three general types of highway crossings are: (1) at-grade intersections, (2) grade separations without ramps and (3) interchanges.

The most important design considerations for intersections fall into two major categories: (1) the geometric design including a capacity analysis and (2) the location and type of traffic control devices. For the most part, these considerations are applicable to both new and existing intersections, although on existing intersections in built-up areas, heavy development may make extensive design changes impractical.

The design elements, capacity analysis and traffic control concepts presented in this Chapter apply to intersections and their appurtenant features. Additional sources of information and criteria to supplement the concepts presented in this Chapter are contained in the 2004 AASHTO Green Book, Chapter 9 and the *MUTCD*.

### 3.1 OBJECTIVES AND FACTORS FOR DESIGN CONSIDERATIONS

The main objective of intersection design is to facilitate the convenience, ease and comfort of people traversing the intersection while enhancing the efficient movement of motor vehicles, buses, trucks, bicycles, and pedestrians.

Refer to the section "General Design Considerations and Objectives" in the 2004 AASHTO Green Book, Chapter 9, for details about the five basic elements that should be considered in intersection design: human factors, traffic considerations, physical elements, economic factors, and functional intersection area. These should be identified and evaluated prior to selecting the type of design used.

For exhibits describing the functional intersection area, refer to the 2004 AASHTO Green Book, Chapter 9, Exhibits 9-1 and 9-2.

### 3.2 TYPES OF INTERSECTIONS

The basic types of intersections are determined primarily by the number of intersecting legs, the topography, the character of the intersecting highways, the traffic volumes, patterns and speeds, and the desired type of operation. The basic types of intersections include: (1) the three-leg or T, (2) the four-leg and (3) the multileg (with five or more intersection legs).

Limited sight distance may make it necessary to control traffic by yield signs, stop signs or traffic signals where the traffic densities are less than those ordinarily considered necessary for such control. The alignment and grade of the intersecting roadways and the angle of intersection may make it advisable to channelize or use auxiliary pavement areas, regardless of the traffic densities. In general, traffic service, highway design designation, physical conditions and cost of right-of-way are considered jointly in choosing the type of intersection.

It is not practical to indicate all possible variations; however, the basic types are presented in the 2004 AASHTO Green Book, Chapter 9, Exhibits 9-3 through 9-17 to illustrate the general application of intersection design. A basic intersection type can vary greatly in scope, shape and degree of channelization. Although many factors enter into the selection of the type of intersection and the extent of design, the principal control factors for the type of intersection design required are the design-hour traffic volume, the character or composition of traffic and the design speed. In selecting the type of intersection, the most significant factor is the traffic volume (actual and relative) involved in various turning and through movements. Once the type of intersection is established, the design controls and criteria and the elements of intersection design shall be applied to arrive at a suitable geometric plan. The modern roundabout may also be considered a type of intersection design and is discussed in more detail in Section 3.5. For additional information on variations of the basic types of intersections, their treatments and applications, refer to the section "Types and Examples of Intersections" in Chapter 9 of the 2004 AASHTO Green Book.

## 3.3 GEOMETRIC DESIGN ELEMENTS

At intersections, various geometric design elements should be considered to accommodate the type and amount of traffic and the turning movements that are expected.

**A. Alignment and Profile.** Since intersections represent points of conflict between vehicles, pedestrians and bicycles, the alignment and profile of the intersecting roads should permit users to maneuver safely with minimum interference by other users. The alignment should be as straight and the gradients as flat as practical. The sight distance should be equal to or greater than the minimum values for specific intersection conditions. If design objectives are not met, users may have difficulty in discerning the actions of other users, in reading and discerning the messages of traffic control devices, and in controlling their operations.

For an alignment, design considerations should:

- Have intersecting roads generally meet at or nearly at right angles.
- Avoid short-radius horizontal curves on side road approaches to achieve right-angle intersections.
- Consider making an offset intersection to realign roads intersecting at acute angles.
- Avoid intersections on sharp curves because of possible complications from superelevation, widening of pavements, and reduced sight distance.

For a profile, design considerations should:

- Avoid combinations of grade lines that make vehicle control difficult.
- Avoid substantial grade changes.
- Provide adequate sight distance along both intersecting roads and across their included corners.
- Provide gradients as flat as practical on those sections that are to be used for storage of stopped vehicles.
- Adjust profile gradelines and cross sections on legs of an intersection a distance back from the intersection proper to provide a smooth junction and proper drainage.

For a more detailed discussion of considerations for alignments and profiles, refer to the section "Alignment and Profile" in the 2004 AASHTO Green Book, Chapter 9.

**B. Types of Turning Roadways.** The widths of turning roadways for intersections are governed by the volumes of turning traffic and the types of vehicles to be accommodated. In almost all cases, turning roadways are designed for use by right-turning traffic. The widths for right-turning roadways may also be applied to other roadways within an intersection, such as between channelizing islands.

There are three typical types of right-turning roadways at intersections: (1) a minimum edge-of-traveled-way design; (2) a design with a corner triangular island; and (3) a free-flow design using a simple radius or compound radii. The turning radii and the pavement cross slopes for free-flow right turns are functions of design speed and type of vehicles.

As a control for the geometric design of turning roadways, the largest design vehicle likely to use that facility with considerable frequency, or a design vehicle with special characteristics that must be taken into account in dimensioning the facility, is used to determine the design of such critical features as radii at intersections and radii of turning roadways.

There are four general classes of design vehicles, namely (1) passenger cars, (2) buses, (3) trucks, and (4) recreational vehicles. Dimensions for 19 typical design vehicles, representing vehicles within these general classes, are presented in the 2004 AASHTO Green Book, Chapter 2, Exhibit 2-1. The minimum radii of the outside and inside wheel paths and the centerline radii for specific design vehicles are presented in the 2004 AASHTO Green Book, Chapter 2, Exhibit 2-2. The minimum turning paths for 19 typical design vehicles are illustrated in the 2004 AASHTO Green Book, Chapter 2, Exhibits 2-3 through 2-23. These exhibits should be used as a guide to determine the turning radii at intersections and the width of turning roadways.

The values for the minimum radii for intersection curves for operation at design speed, and the derived pavement widths for turning roadways for different design vehicles, shall conform to the values derived in the 2004 AASHTO Green Book, Chapter 3, Exhibits 3-25 through 3-27 and 3-50, respectively.

Where it is appropriate to provide for turning vehicles within minimum space and with minimum attainable speeds less than 15 km/h (10 mph), as at unchannelized intersections, the corner radii should be based on minimum turning paths of the design vehicles. In the design of the edge of the traveled way based on the path of a given design vehicle, the vehicle is assumed to be properly positioned within the traffic lane at the beginning and end of the turn, i.e., 0.6 m (2 ft) from the edge of traveled way on the tangents approaching and leaving the intersection curve. The minimum curve designs for edge of traveled way conforming to this assumption are shown in the 2004 AASHTO Green Book, Chapter 9, Exhibits 9-21 through 9-28.

For most simple intersections with an angle of turn equal to 90° or less, a single circular arc joining the tangent edges of pavement provides an adequate design. However, where provisions must be made for large design vehicles or when the angle of turn exceeds 90°, a three-centered curve to fit the traffic conditions may be selected. An alternate design that closely approximates the three-centered curve layout consists of a simple offset curve with connecting tapers. The suggested minimum designs in which simple curves and three-centered compound curves are used for each design vehicle when making the sharpest turn are indicated in the 2004 AASHTO Green Book, Chapter 9, Exhibits 9-19 and 9-20, respectively.

For additional information on intersection curves relative to widths and turning paths applicable to the various design vehicles, refer to the section "Types of Turning Roadways" in the 2004 AASHTO Green Book, Chapter 9.

**C. Sight Distance.** As a general consideration, the sight distance should be equal to or greater than the minimum values for specific intersection conditions.

Specified areas along intersection approach legs and across their included corners should be clear of obstructions that might block a driver's view of potentially conflicting vehicles. These specified areas are known as clear sight triangles. The dimensions of the legs of the sight triangles depend on the design speeds of the intersecting roadways and the type of traffic control used at the intersection.

For more information about sight triangles at intersections, refer to the section "Sight Triangles" in the 2004 AASHTO Green Book, Chapter 9.

For additional sight distance considerations at intersections, refer to Chapter 2, Section 2.17 and the section "Intersection Sight Distance" in Chapter 9 of the 2004 AASHTO Green Book.

**D. Superelevation.** The general factors that control the maximum rates of superelevation, as discussed in Chapter 2, Section 2.13, also apply to turning roadways at intersections. When entering or leaving a superelevated curve, the problem of how fast to introduce or remove the superelevation rate arises. The control of the rate of cross slope change for curves at intersections is that of riding comfort and appearance and shall be determined in accordance with the 2004 AASHTO Green Book, Chapter 9, Exhibit 9-44.

For additional information concerning superelevation for curves at intersections, refer to the section "Superelevation for Turning Roadways at Intersections" in the 2004 AASHTO Green Book, Chapter 9.

**E. Traffic Islands.** A traffic island is a defined area between traffic lanes used to control vehicle movements. Islands generally are either elongated or triangular in shape whose dimensions are dependent on the particular intersection conditions. They serve three primary functions:

1. Channelization (to control and direct traffic movement, usually turning).
2. Division (to divide opposing or same-direction traffic streams, usually through movements).
3. Refuge (to provide refuge for pedestrians).

For additional information concerning traffic island sizes and designations, delineation, approach-end treatments and island designs based on turning roadways, refer to the section "Islands" in the 2004 AASHTO Green Book, Chapter 9.

**F. Median Openings.** Intersections include median openings to accommodate crossing and turning traffic movements. Where appropriate, median openings may also be provided for U-turns. Factors to consider are the median width, the location and length of the opening and the design of the median ends, and the character and volume of through and turning traffic. Median openings should reflect street or block spacing and the access classification of the roadway. In addition, full median openings should be consistent with traffic signal spacing criteria.

An important factor in designing median openings is the path of each design vehicle making a minimum turn at 15 to 25 km/h (10 to 15 mph). The section "Control Radii for Minimum Turning Paths", found in the 2004 AASHTO Green Book, Chapter 9, discusses the minimum turning paths of various design vehicles and the minimum practical radii for the design of median ends.

The ends of medians at openings may be either a semicircular shape or a bullet nose shape. The minimum designs for the shape of median ends are shown in the 2004 AASHTO Green Book, Chapter 9, Exhibits 9-77 through 9-87.

For any three-leg or four-leg intersections on a divided highway, the length of median opening is determined by the widths of the intersecting highways. The minimum opening should be as long as the width of the crossroad traveled way pavement plus shoulders. Where the crossroad is a divided highway, the length of opening should be at least equal to the width of the crossroad traveled ways plus the width of the median. In general, median openings longer than 25 m (80 ft) should be avoided, regardless of skew.

Above-minimum designs for direct left turns are often appropriate for intersections where through-traffic volumes and speeds are high and left-turn movements are important. At such intersections median openings should be long enough to permit turns without encroachment on adjacent lanes. Longer median openings enable higher speed turns and provide space for vehicle protection while turning or stopping.

For further discussion of median openings, including general design considerations, control radii for minimum turning paths, end shapes and dimensional requirements, refer to the section "Median Openings" in the 2004 AASHTO Green Book, Chapter 9.

**G. Acceleration and Deceleration (Speed-Change) Lanes.** When undue deceleration or acceleration by entering or leaving traffic takes place directly on the highway traveled way, it disrupts the flow of through traffic. To preclude or minimize these undesirable operations, the use of speed-change lanes has been developed as standard practice. A speed-change lane represents an auxiliary lane that contains tapered areas primarily for the acceleration or deceleration of vehicles entering or leaving the through-traffic lanes.

Although warrants for the use of speed-change lanes cannot be stated definitely, the general conclusions and considerations for their use are contained in Chapter 1, Section 1.6. For additional information and design guidance relative to speed-change lanes, including taper rates for lane drops, refer to the section "Speed Change Lanes at Intersections" in the 2004 AASHTO Green Book, Chapter 9.

**H. Direct and Indirect Left Turns and U-Turns.** The various design methods and arrangements to accommodate left-turn and U-turn movements are predicated on the design control dimensions (width of median and width of crossroad or street) and the size of vehicle used for design control. The necessity to turn left or to make a U-turn in the urban or heavily developed residential or commercial sectors represents serious problems with respect to safety and efficient operations. The general design for direct and indirect left-turn and U-turns (including jughandles, turns using local streets, wide medians, and location) and for continuous and simultaneous left-turn lanes are contained in the sections "Indirect Left Turns and U-Turns", "Flush or Traversable Medians", "Offset Left Turn Lanes", "Median Left-Turn Lanes, and "Simultaneous Left Turns" in the 2004 AASHTO Green Book, Chapter 9.

**I. Auxiliary Lanes.** An auxiliary lane refers to that portion of the roadway adjoining the traveled lanes that may be provided for median openings and for intersections to supplement through-traffic movements. These lanes should be at least 3.0 m (10 ft) wide and desirably should equal that of the through lane and their length shall be dependent on the individual lengths of three components: (1) entering taper, (2) deceleration length and (3) storage length. Desirably, the total length of the auxiliary lane should be the sum of the length for these components. For additional information and design considerations for auxiliary lanes for intersections, refer to Publication 46, *Traffic Engineering Manual*, Chapter 11.

**J. Curb Radii for Turning Movements in Urban Areas.** Because of space limitations, pedestrians, and lower operating speeds, curve radii used for turning movements may be smaller in urban areas than in rural areas. Curb radii should be based on the number and types of turning vehicles and pedestrian volumes.

The section "Corner Radii into Local Urban Streets", found in the 2004 AASHTO Green Book, Chapter 9, provides guidelines for right-turning and corner radii.

Exhibit 9-29 through Exhibit 9-32 in the 2004 AASHTO Green Book, Chapter 9 indicate how curb radii are influenced with and without the presence of parking lanes.

Corner radii at intersections should satisfy needs of the drivers using them, the amount of right-of-way available, the angle of turn between the intersection legs, numbers of pedestrians using the crosswalk, the width and number of lanes on the intersecting streets and the posted speeds on each street. The section "Effect of Curb Radii on Pedestrians", found in the 2004 AASHTO Green Book, Chapter 9, offers a guide with various dimensions of radii.

For additional guidelines on curb radii for turning movements in urban areas, refer to the section "Types of Turning Roadways" in the 2004 AASHTO Green Book, Chapter 9.

**K. Free-Flow Turning Roadways at Intersections.** Many intersections feature free-flow turning roadways alignment for right-turn movements. Ease and smoothness of operation can result when the free-flow turning roadway is designed with compound curves preceded by a right-turn deceleration lane. Refer to the section "Free-Flow Turning Roadways at Intersections" in the 2004 AASHTO Green Book, Chapter 9 for guidance on the shape and length of these curves.

The design speed of free-flow turning roadways may be equal to, or possibly within 20 to 30 km/h (10 to 20 mph) less, than the through roadway design speed. Turning roadways at intersections should use the "upper-range" design speeds whenever practical, although the "middle range" speeds may be used in constrained situations.

For additional information and design guidance relative to free-flow turning roadways at intersections, including the use of acceleration or deceleration lanes, refer to the section "Free-Flow Turning Roadways at Intersections" in the 2004 AASHTO Green Book, Chapter 9.

**L. Channelization.** Channelization is the separation of traffic flows into well-defined paths that minimize the area of conflict, typically through the use of islands and/or pavement markings. Channelization can increase intersection capacity, improve safety and operations, and is often used to separate left-turning traffic from through traffic.

The section "Channelization" in the 2004 AASHTO Green Book, Chapter 9 identifies the factors and principles that should be considered for channelization of intersections.

Significant controls involved in the design of a channelized intersection should encompass the type of design vehicle, cross sections on the crossroads, projected traffic volumes, pedestrian traffic, vehicle speed, bus stop locations and the type and location of traffic control devices. Certain physical controls such as right-of-way and topography may also affect the extent and amount of channelization that is economically practical.

**M. Additional Design Considerations.** In addition to the design concepts presented above, additional considerations relevant to intersection design include the items listed below. For information and design guidance for these items, refer to the reference indicated:

**1.** Frontage road design elements. (2004 AASHTO Green Book, Chapter 9, "Intersection Design Elements with Frontage Roads")

**2.** Control on wrong-way entry. (2004 AASHTO Green Book, Chapter 9, "Design to Discourage Wrong-Way Entry")

**3.** Curb cut ramps for the physically disabled. (2004 AASHTO Green Book, Chapter 9, "Wheelchair Ramps at Intersections" and Chapter 6)

**4.** Lighting. (2004 AASHTO Green Book, Chapter 9, "Lighting at Intersections" and Chapter 5)

**5.** Driveway terminals. (2004 AASHTO Green Book, Chapter 9, "Driveways"; provisions of 67 PA Code § 441; and Chapter 7)

**6.** Railroad-highway grade crossings. (2004 AASHTO Green Book, Chapter 9, "Railroad-Highway Grade Crossings"; Chapter 2, Section 2.18.D; and Publication 371, *Grade Crossing Manual*)

**7.** Modern roundabouts. (2004 AASHTO Green Book, Chapter 9, "Modern Roundabouts"; NCHRP Report 672, *Roundabouts: An Informational Guide, Second Edition*)

**8.** Flush or traversable medians. (2004 AASHTO Green Book, Chapter 9, "Flush or Traversable Medians")

**9.** Traffic calming. (Publication 383, *Pennsylvania's Traffic Calming Handbook*)

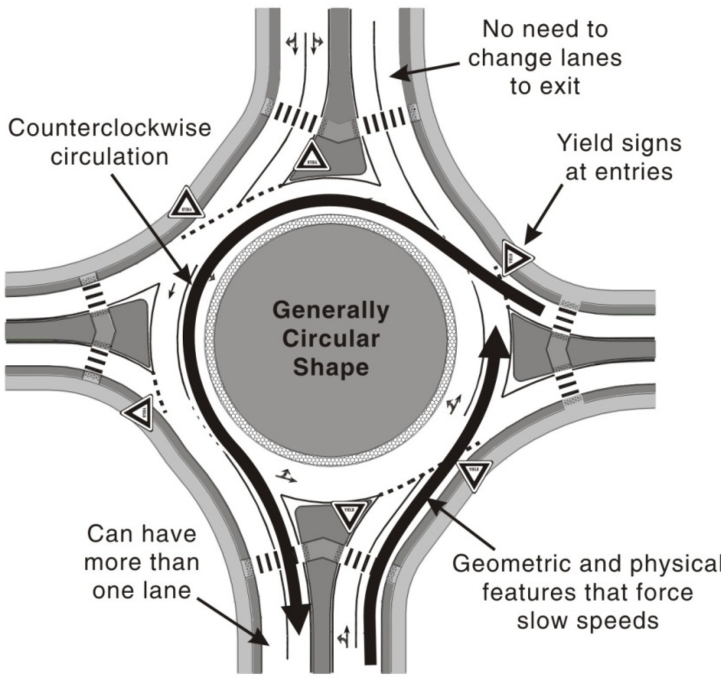
## 3.4 HIGHWAY CAPACITY ANALYSIS AND TRAFFIC CONTROL

The criteria, procedures and guidance for highway capacity analysis used on all Department projects shall comply with capacity concepts presented in the *HCM*. Where traffic signal controls may be required for intersections, the warrants for their installation shall be governed by the sources of reference listed in Chapter 2, Section 2.18.A.

## 3.5 ROUNDABOUTS

**A. Introduction.** A roundabout is a form of circular intersection in which traffic travels counterclockwise around a central island and in which entering traffic must yield to circulating traffic. Modern roundabouts are distinctly different from other forms of circular intersections (rotaries, signalized traffic circles, etc.). Figure 3.1 illustrates the key characteristics of a modern roundabout.

**Figure 3.1**: Key Roundabout Characteristics




Modern roundabouts have demonstrated safety and operational benefits and should be considered as an alternative for intersection improvement projects. They can offer several advantages over signalized and stop controlled alternatives, including better overall safety performance, shorter delays, shorter queues (particularly during off-peak periods), better management of speeds, and opportunities for community enhancement or aesthetic features.

This section is not intended to be an exhaustive review of roundabouts, but rather is meant to emphasize the key principles related to roundabouts. For detailed guidance, the user should refer to National Cooperative Highway Research Program (NCHRP) Report 672, *Roundabouts: An Informational Guide*, *Second Edition*. A principle-based approach to design is recommended, noting that each roundabout will have its own unique design based on the context and goals of a particular project. There will never be a "cookie-cutter" design for a roundabout.

When planning intersection improvements, a variety of improvement alternatives should be evaluated, including roundabouts, to determine the most appropriate alternative.

**B. Planning.** At the planning stage, there are a variety of possible reasons or goals for considering a roundabout at a particular intersection, including but not limited to safety, operations, access management, and aesthetics. Questions to consider once a roundabout is identified as feasible include:

- Is a roundabout appropriate for this location?
- How big should it be or how many lanes are required?
- What sort of impacts are expected?
- What public education and outreach is appropriate?
- How can the construction phasing accommodate the existing traffic?

NCHRP Report 672, Chapter 1 presents a range of roundabout categories and suggested typical daily service volume thresholds below which four-leg roundabouts are expected to operate, without requiring a detailed capacity analysis. Chapter 2 introduces roundabout performance characteristics, including comparisons with other forms of intersection control. By confirming that there is a reason to believe that a roundabout is feasible and the best alternative, these planning activities avoid expending unnecessary effort required in more detailed steps.

The initial steps in planning for a roundabout are to clarify the objectives and understand the context in which the roundabout is being considered. The next step is to specify a preliminary configuration. This identifies the minimum number of lanes required on each approach and thus which type of roundabout is the most appropriate to use a basis for design: mini, single-lane, or multilane. Note that mini-roundabouts are not recommended for use on State roadways.

Figure 3.2 summarizes and compares some fundamental design and operational elements for each of the three roundabout categories.

**Figure 3.2**: Roundabout Category Comparison

| Design Element | Mini-Roundabout | Single-Lane Roundabout | Multilane Roundabout |
|---|---|---|---|
| Desirable maximum entry design speed | 15 to 20 mph (25 to 30 km/h) | 20 to 25 mph (30 to 40 km/h) | 25 to 30 mph (40 to 50 km/h) |
| Maximum number of entering lanes per approach | 1 | 1 | 2-3 |
| Typical inscribed circle diameter | 45 to 90 ft (13 to 27 m) | 90 to 180 ft (27 to 55 m) | 150 to 300 ft (46 to 91 m) |
| Central island treatment | Fully traversable | Raised (may have traversable apron) | Raised (may have traversable apron) |
| Typical daily service volumes on 4-leg roundabout below which may be expected to operate without requiring a detailed capacity analysis (veh/day)* | Up to approximately 15,000 | Up to approximately 25,000 | Up to approximately 45,000 for two-lane roundabout |

*Operational analysis needed to verify upper limit for specific applications or for roundabouts with more than two lanes or four legs.

Figure 3.3 outlines many of the considerations that may need to be investigated prior to deciding whether to implement a roundabout at an intersection. Note that this is not meant to be all-encompassing, nor is it intended to reflect minimum requirements. Rather, it is intended to provide a general framework for the steps typically necessary to determine feasibility.

**Figure 3.3**: Planning Framework

**Consider the Context**

- Is this the first roundabout in a community or are roundabouts already well established?
- Are there regional policy constraints that must be addressed?
- Are there site-specific and/or community impact reasons why a roundabout of any size would not be a good choice?
- What are the site constraints?
- What is the potential for future growth within the vicinity?
- What is the current or desired environment for non-motorized modes?

**Clarify the Objectives**

- Clarifying the objective for considering a roundabout at the beginning of the process may help to better guide the selection of an appropriate treatment and the need for additional information.
- Is the improvement needed from an operational or safety perspective? Both?
- Is the improvement desired to control vehicle speeds?
- Is the improvement intended purely for aesthetic reasons?

**Determine preliminary lane numbers based on capacity requirements**

Section 3.5 of NCHRP Report 672 provides a useful methodology for obtaining a basic understanding of the required number of lanes. Chapter 4 provides additional detail on operational analysis.

**Determine the space requirements**

How big does it need to be and is there enough right-of-way to build it? This is a potential rejection point in some locations due to potential cost or the additional administrative complications caused by right-of-way acquisition. Section 3.5 provides additional information for evaluating the space requirements based upon the required number of lanes.

**Compare to other alternatives**

Make appropriate comparisons with alternative intersection treatments

**Assess Other Impacts**

Are there other impacts that may occur from the roundabout, such as:

- Utilities;
- Existing buildings/structures;
- Business access; and
- Sensitive environmental areas.

**Assess Other Opportunities**

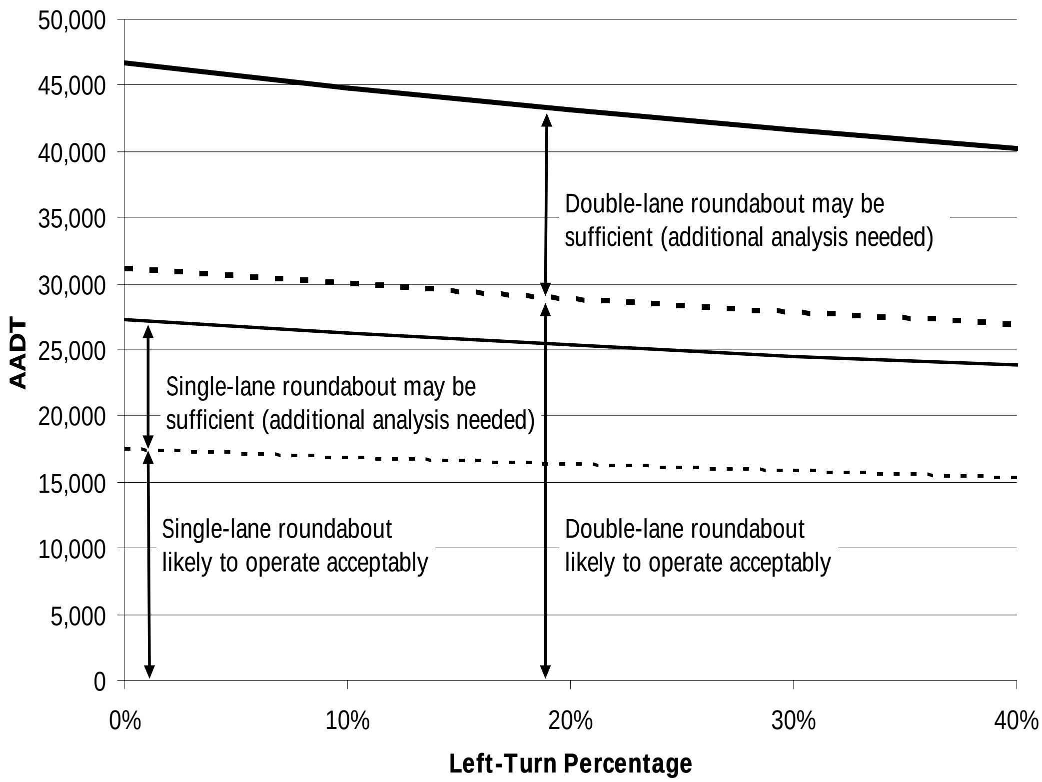
Does the roundabout offer any opportunities to improve existing conditions, such as:

- Improve access management;
- Stimulate redevelopment;
- Improve safety; and
- Improve oddly shaped intersection or other poor geometric condition.

Is a roundabout feasible and/or the preferred alternative worthy of advancing for additional analysis and design?

High-level planning often requires an initial screening of alternatives where turning-movement data may not be available but Annual Average Daily Traffic (AADT) volumes are known. Figure 3.4 presents ranges of AADT volumes to identify scenarios under which single-lane and two-lane roundabouts may perform adequately.

**Figure 3.4**: Planning-Level Daily Intersection Volumes




If the volumes fall within the ranges identified in Figure 3.4 where "additional analysis is needed," a single-lane or two-lane roundabout may still function quite well, but a closer look at the actual turning-movement volumes during the design hour is required. The procedure for such analysis is presented in the *HCM*, Chapter 21.

To help analyze the feasibility of using a roundabout at a particular location, PennDOT has developed a Roundabout Key Considerations Checklist, which can be found in Chapter 3, Appendix A.

**1.** Economic Evaluation. An economic evaluation should be performed when considering various types of intersection control. At a minimum, cost estimates should include construction costs, engineering and design fees, land acquisition, and maintenance costs over the anticipated life of the control form. Benefits may include reduced crash rates and severity, as well as reduced delay, stops, fuel consumption, and emissions. NCHRP Report 672, Section 3.8 provides a cost-benefit methodology for comparing intersection alternatives.

**2.** Public Involvement. Public acceptance of roundabouts has often been found to be one of the biggest challenges facing agencies planning the first roundabout in an area. Without the benefit of explanation or first-hand experience and observation, the public is likely to incorrectly associate roundabouts with older style traffic circles or rotaries. Also, the public will often have a natural hesitation or resistance to changes in their driving behavior and driving environment. Refer to Publication 295, *Project Level Public Involvement Handbook*.

PennDOT has produced brochures aimed at providing information to a variety of audiences. These educational brochures are available as separate publications (Publication 578, *Single-Lane Roundabout - General Information and Driving Tips for Motorists*; Publication 579, *Single-Lane Roundabout - General Information for Bicyclists and Pedestrians*; and Publication 580, *Multi-Lane Roundabout - General Information and*

*Driving Tips for Motorists*). Two of the brochures provide information on how to navigate a roundabout, one for a single-lane and the other for a multilane roundabout. The third brochure deals with similar topics, but as they relate to single-lane roundabouts from the perspective of pedestrians and bicyclists. For additional information regarding public education and outreach, please refer to NCHRP Report 672, Section 3.8.

**C. Operations.** The *HCM* incorporates the roundabout operational analysis model developed in NCHRP Report 572, *Roundabouts in the United States* and allows for the evaluation of existing or planned single-lane and multilane roundabouts (with up to two circulating lanes). In cases where the existing or planned roundabout has more than two circulating lanes, FHWA approved deterministic software (such as SIDRA Intersection, Arcady or RODEL) or simulation (such as VISSIM or PARAMICS) is needed to evaluate the roundabout operations. Whenever deterministic software is utilized to evaluate a roundabout, the user shall ensure that it is calibrated to local driver behavior and effective geometry, and adjustments should be made to account for lane configurations or system effects.

Figure 3.5 displays situations in which the various roundabout analysis tools are appropriate.

**Figure 3.5**: Selection of Analysis Tool

| Application | Typical Outcome Desired | Input Data Available | Potential Analysis Tool |
|---|---|---|---|
| Planning-level sizing | Number of lanes | Traffic volumes | NCHRP Report 672, Chapter 3, *HCM*, deterministic software |
| Preliminary design of roundabouts with up to two lanes | Detailed lane configuration | Traffic volumes, geometry | *HCM*, deterministic software |
| Preliminary design of roundabouts with three lanes and/or with short lanes/flared designs | Detailed lane configuration | Traffic volumes, geometry | Deterministic software |
| Analysis of pedestrian treatments | Vehicular delay, vehicular queuing, pedestrian delay | Vehicular traffic and pedestrian volumes, crosswalk design | *HCM*, deterministic software, simulation |
| System analysis | Travel time, delays and queues between intersections | Traffic volumes, geometry | *HCM*, simulation |
| Public involvement | Animation of no-build conditions and proposed alternatives | Traffic volumes, geometry | Simulation |

For planning purposes, a volume-to-capacity (v/c) ratio of 0.85 or less is targeted for each approach leg. However, higher v/c ratios may be acceptable for future conditions depending upon the corresponding delay and queue prediction. When the *HCM* methodology predicts a v/c ratio greater than 0.85, but less than 0.95, other deterministic software methodologies or simulation should be utilized to verify the roundabout will operate acceptably. If the projected result produces a v/c ratio greater than 0.95, other alternatives, such as revised lane configurations or different intersection control types should be evaluated.

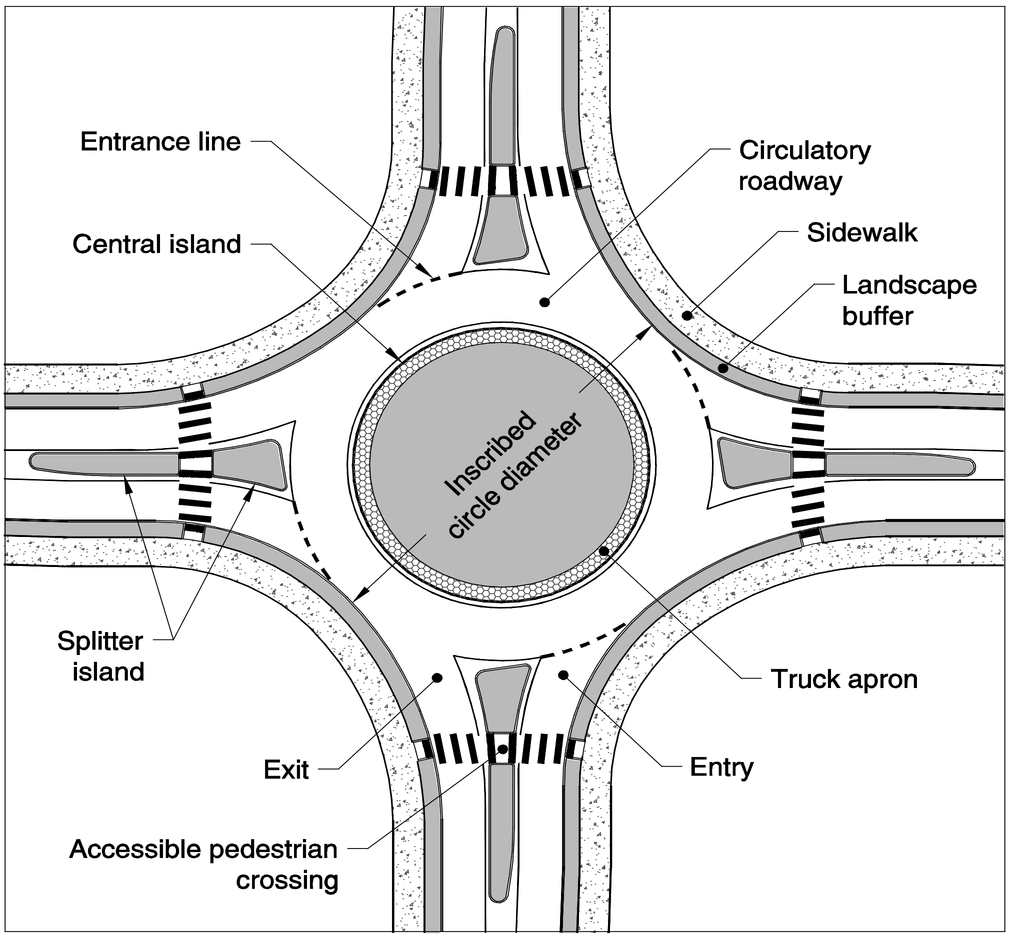
Consistent with the *HCM*, level of service (LOS) thresholds for roundabouts have been established using control delay, and are the same as defined for stop-controlled intersections.

**D. Safety.** Roundabouts are a proven safety measure due to their minimal conflict points and speed control. In particular, roundabouts can provide the most safety benefits when used at intersections with historically high crash rates, roads with historical problem of excessive speeds, and at intersections with more than four legs or with difficult skew angles. In order to achieve the full safety benefits of a roundabout, a principle-based design process including the proper application of performance checks should be utilized. The subsequent section discusses the principles of roundabout design.

Further information pertaining to roundabout safety is found in NCHRP Report 672, Chapter 5.

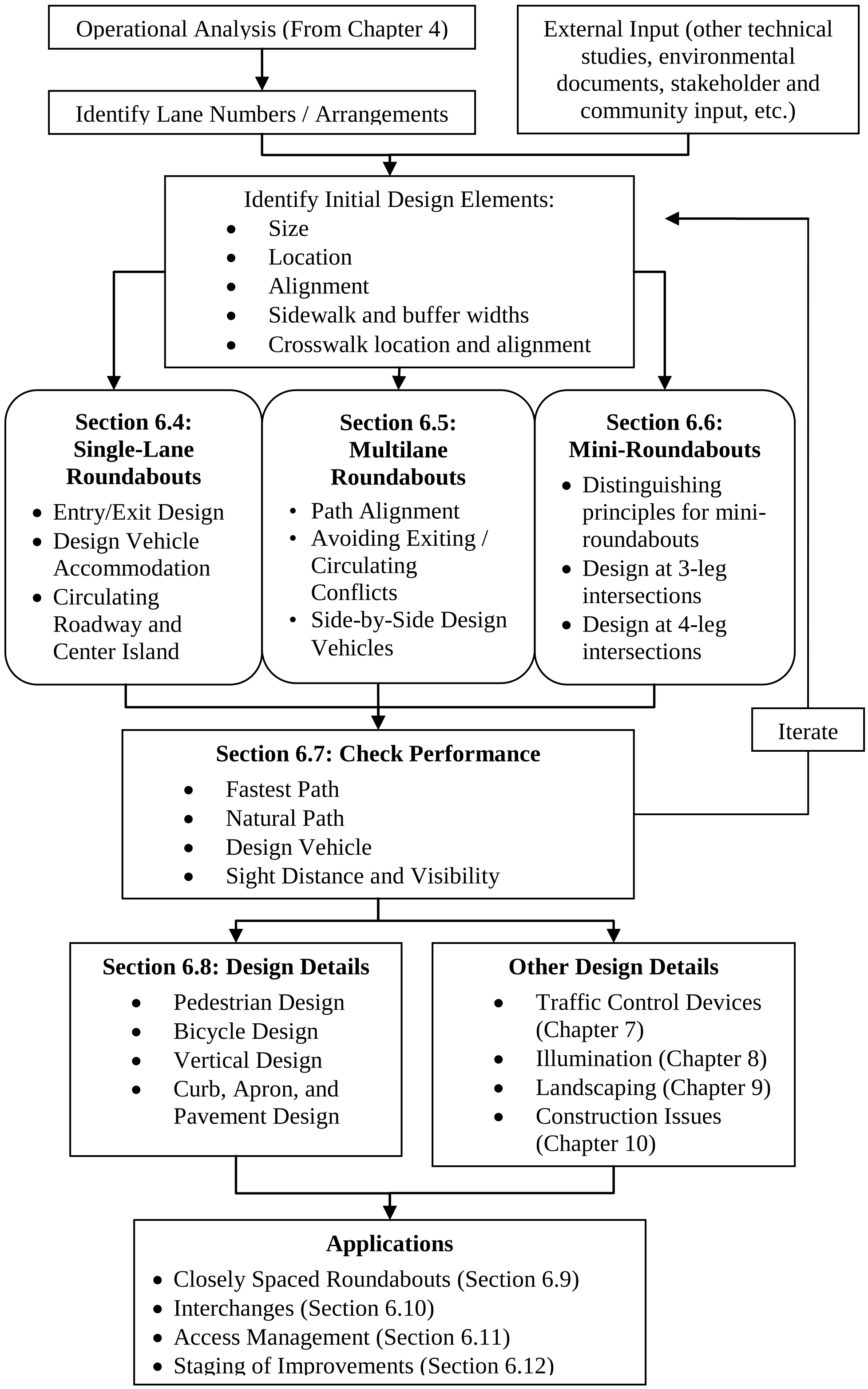
**E. Design.** Roundabout design follows a principles based design process. This process is focused on achieving and balancing several key objectives. Figure 3.6 displays the basic geometric elements of a roundabout.

**Figure 3.6**: Basic Geometric Elements of a Roundabout




The principles and objectives of the geometric design of roundabouts are achieved using the general design process shown in Figure 3.7. In particular, performance checks are an important element of the design process and guidance found in the NCHRP Report 672, Section 6.7 should be followed to ensure the performance checks are completed appropriately, including sight distances.

**Figure 3.7**: General Roundabout Design Process *




* Chapter and Section references are from NCHRP Report 672.

Roundabout projects should be classified as Moderately Complex or Major Projects. Therefore, Design Field View submissions are required for review and approval by the Bureau of Project Delivery. The need for a Final Design Office Meeting will be made on a project by project basis by the Bureau of Project Delivery or the FHWA as applicable.

Since modern roundabouts are somewhat new to Pennsylvania and much of its design community, the use of a Peer Review is highly recommended, especially for roundabouts being designed in-house or by design consultants with limited roundabout design experience.

**1.** Design Vehicle. The recommended design vehicle is an AASHTO WB-67 for roundabouts on state routes and interchange ramp terminals. The roundabout geometry should accommodate the swept path of the design vehicle tires and body and should be evaluated using a CAD-based vehicle turning path program for each of the turning movements. The use of other design vehicles will be made on site specific considerations, usually related to truck restrictions.

**2.** Splitter Islands. Splitter islands should be incorporated into all roundabouts, and generally at least 50 ft in length, although specific situations or design constraints may necessitate shorter splitter islands. Splitter islands should be a minimum of 6 ft wide at crosswalk locations to adequately provide refuge for pedestrians, including those using wheelchairs, pushing a stroller, or walking a bicycle. Splitter islands also alert approaching drivers to the geometry of the roundabout. For higher speed approaches, splitter island lengths of 150 ft or more are often beneficial. A more detailed discussion of splitter island geometry for high-speed approaches can be found in NCHRP Report 672, Section 6.8.5.3. See NCHRP Report 672, Sections 6.4.1 and 6.5.5 for more information regarding general design details for splitter islands.

**3.** Pedestrian Design Considerations. Pedestrians should generally be considered and accommodated at all roundabout intersections. Pedestrian accommodations typically include cut-throughs on splitter islands, two-stage perpendicular crossings, curb ramps and accessibility features such as detectable warning surfaces. In some situations (such as rural intersections), pedestrian accommodations may not be necessary; however, it is recommended that such splitter islands be designed to be wide enough to accommodate potential future crossings. Current Draft Public Right-of-Way Accessibility Guidelines (PROWAG) require pedestrian-activated signals at all multilane roundabout entries and exits as well as detectable edging where pedestrian crossings are not intended. Further information for the design of pedestrian accommodations for roundabouts is provided in NCHRP Report 672, Section 6.8.1. Also, refer to Chapter 6 for ADA compliance.

**4.** Bicycle Design Considerations. Where bicycle lanes are used on approach roadways, they should be terminated in advance of roundabouts using tapers to merge cyclists into traffic for circulation with other vehicles. For bike routes where cyclists remain within the traffic lane, it can be assumed that cyclists will continue through the roundabout in the travel lane. At multilane roundabouts consider providing bicycle ramps to allow bicyclists to exit the roadway onto the sidewalk and travel as pedestrians. Ramps should not normally be used at urban, single-lane roundabouts except where the complexity of the roundabout would make circulating like other vehicles more challenging for bicyclists. Further information for the design of bicycle accommodations for roundabouts is provided in NCHRP Report 672, Section 6.8.2.

**5.** High Speed Approaches. The primary safety concern in rural locations where approach speeds are high is to make drivers aware of the roundabout with sufficient advance distance to comfortably decelerate to the appropriate speed for entering the roundabout. Where possible, the geometric alignment of approach roadways should be constructed to maximize the visibility of the central island and the shape of the roundabout. Further information on treatments for high speed approaches is provided in NCHRP Report 672, Section 6.8.5 and 7.4.4.

**6.** Drainage. Drainage structures should normally be placed on the outer curb line of the roundabout and upstream of crosswalks, but should not be placed in the entry and exit radii of the approaches. Drainage structures located on the outer curb line of the circulatory roadway shall be designed to withstand vehicle loading. Maximum gutter spreads should match the requirements for the approach roadways. Refer to NCHRP Report 672, Section 6.8.7 and Chapter 13 for a discussion of vertical alignment considerations which includes drainage.

**7.** Curbing. Concrete curb, as specified in Publication 72M, *Roadway Construction Standards*, should be used along the outside edge of all roundabouts which includes the entry radius, the circulatory roadway, and the exit radius, and for the splitter islands. For rural roadways it is desirable to extend outside curbing along approaches to the length of the required deceleration distance to the roundabout. A truck apron curb should be used between the truck apron and the circulatory roadway. Further information on the principles of using curbs on roundabouts is provided in NCHRP Report 672, Sections 6.8.7.4 and 6.8.8.1.

**8.** Pavement. Asphalt or dark colored concrete is the recommended material for the circulatory roadway to differentiate it from the concrete truck apron. At locations where a single-lane roundabout is constructed with the intention of later conversion to a multilane roundabout, asphalt pavement should be considered due to the need to redo the concrete jointing during conversion. Sidewalks should be constructed with a different texture and/or color than the truck apron to differentiate the pedestrian path and to deter pedestrians from using the truck apron. Further information on the design of pavements for roundabouts is provided in NCHRP Report 672, Section 6.8.8.

**9.** Staging of Improvements. When projected traffic volumes indicate that a multilane roundabout is required for the design year, the duration of time that a single-lane roundabout can be expected to operate acceptably should be estimated. Consideration should be given to first constructing a single-lane where a single-lane roundabout is expected to be sufficient for ten years or more from the date the roundabout would open to traffic.

To allow for this future expansion, the right-of-way and geometric needs of both the single-lane and multilane roundabout should be acquired. For further information refer to NCHRP Report 672, Section 6.12.

**10.** Traffic Control Devices. Traffic control devices for roundabouts shall be in accordance with the *MUTCD* and Publication 236, *Handbook of Approved Signs*. NCHRP Report 672, Chapter 7 provides a helpful presentation of the application of traffic control devices to roundabouts.

**11.** Illumination. Lighting of roundabouts serves two main purposes:

**a.** It provides visibility from a distance for users approaching the roundabout; and

**b.** It provides visibility of the key conflict areas to improve users' perception of the layout and visibility of other users within the roundabout.

For additional guidance and details regarding lighting layouts, illuminance levels, and other considerations, please refer to NCHRP Report 672, Chapter 8.

**F. Other Considerations.**

**1.** Landscaping. A realistic maintenance program should be considered in the design of landscape features, including identification of the responsible party for future maintenance, water supply, drainage, and expected growth of plantings. Maintenance Agreements with the Municipality should be setup as early as possibly during project development.

Landscaping must not reduce sight distances below minimum criteria. For a more detailed discussion of landscaping design consideration and best practices, please refer to NCHRP Report 672, Chapter 9.

**2.** Construction and Maintenance. Roundabouts can be constructed under three types of traffic conditions:

- With all traffic diverted away from the work area,
- With some traffic diverted, or
- Under full traffic.

The guiding principle is to minimize staging and provide large sections of the project to construct during each construction stage. This will increase quality of construction, reduce driver confusion, and reduce construction duration and cost. Generally, diverting or detouring as much traffic from the intersection as possible is the most desirable option. For a more detailed discussion of construction staging under all three types of conditions, please refer to NCHRP Report 672, Section 10.3.

**3.** Snow Removal. For a discussion of snow removal considerations and best practices, please refer to NCHRP Report 672, Section 10.7.2.

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# CHAPTER 3, APPENDIX A

## ROUNDABOUT KEY CONSIDERATIONS CHECKLIST

County: ____________________________________________
SR & Section: ____________________________________________
Intersection: ____________________________________________
Reviewer: ____________________________________________
Date: ____________________________________________

1. Location Description
    - Highway Classification & Typology, Design Speed, AADT, Left Turn %, etc. More than four legs?

    Cross Street 1:

    Cross Street 2:

    Fifth Leg:

2. Site Characteristics/Context
    - Describe the surrounding environment. Describe general area conditions, setting, topography, railroads, historic district, etc. Is this a new intersection?

3. Project Objective
    - What are the operational and safety issues? (Capacity, traffic calming, skewed geometry, etc.) Document any crash history or clusters.

4. Roundabout Sizing
    - Refer to NCHRP Report 672, Exhibit 3-12 or Publication 13M, Design Manual, Part 2, *Highway Design*, Chapter 3, Figure 3.4). Refer to the *HCM*, Chapter 21 should a more detailed capacity analysis be required.

5. Design Vehicle
    - Consider the anticipated truck volumes. What is the appropriate design vehicle? How will emergency vehicles navigate the roundabout? Do oversized loads need to be accommodated? Is there a need to accommodate trucks side-by-side (if multilane roundabout is anticipated)?

6. Right of Way & Utilities
    - Is adequate right-of-way available at the intersection location? Document potential ROW impacts. What utility conflicts exist?

7. Pedestrian & Bicycle Usage
    - Document anticipated pedestrian/bicycle volumes.

8. Alternative Intersection Control
    - Two-Way Stop Control (TWSC)? All-Way Stop Control (AWSC)? Signal?

9. Public Involvement
    - What type of public involvement should be considered? Is this the first roundabout in the area?

# CHAPTER 4

## GRADE SEPARATIONS AND INTERCHANGES

### 4.0 INTRODUCTION

The ability to accommodate high volumes of intersecting traffic safely and efficiently through the arrangement of one or more interconnecting roadways can be achieved by utilizing a grade separation or an interchange system to provide for the movement of traffic between the roadways. By definition, a grade separation represents a crossing of two highways (or a highway and a railroad) at different levels while an interchange represents a system of interconnecting roadways, in conjunction with one or more grade separations, to provide for the movement of traffic between two or more roadways on different levels.

For Interstate highways, interchanges shall be provided between all intersecting Interstate routes, between other selected access controlled highways and at other selected public highways to facilitate distribution of traffic. Each interchange shall provide for all traffic movements.

The type and design of grade separations and interchanges are influenced by many factors such as highway classification, character and composition of traffic, design speed and degree of access control. These controls plus signing needs, economics, terrain and right-of-way are of great importance in designing facilities with adequate capacity to safely accommodate traffic demands. Although each interchange presents an individual problem, its design shall be considered in conjunction with adjacent interchanges or grade separations on the project as a whole to provide uniformity and route continuity to avoid confusion in driver expectancy.

The design elements, capacity analysis and traffic control concepts presented in this Chapter apply to grade separations and interchanges and their appurtenant features. Additional sources of information and criteria to supplement the concepts presented in this Chapter are contained in the 2004 AASHTO Green Book, Chapter 10 and the MUTCD.

### 4.1 TYPES OF INTERCHANGES

Interchanges vary in type from single ramps connecting local streets to complex and comprehensive design layouts involving the intersection of multiple highways. The basic interchange configurations are indicated in the 2004 AASHTO Green Book, Chapter 10, Exhibit 10-1. Their application at a particular location is reflected by surrounding topography and culture, the degree of flexibility in the traffic operations desired and the practical aspects of costs. Any one configuration can vary extensively in shape and scope since numerous combinations of interchange types can evolve through the assembly of one or more of the basic types. An important element of interchange design which influences the efficiency, safety and capacity attained is the size and arrangement of ramps that connect two or more legs at an interchange.

For additional information concerning the types of interchanges and their application at a particular site, refer to the section "Introduction and General Types of Interchanges" in the 2004 AASHTO Green Book, Chapter 10.

### 4.2 WARRANTS FOR GRADE SEPARATIONS AND INTERCHANGES

The justification of an interchange at a given location is difficult due to the wide variety of site conditions, traffic volume, highway types and interchange layouts. Six warrants should be considered when determining if an interchange is justified at a particular site: (1) design designation; (2) reduction of bottlenecks or spot congestion; (3) safety improvement; (4) site topography; (5) road-user benefits; and (6) traffic volumes. For more information concerning these six warrants, refer to the section "Warrants for Interchanges and Grade Separations" in the 2004 AASHTO Green Book, Chapter 10.

Not all warrants for grade separations are included in the warrants for interchanges. For these additional warrants for grade separations, refer to the section "Warrants for Interchanges and Grade Separations" in the 2004 AASHTO Green Book, Chapter 10.

## 4.3 ADAPTABILITY OF HIGHWAY GRADE SEPARATIONS AND INTERCHANGES

Intersections are comprised of three general types: intersections, highway grade separations and interchanges. Each type has a practical range of situations but the limits of that range are not sharply defined. Therefore, there is considerable overlapping and the final selection usually represents a compromise after joint consideration of design traffic volume and pattern, cost, topography, and availability of right-of-way. Each type is based on the following considerations: (1) traffic and operation; (2) site conditions; (3) type of highway and intersecting facility; (4) access separations and control on the crossroad; (5) safety; (6) stage development; and (7) economic factors.

For additional presentations on the above considerations, refer to the section "Adaptability of Highway Grade Separations and Interchanges" in the 2004 AASHTO Green Book, Chapter 10.

## 4.4 GRADE SEPARATION STRUCTURES

The section "Grade Separation Structures", found in the 2004 AASHTO Green Book, Chapter 10, discusses various types of structures that are employed to separate the grades of two intersecting roadways or a highway and a railroad. Although many phases of structural design should also be considered, AASHTO's discussion is confined to the geometric features of grade separation structures. The discussion focuses on the following topics:

**A. Types of Separation Structures.** There are three general types of grade separation structures: through, partial through and deck type. Every effort should be made to design a grade separation structure that fits the environment in a pleasing and functional manner without drawing unnecessary or distracting attention.

**B. Overpass Versus Underpass Roadways.** A detailed study should be made at each proposed highway grade separation site to determine whether the main road should be carried over or under the crossroad. The issues governing whether a road should be carried over or under usually fall into one of three general groups:

**1.** The influence of topography predominates and the design should be closely fitted to it.

**2.** The topography does not favor any one arrangement.

**3.** The alignment and gradeline controls of one highway predominate and the design should accommodate that highway's alignment instead of the site topography.

Where topography does not govern, as in the case of flat topography, the section "Overpass versus Underpass Roadways", found in the 2004 AASHTO Green Book, Chapter 10, identifies additional secondary factors and general guidelines that should be examined.

When determining the appropriate width of the roadway over or under a grade separation, in determining the dimensions, location, and design of the structure as a whole, and in detailing features adjacent to the road, the designer should aim to provide a facility on which driver reaction and vehicle placement will be essentially the same as elsewhere on the intersecting roads. However, the width should not be so great as to result in the high cost of structure without proportionate value in usefulness and safety.

**C. Underpass Roadways.** For each underpass, the type of structure used should be determined by the dimensional, load, foundation and general site needs for that particular location. It is desirable that the entire roadway cross section, including the median, traveled way, shoulders and clear roadside areas be carried through the structure without change.

Several possible limitations may require some reduction in basic roadway cross section: structural design limitations; vertical clearance limitations; controls on grades and vertical clearance; limitations due to skewed crossings, appearance, or aesthetic dimension relations; and cost factors such as lengthy depressed sections of roadway.

The lateral clearances for major roadway underpasses are illustrated in the 2004 AASHTO Green Book, Chapter 10, Exhibit 10-6. For a two-lane roadway or an undivided multilane roadway, the minimum lateral clearance from the edge of the traveled way to the face of the protective barrier should be the normal shoulder width. On divided highways, the clearances on the left side of each roadway are usually governed by the median width. A minimum median width of 3.0 m (10 ft) may be used on a four-lane roadway to provide 1.2 m (4 ft) shoulders and rigid median barrier. For a roadway with six or more lanes, the minimum median width should be 6.6 m (22 ft) to provide 3.0 m (10 ft) shoulders and a rigid median barrier. Where structural design makes it necessary to reduce their horizontal clearance through an underpass, the change in lateral width should be accomplished through gradual adjustments in the cross section of the approach roadway rather than abruptly at the structure. Such transitions in width may have a longitudinal/lateral ratio of 0.6 × design speed to 1 for a design speed in kilometers per hour (design speed to 1 for a design speed in miles per hour). For lateral width "flare" transitions, refer to Chapter 12, Table 12.7 (Flare Rates for Barrier Design).

For new or reconstruction projects, the minimum lateral clearance from the edge of the pavement to the face of the protective barrier in front of retaining walls and bridge substructures including piers, columns, and abutments shall be 4300 mm (14 ft) unless supporting documentation is provided. A design exception for lateral clearance will not be required if 4300 mm (14 ft) of lateral clearance is not provided; however, other geometric criteria such as required shoulder width and sight distance must still be met unless properly justified through the design exception process.

Sound barrier walls shall be located as far away as possible from the edge of traveled way while still providing the maximum benefit for insertion loss. Positive protection is required as per Publication 218M, *Standards for Bridge Design*, for sound barrier walls located within the clear zone. When a sound barrier wall protected by a concrete barrier is constructed along a highway or when a concrete barrier alone is constructed along a highway, the barrier shall be located no closer than the outer edge of shoulder and preferably should be located 0.6 m (2 ft) beyond the outer edge of shoulder.

Positive protection shall be provided when substructure units, retaining walls, or sound barrier walls must be placed within the clear zone width identified in Chapter 12, Table 12.1.

For the vertical clearance requirements of all structures, refer to Chapter 2, Section 2.20.

**D. Overpass Roadways.** The roadway dimensional design of an overpass or other bridge should be the same as that of the basic roadway in cross section dimensions unless the cost becomes prohibitive. The use of bridge railings, lateral clearances and median treatment should be as specified in Publication 15M, Design Manual, Part 4, *Structures,* and Publication 218M, *Standards for Bridge Design*.

**E. Longitudinal Distance to Attain Grade Separation.** The longitudinal distance needed for adequate design of a grade separation depends on the design speed, the roadway gradient and the amount of rise or fall needed to achieve the separation. To determine whether or not a grade separation is practical for given conditions, Exhibit 10-8 from Chapter 10 of the 2004 AASHTO Green Book should be used as a guide for preliminary design to determine horizontal distance in flat terrain. The figure also may serve as a general guide in other than flat terrain and adjustments can be made in the length of the terminal vertical curves.

**F. Grade Separations Without Ramps.** There are many situations where grade separations are constructed without the provision of ramps. In other situations, despite sufficient traffic demand, ramps may be omitted: (1) to avoid having interchanges so close to each other that signing and operation would be difficult, (2) to eliminate interference with large highway traffic volumes and (3) to increase safety and mobility by concentrating turning traffic where it is practical to provide adequate ramp systems.

For additional guidelines and criteria for the procedures, considerations and geometric design features for grade separation structures, refer to the section "Grade Separations without Ramps" in the 2004 AASHTO Green Book, Chapter 10.

## 4.5 INTERCHANGES

The basic types of interchanges can be classified in general terms to include: (1) three-leg designs, (2) four-leg designs and (3) other special interchange designs involving two or more structures. The type of configuration used at a particular site is determined by the number of intersection legs, expected volumes of through and turning movements, type of truck traffic, topography, culture, design controls, proper signing and the designer's initiative.

Signing and operations are major considerations in the design of the interchanges. The signing of each design should be tested to determine if it can provide for the smooth, safe flow of traffic. The need to simplify interchange design from the standpoint of signing and driver understanding cannot be overstated.

Three-leg designs represent an interchange with three intersecting legs consisting of one or more highway grade separations and one-way roadways for all traffic movements. When two of the three intersection legs form a through road and the angle of intersection is not acute, the interchange is classified as a T interchange. When all three intersection legs have a through character or the intersection angle with the third intersection leg is small, the interchange is classified as a Y interchange. The 2004 AASHTO Green Book, Chapter 10, Exhibits 10-9 and 10-10 illustrate various patterns of three-leg interchanges.

Four-leg designs represent interchanges with four intersection legs which may be grouped under six general configurations:

**1.** Ramps in one quadrant.
**2.** Diamond interchanges.
**3.** Single-point urban interchanges (SPUIs).
**4.** Partial cloverleafs.
**5.** Full cloverleafs.
**6.** Interchange with direct and semidirect connections.

The section "Four-Leg Designs", found in the 2004 AASHTO Green Book, Chapter 10, provides additional discussion about the operational characteristics and adaptations of each configuration. The 2004 AASHTO Green Book, Chapter 10, Exhibits 10-15 through 10-37 presents actual examples of existing or planned interchanges for each configuration.

Additional interchange configurations may include special interchange arrangements that would include an offset interchange or a combination of two or more of the previously discussed interchanges. An offset interchange may be applicable where there are major buildings or other developments near the crossing of the freeways. The need for a combination interchange design may be predicated on an analysis that requires the accommodation of one or two turning movements that have high volumes with respect to the other turning movements.

For overpass lengths exceeding 24 m (80 ft), consider providing supplemental lighting during daylight hours beneath the underpass structures. This consideration should include design and construction costs, as well as long-term energy and maintenance requirements.

The following concepts should be used to govern the general design considerations for interchanges:

**A. Determination of Interchange Configuration.** For detailed discussion, refer to the section "Determination of Interchange Configuration" in the 2004 AASHTO Green Book, Chapter 10.

**B. Approaches to the Structure.** For detailed discussion, refer to the section "Approaches to the Structure" in the 2004 AASHTO Green Book, Chapter 10.

**C. Interchange Spacing.** Since interchange spacing has a pronounced effect on freeway operations, proper spacing can be difficult to attain due to traffic demand for frequent access. As a rule, the 2005 AASHTO publication, *A Policy on Design Standards - Interstate System*, notes that minimum spacing should be 1.5 km (1 mi) in urban areas and 5 km (3 mi) in rural areas. In urban areas, spacing of less than 1.5 km (1 mi) may be developed by grade-separated ramps or by collector-distributor roads.

**D. Uniformity of Interchange Patterns.** For detailed discussion, refer to the section "Uniformity of Interchange Patterns" in the 2004 AASHTO Green Book, Chapter 10.

**E. Route Continuity.** For detailed discussion, refer to the section "Route Continuity" in the 2004 AASHTO Green Book, Chapter 10.

**F. Overlapping Routes.** For detailed discussion, refer to the section "Overlapping Routes" in the 2004 AASHTO Green Book, Chapter 10.

**G. Signing and Marking.** Signing and marking are important elements of driver communication at interchanges and should conform to the sources of reference listed in Chapter 2, Section 2.18.A. For additional information, refer to the section "Signing and Marking" in the 2004 AASHTO Green Book, Chapter 10.

**H. Basic Number of Lanes.** For detailed discussion, refer to the section "Basic Number of Lanes" in the 2004 AASHTO Green Book, Chapter 10.

**I. Coordination of Lane Balance and Basic Number of Lanes.** For detailed discussion, refer to the section "Coordination of Lane Balance and Basic Number of Lanes" in the 2004 AASHTO Green Book, Chapter 10.

**J. Auxiliary Lanes.** For detailed discussion, refer to the section "Auxiliary Lanes" in the 2004 AASHTO Green Book, Chapter 10.

**K. Lane Reduction.** For detailed discussion, refer to the section "Lane Reduction" in the 2004 AASHTO Green Book, Chapter 10.

**L. Collector-Distributor Roads Within an Interchange.** For detailed discussion, refer to the section "Collector-Distributor Roads" in the 2004 AASHTO Green Book, Chapter 10.

**M. Two-Exit Versus Single-Exit Interchange Design.** For detailed discussion, refer to the section "Two-Exit versus Single-Exit Interchange Design" in the 2004 AASHTO Green Book, Chapter 10.

**N. Wrong-Way Entrances.** Signing in these areas should be in accordance with the sources of reference listed in Chapter 2, Section 2.18.A. For additional discussion, refer to the section "Wrong-Way Entrances" in the 2004 AASHTO Green Book, Chapter 10.

**O. Other Interchange Design Features.** Additional design considerations for interchanges involve the following features:

**1.** Testing for Ease of Operation.
**2.** Pedestrians.
**3.** Ramp Metering.
**4.** Grading and Landscape Development.
**5.** Models.

For more information concerning these additional design considerations, design concepts and features for interchanges, refer to the section "Other Interchange Design Features" in the 2004 AASHTO Green Book, Chapter 10.

## 4.6 WEAVING SECTIONS

Weaving sections represent highway segments where the patterns of traffic merging or diverging at contiguous points of access result in vehicle streams or paths that cross each other in the same direction. These weaving sections may occur within an interchange, between entrance ramps followed by exit ramps of successive interchanges and on segments of overlapping roadways.

For additional information, refer to the section "Weaving Sections" in the 2004 AASHTO Green Book, Chapter 10. For the capacity analysis of weaving sections, refer to the HCM.

## 4.7 RAMPS

**A. Types and Examples.** A ramp represents various types, arrangements and sizes of turning roadways that connect two or more legs at an interchange. The 2004 AASHTO Green Book, Chapter 10, Exhibit 10-55 illustrates several types of ramps and their characteristic shapes, each of which can be used to create numerous shape variations for an interchange. For additional information, refer to the section "Types and Examples" in the 2004 AASHTO Green Book, Chapter 10.

**B. General Ramp Design Considerations.** The section "General Ramp Design Considerations", found in the 2004 AASHTO Green Book, Chapter 10, describes the following items to be considered:

**1.** Design Speed. Refer to the 2004 AASHTO Green Book, Chapter 10, Exhibit 10-56 for guide values for ramp design speed as related to highway design speed.

**2.** Portion of Ramp to Which Design Speed is Applicable.

**3.** Ramps for Right Turns.

**4.** Loops.

**5.** Semidirect Connections.

**6.** Direct Connections.

**7.** Different Design Speeds on Intersecting Highways.

**8.** At-Grade Terminals.

**9.** Curvature. The design guidelines for turning roadways at interchanges apply directly to the design of ramp curves for various design speeds and are discussed in Chapter 2, Section 2.6.

**10.** Sight Distance. Decision sight distance, as discussed in Chapter 2, Section 2.17.E, is desired where feasible. For ranges in design values for stopping sight distance on horizontal and vertical curves for turning roadways and open road conditions, refer to Chapter 2.

**11.** Grade and Profile Design.

**12.** Vertical Curves. For additional information on design values and turning roadway conditions for vertical curvature, refer to Chapter 2, Section 2.12.

**13.** Superelevation and Cross Slope. For additional information on superelevation and cross slope, refer to Chapter 2, Section 2.13.

**14.** Gores.

**C. Ramp Traveled-Way Widths.** Ramp traveled-way widths are governed by the type of operation, curvature, and volume and type of traffic. The design width of pavements for ramps including shoulder, and lateral clearances and pavement widening on curvature shall be in accordance with the design criteria and guidelines presented in the section "Ramp Traveled-Way Widths" in the 2004 AASHTO Green Book, Chapter 10 with the caveat that the paved ramp shoulder widths are to be 2.4 m (8'-0") minimum right and 1.2 m (4'-0") left.

**D. Ramp Terminal Design.** The terminal of a ramp is that portion adjacent to the through traveled way, including acceleration and deceleration (speed-change) lanes, tapers and islands. Ramp terminals may be the at-grade type, as at the crossroad terminal of a diamond or partial cloverleaf interchange, or the free-flow type where ramp traffic merges with or diverges from high-speed through traffic at flat angles.

Terminals are classified according to the number of lanes on the ramp at the terminal, as either single or multilane, and according to the configuration of the acceleration and deceleration (speed-change) lane, as either a taper or parallel type.

The section "Ramp Terminals", found in the 2004 AASHTO Green Book, Chapter 10, provides additional information about the following topics:

**1.** Ramp Terminals.

**a.** Left-hand Entrances and Exits.

**b.** Terminal Location and Sight Distance.

**c.** Ramp Terminal Design.

**d.** Traffic Control. Refer to Section 4.7.E when traffic signal controls are required at ramp terminals on the minor roadways containing sufficient volumes of through and turning movements.

**e.** Distance Between a Free-Flow Terminal and Structure. The terminal of a ramp should not be located near the grade separation structure but placed in advance of the structure using sight distances comparable to the guidelines established for decision sight distance in Chapter 2, Section 2.17.E.

**f.** Distance Between Successive Ramp Terminals. The values should be checked with the procedures outlined in the HCM especially where weaving considerations may govern (See Section 4.6).

**g.** Acceleration and Deceleration (Speed-Change) Lanes. For additional discussions concerning the factors to consider for the design of acceleration and deceleration (speed-change) lanes, refer to Chapter 1, Section 1.6 and the section "Speed-Change Lanes at Intersections" in the 2004 AASHTO Green Book, Chapter 9.

**2.** Single-Lane Free-Flow Terminals (Entrances). For the design of acceleration lanes on all Department projects, refer to the section "Single-Lane Free-Flow Terminals, Entrances" in the 2004 AASHTO Green Book, Chapter 10. The minimum lengths required for acceleration lanes are governed by the highway design speed and ramp design speed. The minimum lengths required are presented in the section "Single-Lane Free-Flow Terminals, Entrances" in the 2004 AASHTO Green Book, Chapter 10.

**3.** Single-Lane Free-Flow Terminals (Exits). For the design of deceleration lanes on all Department projects, refer to the section "Single-Lane Free-Flow Terminals, Exits" in the 2004 AASHTO Green Book, Chapter 10. The minimum lengths required for deceleration lanes are governed by the highway design speed and the ramp design speed. The minimum lengths required are presented in the section "Single-Lane Free-Flow Terminals, Exits" in the 2004 AASHTO Green Book, Chapter 10.

**4.** Free-Flow Terminals on Curves. The discussions in 2 and 3 above for acceleration and deceleration lanes are stated in terms of tangent through-lane alignment. Because curvature on most freeways is slight, there is usually no need to make any appreciable adjustments at ramp terminals on curves. However, where curves on a freeway are relatively sharp and there are exits and entrances located on these curves, adjustments in design may be desirable to avoid operational difficulties. The guidelines and methods of design to follow for exit and entrance terminals on curves are presented in the section "Single-Lane Free-Flow Terminals, Exits" in the 2004 AASHTO Green Book, Chapter 10.

**5.** Multilane Free-Flow Terminals. Multilane terminals may be appropriate where traffic is too great for single-lane operation. Other considerations that may call for multilane terminals are through-route continuity, queuing on long ramps, lane balance and design flexibility. The most common multilane terminals consist of two-lane entrances and two-lane exits, two-lane terminals on curved alignment and major forks and branch connections as discussed below:

**a.** Two-Lane Entrances. Two-lane entrances or two-lane acceleration lanes are warranted for two situations either as branch connections or because of capacity needs for the on-ramp. When using two-lane entrances, to satisfy lane-balance needs, at least one additional lane shall be provided downstream. The design of two-lane entrances on all Department projects shall use the taper type as presented in the 2004 AASHTO Green Book, Chapter 10, Exhibit 10-76.

**b.** Two-Lane Exits. Two-lane exits or two-lane deceleration lanes may be provided where the traffic volume leaving the freeway at an exit terminal exceeds the design capacity of a single lane. To satisfy lane balance needs and not to reduce the basic number of through lanes, it usually is necessary to add an auxiliary lane upstream from the exit.

The design of two-lane exits on all Department projects shall use the parallel-type as presented in the 2004 AASHTO Green Book, Chapter 10, Exhibit 10-77. Refer to Section 4.5.M for additional guidelines for two-exit versus single-exit design.

**c.** Two-Lane Terminals on Curved Alignment. The design of ramp terminals where the freeway is on curved alignment is discussed in 4 above for single-lane terminals. The same principles of design may be used in the layout of two-lane terminals.

**d.** Major Forks and Branch Connections. A major fork is defined as the bifurcation of a directional roadway, of a terminating freeway route into two directional multilane ramps that connect to another freeway or of a freeway route into two separate freeway routes of about equal importance. A branch connection is defined as the beginning of a directional roadway of a freeway formed by the convergence of two directional multilane ramps from another freeway or by the convergence of two freeway routes to form a single freeway route. For additional information concerning those two types of multilane free-flow terminals, refer to the section "Single-Lane Free-Flow Terminals, Exits" in the 2004 AASHTO Green Book, Chapter 10.

**E. Ramp Capacity Analysis and Traffic Control.** The capacity and service volume determination procedures for ramp analysis on all Department projects shall adhere to the concepts presented in the *HCM*. Where traffic signal controls may be required at ramp terminals, their installation shall be governed by Publication 149, *Traffic Signal Design Handbook*.

**F. Ramp Design Sheet.** In order to facilitate the preparation and checking of ramp designs and to avoid an oversight of the items that shall be considered, a Ramp Design Sheet (see Table 4.1) may be used to identify these items, to indicate the source of design criteria and to indicate the proposed design.

Where the proposed design does not comply with the identified design criteria, an explanation shall be submitted at the time of request for interchange approval.

# TABLE 4.1
# RAMP DESIGN SHEET

**SR_________________**
**RAMP________________**

**DATE___________________**
**MADE BY_________________**
**CHECKED BY________________**

| ITEMS | SOURCE OF DESIGN CRITERIA AASHTO REFERENCE | REMARKS |
|---|---|---|
| (1) Design Speed of Highway | | |
| (2) Ramp Design Speed* | | |
| (3) Minimum Radius | | |
| (4) Compound Curve Ratio* | | |
| (5) Length of Circular Arc for Compound Curves<br>Radius _________<br>Radius _________<br>Radius _________<br>Radius _________ | | |
| (6) Ramp Gradient | | |
| (7) Superelevation Rates*<br>Radius _________<br>Radius _________<br>Radius _________<br>Radius _________ | | |
| (8) Rate of Cross Slope Change | | |
| (9) Maximum Algebraic Difference in Cross Slope at Terminals* | | |
| (10) Design Width of Pavement Case Traffic Condition (Include Any Modifications)<br>R _________<br>R _________<br>R _________<br>R _________ | | |
| (11) Internal Clearances<br>(a) Post or Rails<br>(b) Shoulder Right<br>(c) Shoulder Left | | |

*Comments pertaining to specific items on the Ramp Design Sheet above are as follows:

(2) Desirable ramp design speeds should approximate the low volume running speed on the intersecting highways. Where it is not practical to maintain desirable ramp speeds, considerations should be given to provide acceleration and deceleration lanes at the intersected road to minimize the relative speed differential between the ramp and the intersected road.

(4) The ratio of the flatter radius to the sharper radius should not exceed 2 if practical; otherwise, spiral transitions should be utilized between the two curves.

(7) Superelevation rates should not exceed 8.0% in rural areas and 6.0% in urban areas.

(9) The maximum algebraic difference in cross slope at ramp terminals should be determined at the ramp nose.

During the design development, considerations should be given to the striping and the auxiliary lanes that may be required for safe operations even though total traffic volumes may not indicate their need.

# TABLE 4.1 (CONTINUED)
# RAMP DESIGN SHEET

| ITEMS | SOURCE OF DESIGN CRITERIA<br>AASHTO<br>REFERENCE | REMARKS |
|---|---|---|
| (11) Internal Clearances (Cont'd)<br>(d) Extent of Stabilization-Lt<br>(e) Extent of Stabilization-Rt<br>(f) Structures - Underpass<br>(g) Structures - Overpass<br>(h) Curbs - From Parapets<br>(j) Curbs - From Traffic Lane<br>(k) Other Clearances<br>____________________<br>____________________<br>____________________<br>____________________ | | |
| (12) Deceleration Lane Length<br>(a) 2% or Less<br>(b) Greater than 2%<br>(c) Taper Length | | |
| (13) Acceleration Lane Length<br>(a) 2% or Less<br>(b) Greater than 2%<br>(c) Taper Length | | |
| (14) Sight Distance*<br>(a) Ramp Proper<br>(b) Terminals | | |
| (15) Other Items<br>____________________<br>____________________<br>____________________<br>____________________ | | |

*Comments pertaining to specific items on the Ramp Design Sheet above are as follows:

**14.** Sight distance requirements for the ramp proper shall be determined similar to alignment and profile stopping sight distance for the main line and sight distance at the termini shall be determined in accordance with requirements for sight distance at intersections (See Chapter 2, Section 2.17).

During the design development, considerations should be given to the striping and the auxiliary lanes that may be required for safe operations even though total traffic volumes may not indicate their need.

# CHAPTER 5

## LIGHTING

### 5.0 INTRODUCTION

The design criteria in this Chapter are not intended to be a textbook. The information herein is written for qualified lighting engineers and to assist them in preparing a uniform and standard lighting design of highway lighting systems.

The criteria included in this Chapter apply to Freeway Interchanges, except as specifically designated. Roadway areas not covered in this Chapter should be based on the criteria listed in the AASHTO *Roadway Lighting Design Guide* and as specified at the predesign meeting.

The designer's engineering judgment in the application of the criteria is subject to review and concurrence by the Central Office. It is suggested that the designer obtain prior approval from the Central Office on matters of design which raise questions in the application of these criteria to a specific condition.

Present the design report in the format shown by the sample design reports in Section 5.12.

Sources of reference in addition to this Manual are:

- AASHTO-Current *Roadway Lighting Design Guide*.
- AASHTO-*Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals*.
- Publication 408, *Specifications,* and associated changes, Pennsylvania Department of Transportation.
- NCHRP Report 672-*Roundabouts: An Informational Guide, Second Edition.*
- Current Publication 72M, *Roadway Construction Standards*, Highway Lighting Drawings, RC-80M, RC-81M, RC-82M, RC-83M and RC-84M.
- Current Publication 219M, *Standards for Bridge Construction*, BC-721M and BC-722M.
- Publication 10, Design Manual, Part 1, *Transportation Program Development and Project Delivery Process.*
- Publication 10C, Design Manual, Part 1C, *Transportation Engineering Procedures.*
- Publication 10X, Design Manual, Part 1X, *Appendices to Design Manuals 1, 1A, 1B, and 1C.*
- Publication 14M, Design Manual, Part 3, *Plans Presentation.*
- Publication 15M, Design Manual, Part 4, *Structures*.

### 5.1 SITE INSPECTION

The designer shall familiarize himself with existing overhead and underground facilities which may interfere with lighting facilities. Facilities which are to be installed, such as underground drains, guide rail, utility structures and/or appurtenances and overhead signs, require coordination with proposed lighting facilities and should be coordinated prior to the start of design.

To avoid conflict with any proposed utility facility relocations and to obtain, at an early date, an available source of electrical service, the lighting designer is to proceed as follows:

**1.** Invite the District Utility Relocation Supervisor to attend the scheduled field meeting with the lighting designer and the utility to review the preliminary design requirements for sign or highway lighting, and to determine the available source of energy and the location of the service terminal.

**2.** Prepare and forward a summary of the field review meeting to the utility with a request for confirming in writing the location of the service terminal and the location of the available source of energy.

**3.** Furnish a copy of the letter of confirmation received from the utility to the District Utility Relocation Unit for current investigation of any conflict with interim relocation plans being furnished.

**4.** Have any conflicts observed by the District Utility Relocation Unit brought to the attention of the lighting designer and the utility for further investigation and coordination of any necessary adjustments.

Existing lighting facilities to be removed, relocated or coordinated with are part of the total scope of work of the proposed lighting system under design.

Include facilities other than lighting facilities which are to be moved or relocated in the scope of work for the roadway construction or alterations.

## 5.2 PRELIMINARY DESIGN

### A. Conventional Lighting:

**1.** Design Criteria. Design all roadway surfaces based on the current AASHTO *Roadway Lighting Design Guide*.

**2.** Pole Spacing. Determine pole spacing using the following formula. However, the use of computer programs is encouraged, especially for the glare ratio computation:

$$S = \frac{L \times LLD \times UF \times MF}{LX \times W}$$

where:

S = Spacing is the distance in meters (feet) between luminaires. In curved sections of roadways, use the baseline distance as basis of spacing.

L = The initial lumen value is obtained from manufacturers' lamp data. Use horizontal lumens if the lamp is burned in a horizontal position and vertical lumens if the lamp is burned in a vertical position. Confirm values obtained with Central Office's latest data before the start of design.

UF = The utilization factor is from the luminaire photometric data sheet.

MF = The maintenance or dirt factor assumes the luminaire output at the end of rated life if the lamp is reduced because of dirt on the reflector and the refractor.

LX (FC) = The average maintained horizontal lux (footcandles) on the roadway at the end of rated life of the lamp with maintenance factor.

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W = Width of the roadway as associated with the spacing to define the illuminated area. Use the following widths: (1) curb to curb for bridges and curbed roadways, (2) wall to wall or barrier to barrier when the distance from edge of pavement to wall or barrier is less than 3.0 m (10 ft) and (3) Edge of Pavements for all open roadways.

LLD = Lamp lumen depreciation factor. Use 0.8 for HPS lamps. For MV or MH lamps, consult the Central Office Lighting Unit.

**3.** Uniformity Ratio. Refer to the current AASHTO *Roadway Lighting Design Guide*. The uniformity ratio is the ratio of the average maintained horizontal lux (footcandles) to the darkest spot lux (footcandles) at the end of rated life (ERL) of the lamp, including the maintenance factor (MF). Compute the uniformity ratio using the following formula:

**METRIC:**

$$UR = \frac{LX}{CF \times lx}$$

where:

LX = Average maintained horizontal lux (same value used in the pole spacing formula)

lx = Darkest point lux from the isolux diagram.

CF = Correction factor to convert the diagram value (lx) to the end of rated life value. Photometric data gives lamp lumen output on which the isolux plot was based. Hence,

$$CF = \frac{L \times 0.8ERL \times 0.8MF}{Photo\text{-}Data\text{-}Test\ Lumens}$$

where:

ERL = End of rated life

**ENGLISH:**

$$UR = \frac{FC}{CF \times fc}$$

where:

FC = Average maintained horizontal footcandles (same value used in the pole spacing formula)

fc = Darkest point footcandles from the isofootcandle diagram.

CF = Correction factor to convert the diagram value (fc) to the end of rated life value. Photometric data gives lamp lumen output on which the isofootcandle plot was based. Hence,

$$CF = \frac{L \times 0.8ERL \times 0.8MF}{Photo\text{-}Data\text{-}Test\ Lumens}$$

where:

ERL = End of rated life

Apply a second correction factor for the darkest spot lux (footcandles) when the mounting height is other than for which the data was plotted. Refer to the photometric data sheet for this correction factor.

**4.** Illumination Level. Illumination levels greater than recommended by AASHTO criteria, or the level on which the design is based, are justified under the following conditions:

**a.** To obtain acceptable uniformity ratio.
**b.** Spacing is the result of fixed or control points on the roadway.
**c.** Full spacing not available at specific locations because of control or fixed points.

**5.** Overhang. Base the overhang of the luminaire from edge of pavement, either positive or negative, upon the following considerations:

**a.** System efficiency.
**b.** Driver comfort.
**c.** Pole setback and arm length required. (Only standard arm lengths are to be specified.)
**d.** Illumination level and uniformity.

**6.** Mounting Height. The mounting height is the height of the luminaire above the edge of pavement. Pole shaft lengths must necessarily vary to compensate for the difference in elevations between the pole foundation or anchorage and the roadway surface. Publication 72M, *Roadway Construction Standards*, gives this adjustment to the pole shaft length by the C-dimension.

**B. High Mast Lighting:**

**1.** Design Criteria. All roadway surfaces are typically designed for illumination of 6 to 10 average maintained horizontal lux (0.6 to 0.9 average maintained horizontal footcandle) at the end of rated life of the lamp. Provide the minimum lux (footcandle) level at any point on the roadway as 2 lx (0.2 fc) maintained. Do not exceed uniformity ratio of 4:1.

Use the 400 W High Pressure Sodium (HPS) lamp with the required number of luminaires necessary to achieve the proper lux (footcandle) level and uniformity ratio period. Mount on high mast poles at a nominal mounting height of 30.5 m (100 ft) above the road surface. Do not exceed a pole length of 36.6 m (120 ft).

At the time of the pre-design meeting, the Department will furnish the consultant with the required candela (candlepower) and lux (footcandle) data necessary to accomplish the lighting design. Do not consider light at angles greater than 75°.

**2.** Design Procedures. Determine the average maintained lux (footcandle) level on the roadway in the following manner:

**a.** Locate points at 30 m (100 ft) intervals on the centerline of the mainline in each direction, all ramps and the crossroad.

**b.** Determine the end of rated life maintained horizontal lux (footcandle) level at each of these points, considering the usable contribution from all poles in the vicinity of each point.

**c.** Calculate the lux (footcandle) level at each point by a computerized program. With prior approval, the Central Office, Bureau of Maintenance and Operations may accept manual computations for specific projects. Use the lux (footcandle) data previously supplied by the Central Office, Bureau of Maintenance and Operations.

**d.** Divide the interchange area into sections of the mainline in each direction, each ramp and the crossroad.

**e.** Determine the average maintained lux (footcandle) level in each section by adding all lux (footcandle) points in that section and dividing by the number of points in the section. Obtain a result between 6 and 10 lx (0.6 and 0.9 fc).

**f.** Determine the uniformity ratio of each road section by dividing the average maintained lux (footcandle) level in that section by the minimum lux (footcandle) level at any point in the section. Obtain a result equal to or less than 4.0. Tabulate all design results as shown in Section 5.12.

## 5.3 PRELIMINARY DESIGN REPORT

Prepare the preliminary design report for present lighting by including the following:

**1.** All information developed in the design shown on a 1:500 or 1:1000 (1" = 50' or 1" = 100') standard size drawing as prescribed in Publication 10C, Design Manual, Part 1C, *Transportation Engineering Procedures*, Chapter 4, Section 4.4.C.

**2.** Guide rail, type, location and distance from edge of pavement (also include for final review).

**3.** Boundary lines of political subdivisions.

**4.** Light pole locations by stations. (Include high mast pole foundation ground elevations on both the preliminary and the final plans.)

**5.** Complete calculations and tabulation of results, as shown in Section 5.12, for each different road width and situation, including calculations for coefficient of utilization, uniformity ratio, etc.

**6.** Bridge and underpass lighting provisions.

**7.** ADT of roadway at the time facility is opened to traffic.

**8.** Legend of symbols used, scale of plans and date.

**9.** Right-of-way lines.

**10.** Shoulder and curb lines.

**11.** Location and parameters of existing lights.

**12.** Overhead and underground electrical utilities (for locating power supplies).

**13.** Electronic copy of the .ies file from an accredited Testing Laboratory.

## 5.4 LUMINAIRES

**A. Conventional Lighting.** Install conventional roadway luminaires at nominal mounting heights of 9.1 m to 15.2 m (30 ft to 50 ft) using HPS lamps. Have the design agency determine the best wattages, distribution types and mounting heights for specific roadways.

**B. High Mast Lighting.** For a high mast roadway lighting system with 30.5 m (100 ft) nominal mounting heights, employ area type luminaires with symmetrical (Type V) light distributions. Employ 400 W HPS luminaires for the lighting system. If "run-out" lighting is required, use HPS lamps as detailed above for conventional lighting.

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## 5.5 POLES

### A. Conventional Lighting:

**1.** Know what restrictions are upon light pole locations when designing a highway lighting system. The restrictions are based upon vehicular safety, driver comfort, ease of maintenance, protection of facilities and aesthetic considerations and are as follows:

**a.** Locate poles on driver's right, whenever possible.

**b.** Locate poles on the inside of curves when required for safety. Do not place guide rail solely for light pole protection.

**c.** Use pole arm lengths not exceeding 9.1 m (30 ft).

**d.** Do not locate poles in the median strip except under special conditions and with specific approval.

**e.** Locate poles at exit ramp gores on interchanges at 45 m ± 3 m (150 ft ± 10 ft) minimum from the actual shoulder nose.

**f.** Locate poles at entrance ramp gores on interchanges at 30 m ± 3 m (100 ft ± 10 ft) minimum from the actual shoulder nose.

**g.** Provide minimum pole clearance from overhead sign structures and bridges as follows:

| MOUNTING HEIGHT (MH) FOR POLE | MINIMUM POLE CLEARANCE FROM OVERHEAD SIGN STRUCTURES AND BRIDGES |
|---|---|
| 9.1 m (30 ft) | 15.2 m ± 3.0 m (50 ft ± 10 ft) |
| 10.7 m (35 ft) | 18.3 m ± 3.0 m (60 ft ± 10 ft) |
| 12.2 m (40 ft) | 21.3 m ± 3.0 m (70 ft ± 10 ft) |
| 13.7 m (45 ft) | 24.4 m ± 3.0 m (80 ft ± 10 ft) |
| 15.2 m (50 ft) | 27.4 m ± 3.0 m (90 ft ± 10 ft) |

**h.** Locate poles on the high barrier of bridges when the superelevation is greater than 6.0%.

**i.** Set back all unprotected or exposed poles as far as possible from the roadway, consistent with available approved equipment.

Where poles are considered to be exposed to traffic, design them to have a suitable breakaway or yielding feature. For the breakaway or yielding feature, comply with all applicable AASHTO requirements for structural supports. Poles provided with breakaway or yielding features are described as Type S Poles available with arm lengths up to and including 6.1 m (20 ft). In general, locate Type S poles on a 6:1 slope or less. Use Modified Foundations when the slope is greater than 6:1 and less than or equal to 4:1.

**j.** Do not place poles in front of guide rail.

**k.** Do not locate poles less than 4.6 m (15 ft) from the edge of pavement and 1.5 m (5 ft) from the edge of paved shoulder, except when the poles are placed behind barrier, guide rail, walls or other approved protection.

**l.** Install pole foundations as shown in Publication 72M, *Roadway Construction Standards*.

**m.** Locate poles on bridges on the side least likely to be disturbed if there are plans to widen the bridge in the future. Locate poles at pier locations if feasible.

**n.** Provide poles on bridges with arms not exceeding 2.5 m (8 ft). Provide bridge mounted poles with vibration dampers.

**o.** Determine minimum arm lengths for poles by the following formula:

Arm Length = Setback - 0.6 m (2 ft) + Overhang. Use only standard arm lengths. Overhang resulting from actual setback can vary ± 0.5 m (± 2 ft) from overhang used in the design.

**p.** Determine minimum pole setback in guide rail areas by the following formulas:

**(1)** Strong Post Guide Rail (Type 2-S)*
SB = d + 1.1 m (3.5 ft)
= Arm Length + 0.6 m (2 ft) - Overhang.

*Refer to Chapter 12.

**(2)** Weak Post Guide Rail (Type 2-W)*
SB = d + 2.6 m (8.5 ft)
= Arm Length + 0.6 m (2 ft) - Overhang.
d = Distance from edge of pavement to back of post. Overhang resulting from actual setback can vary ± 0.6 m (± 2 ft) from design. Use only standard arm lengths. (See Figure 5.1)

**2.** Pole Types:

Specify lighting poles as follows:

**a.** Normally specify steel or aluminum poles.

**b.** Specify aluminum poles only or steel poles only when justified and approved for the project.

**c.** Specify steel poles with single member arms and aluminum poles with truss arms. (Bracket type unless approved otherwise).

**d.** Specify pole arm rise compatible for each length specified. Refer to Publication 72M, *Roadway Construction Standards*.

**e.** Specify poles and arms compatible with adjacent existing installations.

**f.** Provide anchor base, Type A Poles, when:

**(1)** Pole is mounted on a bridge barrier or wall.
**(2)** Pole is located behind guide rail.
**(3)** Pole is considered protected by natural roadside considerations.
**(4)** Poles in or near pedestrian areas.

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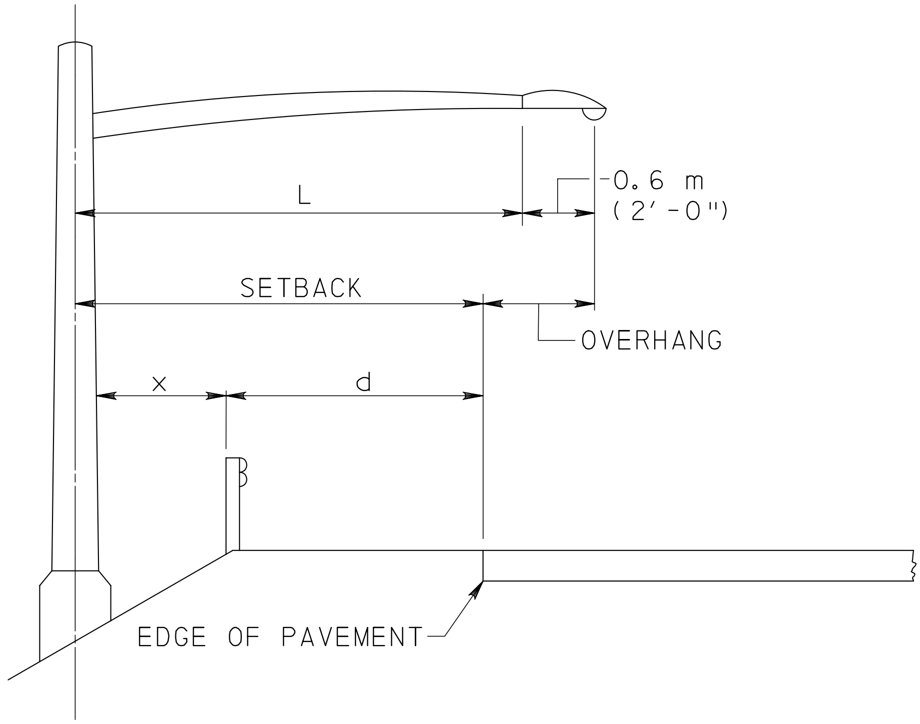


FIGURE 5.1
LIGHTING POLE SETBACK IN
GUIDE RAIL AREAS

* REFER TO CHAPTER 12.

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**3.** Pole Setback:

x = 1.1 m (3.5 ft) min for Strong Post Guide Rail (Type 2-S)*
x = 2.4 m (8.5 ft) min for Weak Post Guide Rail (Type 2-W)*
Set Back = x + d + 0.15 m (0.5 ft) = L + 0.6 m (2 ft) - OH

Note: 0.15 m (0.5 ft) from centerline to face of pole.
L (min) = x + d + OH - 0.6 m (2 ft) + 0.15 m (0.5 ft)

**4.** Example (METRIC):

Design OH = 0.9 m d = 5.5 m
Strong Post Guide Rail (Type 2-S)
L (min) = 1.1 m + 5.5 m + 0.9 m - 0.6 m = 6.9 m
NEAREST STANDARD LENGTH GREATER IS 7.6 m. Now solve for
SB = L + 0.6 m - OH

SB = 7.6 m + 0.6 m - 0.9 m = 7.3 m
x = 7.3 m - 5.5 m = 1.8 m

Table 12.3 requires 0.9 m clearance for Type 2-S guide rail, therefore SB is OK.

Example (ENGLISH):

Design OH = 3.0 ft d = 18.0 ft
Strong Post Guide Rail (Type 2-S)
L (min) = 3.5 ft + 18.0 ft + 3.0 ft - 2.0 ft = 22.5 ft
NEAREST STANDARD LENGTH GREATER IS 25.0 ft. Now solve for
SB = L + 2.0 ft - OH

SB = 25.0 ft + 2.0 ft - 3.0 ft = 24.0 ft
x = 24.0 ft - 18.0 ft = 6.0 ft

Table 12.3 requires 3.0 ft clearance for Type 2-S guide rail, therefore SB is OK.

**B. High Mast Lighting:**

**1.** Pole Locations. Locate poles on tangent sections and on the inside of curves a minimum of 15 m (50 ft) from the edge of pavement wherever practical. Locate poles on the outside of curves either a minimum of 15 m (50 ft) from the edge of pavement or as determined by the required clear zone width criteria in Chapter 12 (use highest value). Shield poles that are located closer than 15 m (50 ft) from the edge of pavement by placement either behind guide rail or on natural earth mounds.

**2.** Pole Types. Construct poles in accordance with Publication 408, *Specifications*, and Publication 72M, *Roadway Construction Standards*.

## 5.6 UNDERPASS LIGHTING

Illuminate underpasses at the same level of illumination as the outside roadway. Supplemental lighting may be needed when the pole mounted luminaires do not sufficiently penetrate the underpass. Daytime and nighttime lighting may be needed when pedestrian safety is involved.

## 5.7 TUNNEL LIGHTING

Tunnels may need daytime and/or nighttime lighting. Base design of tunnel lighting on the AASHTO *Roadway Lighting Design Guide* or on the Illuminating Engineering Society (IES) of North America Publication, *IES Lighting Handbook*. Contact the Central Office Lighting Unit for proper design parameters on each tunnel lighting project.

## 5.8 SAFETY REST AREAS, WELCOME CENTERS AND PERMANENT TRUCK WEIGH STATIONS

Light the ramps leading in, around and out of these areas to 6 average maintained lux (0.6 average maintained footcandle) and a maximum uniformity ratio of 4:1 with HPS lamps.

Light the car parking lot area to 11 average maintained lux (1.0 average maintained footcandle) and the truck parking lot area to 9 average maintained lux (0.8 average maintained footcandle) with a maximum uniformity ratio of 4:1 using HPS lamps.

Light the sidewalks leading from the parking lot to and around the safety rest building with 100 W HPS post-top mounted luminaires at a mounting height of 4.6 m (15 ft), placed approximately 1.0 m to 1.5 m (3 ft to 5 ft) from the edge of the sidewalk with a spacing between luminaires of approximately 12 m (40 ft). The use of high mast lighting poles may delete the need for post-top mounted luminaires.

## 5.9 FINAL DESIGN

Final design entails the development of information needed to prepare the lighting construction plans based upon the preliminary design previously approved. The information involves the following:

**1.** Routing of Lighting Circuits (8.37 $mm^2$ (#8 AWG) cu-minimum for distribution).

**2.** Base wire size calculations upon 3% voltage drop maximum for reactor type ballasts and 5% voltage drop maximum for auto-regulator or regulator-type ballasts.

**3.** Determination of pole arm lengths and pole setbacks.

**4.** Determination of the "C" dimensions for all pole locations as shown in Publication 72M, *Roadway Construction Standards*. Show this dimension to the nearest 0.05 m (0.1 ft) alongside the setback distance on the tabulation of quantities sheet. Refer to Publication 14M, Design Manual, Part 3, *Plans Presentation*.

**5.** Size or rating of power supply components. Size breakers to 75% of rating.

**6.** Size lighting loads to include sign loads when signs are to be energized from the roadway lighting circuits.

**7.** Determination of type of poles required: S-Base or A-Base.

**8.** Power Supply service voltage and location. Supply voltage shall be either 120/240 V or 240/480 V, single phase, 3-wire system. Other voltages require specific approval from the Central Office, Bureau of Maintenance and Operations. Include confirmation letter from the power company as applicable.

**9.** Determination of pole foundation required as detailed in Publication 72M, *Roadway Construction Standards*.

**10.** Necessary details of location required as detailed in Publication 72M, *Roadway Construction Standards*.

**11.** Include guide rail type, location and distance from edge of pavement.

**12.** Standard and special notes and special provisions.

## 5.10 POWER SUPPLY

The electric utility company typically delivers 3 wire, single phase 120/240 V service or a 240/480 V service to the Department service pole as indicated in Publication 72M, *Roadway Construction Standards*. Provide a service location, service disconnect equipment and the meter installation acceptable to the local electric utility company.

Design the sizes of equipment to meet the needs of each project. Simplified diagrams are shown in Publication 72M, *Roadway Construction Standards*.

A step up transformer may be required on larger systems that use a 120/240 V supply. Provide transformers where they can be justified in wire size savings.

Specify a metered service for all projects except where a Department approved unmetered energy only rate is available.

## 5.11 MULTIPLE DISTRIBUTION SYSTEM

Use and install direct burial cable in PVC conduit as shown in Publication 72M, *Roadway Construction Standards*. Balance the luminaires alternately on each side of the 3-wire, single phase distribution system connected line to neutral. Protect each side or phase leg of the distribution system with a breaker of suitable size but not less than 20 A. Provide an interchange with as many circuits as are needed to obtain economical wire sizes within limits of voltage drop and number of power supplies available. If overhead lighted signs are also involved, specify wire sizes and protective devices of sufficient size to provide for the sign loads as well as for the highway lighting loads.

## 5.12 SAMPLE DESIGN REPORTS

Present the design reports for conventional highway lighting and high mast highway lighting using the formats as shown on the following pages.

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# SAMPLE

# CONVENTIONAL

# HIGHWAY LIGHTING

# DESIGN REPORT

_______________________ County

SR ____________, Section ___________

Interchange with SR _________________

Pre-Design Conference _______________
Date

1. Energy and maintenance letter of intent from county dated _________________ included.
2. This project is to be programmed for Federal-aid.
3. Justification for this lighting is AASHTO case _______________, ADT shown on plan.

Consultant ______________________

Designed by ______________________

Checked by ______________________

Date ______________________

Rev ______________________

# DESIGN CRITERIA (METRIC)
## (Sheet 1 of 2)

I. MOUNTING HEIGHT
- SR _____............................................... 15.2 m
- SR _____............................................... 13.7 m
- Ramps .................................................. 10.7 m
- Underpass............................................. 4.6 m

II. LUMINAIRES
- SR _____............................................... 400 W, HPS
- SR _____............................................... 250 W, HPS
- Ramps .................................................. 150 W, HPS
- Underpass............................................. 100 W, HPS

III. LAMPS (LLD = 0.80)
- SR _____............................................... 400 W, 40 000 lm, ERL
- SR _____............................................... 250 W, 22 000 lm, ERL
- Ramps .................................................. 150 W, 12 800 lm, ERL
- Underpass............................................. 100 W, 7600 lm, ERL

IV. PHOTO-METRIC DATA
- GE 35-17XXXX .................................. 400 W, HPS, M-SC-III
- GE 35-17XXXX .................................. 250 W, HPS, M-SC-II
- GE 35-17XXXX .................................. 150 W, HPS, M-SC-II
- GE 35-17XXXX .................................. 100 W, HPS, M-SC-IV

V. OVERHANG
- SR _____ Roadway...........0 m...Structures............2.7 m
- SR _____ Roadway...........0 m...Structures............none
- Ramps.............Roadway............Radius > 75 m = 1.5 m<br>Radius < 75 m = 3.0 m
- Structures...........................1.8 m
- Underpass.........Ramp...........0 m<br>SR______ 1.5 m

VI. DESIGN PARAMETERS
- Average maintained lux at ERL........... 6 lx
- Dirt Factor............................................ 0.80
- Uniformity Ratio.................................. 4:1 maximum
- Glare Ratio........................................... 0.3:1 maximum

# DESIGN CRITERIA (METRIC)
## (Sheet 2 of 2)

VII. CORRECTION FACTORS

A. 400 W Luminaire, HPS — Dirt Factor = 0.80

Mounting Height Factor $\frac{(9)^2}{(15)^2} = 0.36$

Curve Factor $\frac{40\,000}{1000} = 40$ (data per 1000 lm)

CF Total....................................... 0.36 × 0.80 × 40 = 11.52

B. 250 W Luminaire, HPS — Dirt Factor = 0.80

Mounting Height Factor $\frac{(9)^2}{(13.5)^2} = 0.44$

Curve Factor $\frac{22\,000}{1000} = 22$ (data per 1000 lm)

CF Total....................................... 0.44 × 0.80 × 22 = 7.74

C. 150 W Luminaire, HPS — Dirt Factor = 0.80

Mounting Height Factor $\frac{(9)^2}{(10.5)^2} = 0.74$

Curve Factor $\frac{12\,800}{1000} = 12.8$ (data per 1000 lm)

CF Total....................................... 0.74 × 0.80 × 12.8 = 7.58

D. 100 W Luminaire, HPS — Dirt Factor = 0.80

Mounting Height Factor $\frac{(9)^2}{(4.5)^2} = 4$

Curve Factor $\frac{7600}{1000} = 7.6$ (data per 1000 lm)

CF Total....................................... 4 × 0.80 × 7.6 = 24.32

# DESIGN CRITERIA (ENGLISH)
## (Sheet 1 of 2)

I. MOUNTING HEIGHT
SR _____ .............................................. 50 ft
SR _____ .............................................. 45 ft
Ramps .................................................. 35 ft
Underpass............................................. 15 ft

II. LUMINAIRES
SR _____ .............................................. 400 W, HPS
SR _____ .............................................. 250 W, HPS
Ramps .................................................. 150 W, HPS
Underpass............................................. 100 W, HPS

III. LAMPS (LLD = 0.80)
SR _____ .............................................. 400 W, 40,000 lm, ERL
SR _____ .............................................. 250 W, 22,000 lm, ERL
Ramps .................................................. 150 W, 12,800 lm, ERL
Underpass............................................. 100 W, 7,600 lm, ERL

IV. PHOTO-METRIC DATA
GE 35-17XXXX .................................. 400 W, HPS, M-SC-III
GE 35-17XXXX .................................. 250 W, HPS, M-SC-II
GE 35-17XXXX .................................. 150 W, HPS, M-SC-II
GE 35-17XXXX .................................. 100 W, HPS, M-SC-IV

V. OVERHANG
SR _____ Roadway.......0 ft.......Structures.......9 ft
SR _____ Roadway.......0 ft.......Structures.......none
Ramps.............Roadway...........Radius > 250 ft = 5 ft
Radius < 250 ft = 10 ft
Structures................................6 ft
Underpass.........Ramp............0 m
SR _______ 5 ft

VI. DESIGN PARAMETERS
Average maintained footcandle at ERL ..............0.60 fc
Dirt.......................................................................0.80
Uniformity Ratio.................................................4:1 maximum
Glare Ratio..........................................................0.3:1 maximum

## DESIGN CRITERIA (ENGLISH)
## (Sheet 2 of 2)

VII. CORRECTION FACTORS

A. 400 W Luminaire, HPS — Dirt Factor = 0.80

Mounting Height Factor $\frac{(30)^2}{(50)^2} = 0.36$

Curve Factor $\frac{40{,}000}{1000} = 40$ (data per 1000 lm)

CF Total....................................... $0.36 \times 0.80 \times 40 = 11.52$

B. 250 W Luminaire, HPS — Dirt Factor = 0.80

Mounting Height Factor $\frac{(30)^2}{(45)^2} = 0.44$

Curve Factor $\frac{22{,}000}{1000} = 22$ (data per 1000 lm)

CF Total....................................... $0.44 \times 0.80 \times 22 = 7.74$

C. 150 W Luminaire, HPS — Dirt Factor = 0.80

Mounting Height Factor $\frac{(30)^2}{(35)^2} = 0.74$

Curve Factor $\frac{12{,}800}{1000} = 12.8$ (data per 1000 lm)

CF Total....................................... $0.74 \times 0.80 \times 12.8 = 7.58$

D. 100 W Luminaire, HPS — Dirt Factor = 0.80

Mounting Height Factor $\frac{(30)^2}{(15)^2} = 4$

Curve Factor $\frac{7{,}600}{1000} = 7.6$ (data per 1000 lm)

CF Total....................................... $4 \times 0.80 \times 7.6 = 24.32$

## TABULATION OF DESIGN COMPUTATIONS (METRIC)
## (Sheet 1 of 1)

| ROADWAY | STATION | OVER-HANG | WATTS DISTR | MOUNTING HEIGHT | SPACING | AVG MAINT LUX | UNIFORMITY RATIO | GLARE RATIO | COMP SHEET |
|---|---|---|---|---|---|---|---|---|---|
| SR ______ | 23+100 LT | 0 | 400 W<br>M-SC-III | 15.2 m | | | | | |
| | | | | | 75 m | 6.6 | 3.5 | 0.18 | 7 |
| | 23+175 RT | 0 | 400 W<br>M-SC-III | 15.2 m | | | | | |
| | | | | | 75 m | 6.6 | 3.5 | 0.18 | 8 |
| | 23+250 LT | 0 | 400 W<br>M-SC-III | 15.2 m | | | | | |
| | | | | | 72 m | 6.8 | 3.2 | 0.19 | 9 |
| | 23+322 RT | 0 | 400 W<br>M-SC-III | 15.2 m | | | | | |
| SR ______ | 48+800 RT | 0 | 250 W<br>M-SC-II | 13.7 m | | | | | |
| | | | | | 78 m | 6.7 | 3.7 | 0.19 | 18 |
| | 48+878 LT | 0 | 250 W<br>M-SC-II | 13.7 m | | | | | |
| SR ______<br>Seg ______ | 16+200 LT | -1.5 m | 150 W<br>M-SC-II | 10.7 m | | | | | |
| | | | | | 60 m | 7.1 | 3.9 | 0.15 | 22 |
| | 16+260 LT | -1.5 m | 150 W<br>M-SC-II | 10.7 m | | | | | |
| | | | | | 45 m | 7.5 | 3.8 | 0.13 | 23 |
| | 16+305 LT | -4.5 m<br>Wallpack | 150 W<br>S-NC-IV | 4.6 m | | | | | |

## TABULATION OF DESIGN COMPUTATIONS (ENGLISH)
## (Sheet 1 of 1)

| ROADWAY | STATION | OVER-HANG | WATTS DISTR | MOUNTING HEIGHT | SPACING | AVG MAINT FOOT-CANDLE | UNIFORMITY RATIO | GLARE RATIO | COMP SHEET |
|---|---|---|---|---|---|---|---|---|---|
| SR ______ | 23+10 LT | 0 | 400 W M-SC-III | 50 ft | | | | | |
| | | | | | 250 ft | 0.61 | 3.5 | 0.18 | 7 |
| | 25+60 RT | 0 | 400 W M-SC-III | 50 ft | | | | | |
| | | | | | 250 ft | 0.61 | 3.5 | 0.18 | 8 |
| | 28+10 LT | 0 | 400 W M-SC-III | 50 ft | | | | | |
| | | | | | 240 ft | 0.63 | 3.2 | 0.19 | 9 |
| | 30+60 RT | 0 | 400 W M-SC-III | 50 ft | | | | | |
| SR ______ | 48+80 RT | 0 | 250 W M-SC-II | 45 ft | | | | | |
| | | | | | 260 ft | 0.62 | 3.7 | 0.19 | 18 |
| | 51+30 LT | 0 | 250 W M-SC-II | 45 ft | | | | | |
| SR ______ Seg ______ | 16+20 LT | -5 ft | 150 W M-SC-II | 35 ft | | | | | |
| | | | | | 200 ft | 0.66 | 3.9 | 0.15 | 22 |
| | 17+70 LT | -5 ft | 150 W M-SC-II | 35 ft | | | | | |
| | | | | | 150 ft | 0.70 | 3.8 | 0.13 | 23 |
| | 19+70 LT | -15 ft Wallpack | 150 W S-NC-IV | 15 ft | | | | | |

## COMPUTATIONS (METRIC)
## (Sheet 8 of ___)

**Station 0 + 770 to 0 + 845 (400 W) (It is encouraged to substitute computer calculations for manual calculations. Computer analysis is required to determine the glare ratio.)**

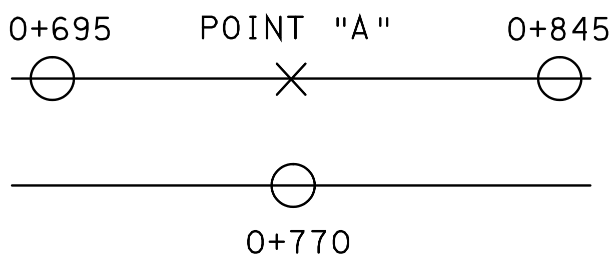
$W_1 = 15.0$, $W_2 = 18.0$ $W_A = (15.0 + 18.0) \div 2 = 16.5$

$CU_1 = \frac{15.0}{15.0} = 1.0$ $CU_2 = \frac{18.0}{15.0} = 1.2$

$UF_1 = 25\%$ $UF_2 = 27\%$ $UF_A = 26\%$

$$S = \frac{(40\ 000)(0.26)(0.8)}{(16.5)(6)} = 84$$

USED S = 75 m $LX = \frac{84}{75} \times 6 = 6.7$ lx




**Point "A" Illumination**

(0 + 770) LR $\frac{0}{15.0} = 0$ (0 + 845) LR $\frac{75}{15.0} = 5.0$

TR $\frac{15}{15} = 1.0$ TR $\frac{0}{15} = 0$

lx = 0.18* lx = Nil

$$UR = \frac{LX\ (Avg)}{LX\ (Min)} = \frac{6.7}{0.18 \times 11.52} = 3.2:1$$

NOTE: It may be necessary to consider other points to determine lowest illumination.

*LX values obtained by interpolation of tabulated manufacturers data or read direct from isolux data. Apply values with curve factor based on ERL lamp lumens.

LR = Longitudinal Ratio of Distance
TR = Transerve Ratio of Distance
CU = Coefficient of Utilization
UF = Utilization Factor
S = Spacing
UR = Uniformity Ratio
W = Road Width

## COMPUTATIONS (ENGLISH)
## (Sheet 8 of ___)

**Station 25 + 60 to 28 + 10 (400 W) (It is encouraged to substitute computer calculations for manual calculations. Computer analysis is required to determine the glare ratio.)**

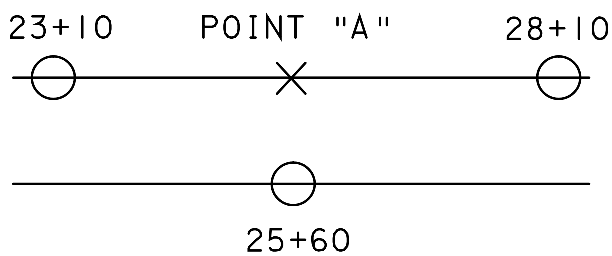
$W_1 = 15.0$, $W_2 = 18.0$ $\quad W_A = (15.0 + 18.0) \div 2 = 16.5$

$CU_1 = \frac{50}{50} = 1.0$ $\quad CU_2 = \frac{60}{50} = 1.2$

$UF_1 = 25\%$ $\quad UF_2 = 27\%$ $\quad UF_A = 26\%$

$$S = \frac{(40\,000)(0.26)(0.8)}{(55)(0.6)} = 253$$

USED S = 250 ft $\quad FC = \frac{253}{250} \times 0.6 = 0.61$




**Point "A" Illumination**

$(25 + 60)\ LR\ \frac{0}{50} = 0$ $\quad (28 + 10)\ LR\ \frac{250}{50} = 5.0$

$TR\ \frac{50}{50} = 1.0$ $\quad TR = \frac{0}{50} = 0$

fc = 0.018* $\quad$ Fc = Nil

$$UR = \frac{FC\ (Avg)}{FC\ (Min)} = \frac{0.61}{0.018 \times 11.52} = 2.9{:}1$$

NOTE: It may be necessary to consider other points to determine lowest illumination.

*FC values obtained by interpolation of tabulated manufacturers data or read direct from isofootcandle data. Apply values with curve factor based on ERL lamp lumens.

LR = Longitudinal Ratio of Distance
TR = Transerve Ratio of Distance
CU = Coefficient of Utilization
UF = Utilization Factor
S = Spacing
UR = Uniformity Ratio
W = Road Width

# SAMPLE

# HIGH MAST

# HIGHWAY LIGHTING

# DESIGN REPORT

________________________ County

SR _____________, Section ____________

Interchange with SR __________________

Pre-Design Conference ________________
Date

1. Energy and maintenance letter of intent from county dated __________________ included.
2. This project is to be programmed for Federal-aid.
3. Justification for this lighting is AASHTO case ________________, ADT shown on plan.

Consultant _______________________

Designed by _______________________

Checked by _______________________

Date _______________________

Rev _______________________

# DESIGN CRITERIA (METRIC)

1. Nominal Mounting Height -- 30.5 m
2. Luminaires -- 400 W
3. Photometric Data -- Holophane Test 24400 Fixture 1138-Sym
4. Design Values -- Avg Maintained 6 lx
   Min Point 2 lx
   Dirt Factor 0.80
   Uniformity Ratio 4:1 maximum
5. Lamp Data -- Initial output 50 000 lm
   End of Life 40 000 lm
   Rated Life 24 000 h
6. Luminaire Specifications (General)
   a. Max Candela angle = 60°
   b. Projected area = 0.33 $m^2$
7. Basis of tabulated values:

$$\text{Initial LX} = \frac{I\,(\text{Cos}\,\theta)^3}{MH^2} \qquad I = \text{Candelas at } \theta$$

$$\text{End Life LX} = \text{Initial LX} \times \frac{\text{Lamp end of life lumens}}{\text{Test lamp lumens}} \times 0.8$$

$$= \text{Initial LX} \times \frac{40\ 000}{50\ 000} \times 0.8$$

Dirt Factor = 0.8

## TABULATION OF HIGH MAST POLES (METRIC)

| POLE ID NO. | NO. OF LUMINAIRES | ROADWAY | STATION | GROUND ELEVATION | POLE HEIGHT | SETBACK |
|---|---|---|---|---|---|---|
| 1 | 8 | SR 8000 SEG 10 | 0 + 466 RT | 330 m | 33.5 m | 18.0 m |
| 2 | 8 | SR 8000 SEG 20 | 0 + 523 LT | 333 m | 36.6 m | 30.0 m |
| 3 | 6 | SR 793 NB | 8 + 530 RT | 329 m | 36.6 m | 18.9 m |
| 4 | 8 | SR 793 NB | 8 + 364 LT | 327 m | 36.6 m | 15.0 m |
| 5 | 7 | SR 793 SB | 8 + 244 LT | 335 m | 33.5 m | 9.0 m |
| 6 | 8 | SR 793 SB | 8 + 060 LT | 331 m | 30.5 m | 17.4 m |

## SUMMARY OF ROADWAY ILLUMINATION (METRIC)

| ROADWAY | AVERAGE ILLUMINATION | UNIFORMITY RATIO |
|---|---|---|
| SR 793 NB | 8.21 | 2.54 |
| SR 793 SB | 7.85 | 2.80 |
| SR 820 | 7.44 | 3.45 |
| SR 8000 SEG 10 | 6.92 | 2.30 |
| SR 8000 | 7.32 | 2.52 |
| | | |
| ENTIRE | 7.36 | 3.09 |

## TABULATION OF ROADWAY POINT ILLUMINATION (METRIC)

SR 8000, SEG 10

| STATION | ELEVATION | TOTAL LUX | CONTRIBUTING SOURCES (Pole No. and Contribution) |
|---|---|---|---|
| 0 + 490 | 331 m | 4.56 | #5-4.12 #10-0.44 |
| 0 + 460 | 332 m | 3.57 | #5-1.79 #10-1.78 |
| 0 + 400 | 332 m | 5.35 | #3-1.15 #12-4.20 |
| 0 + 370 | 329 m | 5.98 | #3-0.37 #12-5.47 #6-0.14 |

No of Points 16, Average Lux 6.92, Uniformity Ratio 2.30

# DESIGN CRITERIA (ENGLISH)

| | | | |
|---|---|---|---|
| 1. | Nominal Mounting Height | -- | 100 ft |
| 2. | Luminaires | -- | 400 W |
| 3. | Photometric Data | -- | Holophane Test 24400 Fixture 1138-Sym |
| 4. | Design Values | -- | Avg Maintained 0.60 footcandle<br>Min Point 0.20 footcandle<br>Dirt Factor 0.80<br>Uniformity Ratio 4:1 maximum |
| 5. | Lamp Data | -- | Initial output 50,000 lm<br>End of Life 40,000 lm<br>Rated Life 24,000 h |

6. Luminaire Specifications (General)
   a. Max Candela angle = 60°
   b. Projected area = 3.5 $ft^2$
7. Basis of tabulated values:

$$\text{Initial FC} = \frac{I(\cos\theta)^3}{MH^2}$$

I = Candelas at θ

$$\text{End Life FC} = \text{Initial FC} \times \frac{\text{Lamp end of life lumens}}{\text{Test lamp lumens}} \times 0.8$$

$$= \text{Initial FC} \times \frac{40{,}000}{50{,}000} \times 0.8$$

Dirt Factor = 0.8

## TABULATION OF HIGH MAST POLES (ENGLISH)

| POLE ID NO. | NO. OF LUMINAIRES | ROADWAY | STATION | GROUND ELEVATION | POLE HEIGHT | SETBACK |
|---|---|---|---|---|---|---|
| 1 | 8 | SR 8000 SEG 10 | 15 + 30 RT | 1083 ft | 110 ft | 60 ft |
| 2 | 8 | SR 8000 SEG 20 | 17 + 17 LT | 1091 ft | 120 ft | 100 ft |
| 3 | 6 | SR 793 NB | 279 + 84 RT | 1081 ft | 120 ft | 63 ft |
| 4 | 8 | SR 793 NB | 274 + 40 LT | 1073 ft | 110 ft | 50 ft |
| 5 | 7 | SR 793 SB | 270 + 47 RT | 1099 ft | 100 ft | 30 ft |
| 6 | 8 | SR 793 SB | 264 + 42 LT | 1085 ft | 100 ft | 58 ft |

## SUMMARY OF ROADWAY ILLUMINATION (ENGLISH)

| ROADWAY | AVERAGE ILLUMINATION | UNIFORMITY RATIO |
|---|---|---|
| SR 793 NB | 0.763 | 2.54 |
| SR 793 SB | 0.729 | 2.80 |
| SR 820 | 0.691 | 3.45 |
| SR 8000 SEG 10 | 0.643 | 2.30 |
| SR 8000 | 0.680 | 2.52 |
| | | |
| ENTIRE | 0.684 | 3.09 |

## TABULATION OF ROADWAY POINT ILLUMINATION (ENGLISH)

SR 8000, SEG 10

| STATION | ELEVATION | TOTAL FOOTCANDLES | CONTRIBUTING SOURCES (Pole No. and Contribution) |
|---|---|---|---|
| 16 + 00 | 1085 ft | 0.424 | #5-0.383 #10-0.041 |
| 15 + 00 | 1090 ft | 0.332 | #5-0.166 #10-0.166 |
| 13 + 00 | 1088 ft | 0.497 | #3-0.106 #12-0.390 |
| 12 + 00 | 1080 ft | 0.555 | #3-0.34 #12-0.508 #6-0.013 |

No of Points 16, Average Footcandles 6.43, Uniformity Ratio 2.30

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# CHAPTER 6

## PEDESTRIAN FACILITIES AND THE AMERICANS WITH DISABILITIES ACT

### 6.0 INTRODUCTION

Pedestrians are a part of every roadway environment and attention must be paid to their presence in urban as well as rural areas. Pedestrian access, safety and needs must be given full consideration during the planning and design of all transportation projects. The District Traffic Engineer should be consulted to see if there is a history of pedestrian crashes within the project limits or if the route has been declared an unsafe walking route for school children under Pennsylvania Department of Transportation (PennDOT) regulations.

The Americans with Disabilities Act (ADA) of 1990 is a federal civil rights statute that prohibits discrimination against people with disabilities. ADA implementing regulations for Title II prohibit discrimination in the provision of services, programs, and activities by state and local governments. Designing and constructing pedestrian facilities in the public right-of-way that are not usable by people with disabilities may constitute discrimination. Section 504 of the Rehabilitation Act of 1973 (504) includes similar prohibitions in the conduct of federally-funded programs.

Title II, Subpart A, of the ADA covers State and local government services, including the design and construction of buildings and facilities and the operation of government programs. Rulemaking authority and enforcement are the responsibility of the Department of Justice. However, the United States Department of Transportation has been designated to implement compliance procedures relating to transportation, including those for highways, streets and traffic management. The Federal Highway Administration (FHWA) Office of Civil Rights oversees the US DOT mandate in these areas.

ADA accessibility provisions apply to the entire transportation project development process including planning, design, construction and maintenance activities.

This Chapter provides the designer with the general guidance and direction to the Department's design procedures and requirements for the design of pedestrian facilities. There are a number of design facilities that should be considered in projects which will accommodate pedestrians. In special situations, some of these facilities can be used as countermeasures to reduce the potential for pedestrian accidents. These facilities include but are not limited to:

1. Sidewalks
2. Grade separations (overpasses and underpasses)
3. Refuge islands
4. Pedestrian barriers
5. Installation of pedestrian signals and pedestrian push buttons
6. Prohibition of pedestrians (on interstate highways, some intersections, or by statute or permit)
7. Widening of shoulders (in rural areas)
8. Improvements or installation of lighting
9. Installation of special signing and pavement markings
10. Prohibition of vehicle parking
11. Designation of one-way streets

The following references provide additional guidance for accessibility issues to assist in the determination of pedestrian needs and/or design of pedestrian accommodation within the highway right-of-way. The following documents were used in the development of PennDOT's standards and policies.

- Publication 10, Design Manual, Part 1, *Transportation Program Development and Project Delivery Process*, including Publication 10X, Design Manual, Part 1X, *Appendices to Design Manuals 1, 1A, 1B, and 1C*, Appendix S, Bicycle and Pedestrian Checklist
- PennDOT Training Manual, "Pennsylvania Pedestrian and Bicyclist Safety and Accommodation"
- AASHTO - "A Policy on Geometric Design of Highways and Streets" - 2004 AASHTO Green Book

- AASHTO - "Guide for the Planning, Design and Operation of Pedestrian Facilities" - 2004
- U.S. Access Board, "Draft Public Rights-of-Way Accessibility Guidelines" (PROWAG)
- U.S. Access Board, "Special Report: Accessible Public Rights-of-Way Planning and Design for Alterations"
- U.S. Department of Transportation, Federal Highway Administration, "Designing Sidewalks and Trails for Access, Part II of II, Best Practices Design Guide"
- U.S. Department of Transportation, Federal Highway Administration, "Manual on Uniform Traffic Control Devices"
- 67 PA Code § 212, Official Traffic Control Devices

## 6.1 DEFINITIONS

The following definitions will be used in conjunction with the criteria described in this Chapter:

**1.** Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way (PROWAG) July 26, 2011
www.access-board.gov/prowac/nprm.pdf

**2.** ADA Compliant Pedestrian Signals. Accessible Pedestrian Signals (APS), a device that communicates information about the WALK phase in audible and vibrotactile formats.
(*MUTCD* 2009 Edition Section 4E.06)
mutcd.fhwa.dot.gov

**3.** Alteration Project. A change to a facility in the public right-of-way that affects or could affect pedestrian access, circulation, or use. Alterations include, but are not limited to, resurfacing, rehabilitation, reconstruction, historic restoration, or changes or rearrangement of structural parts or elements of a facility.

**4.** Blended Transition. A pedestrian walkway connection with a grade of 5 percent or less between the level of the walkway and the level of the roadway crosswalk.

**5.** Crosswalk. That part of a roadway at an intersection included within the connections of the lateral lines of the sidewalk on opposite sides of the highway, measured from the curbs or, in the absence of curbs, from the edges of the traversable roadway; and, in the absence of a sidewalk on one side of the roadway, that part of a roadway included within the extension of the lateral lines of the existing sidewalk.

Any portion of a roadway at an intersection or elsewhere distinctly indicated for pedestrian crossing by lines or other markings on the surface.

**6.** Cross Slope. The slope that is perpendicular to the direction of travel.

**7.** Curb. The edge of a roadway surface which has been raised to contain, protect or form a gutter and is usually made of concrete or cut stone.

**8.** Curb Ramp. A short pedestrian ramp cutting through a curb or built up to a curb from a lower level.

**9.** Detectable Warning Surface (DWS). A standardized truncated dome grid surface built in or applied to the pedestrian access route to warn visually impaired people of hazards. The surface is placed where pedestrians will encounter the presence of hazards in the line of travel, such as the edge of roadway and railroads, indicating that they should stop and determine the nature of the hazard before proceeding further.

**10.** Engineering Judgment. The evaluation of available pertinent information and the application of appropriate principles, standards, guidelines and practices as contained in this Manual and other sources, for the purpose of deciding upon the applicability, design, operation, or installation of highway related facilities. Engineering judgment will be exercised by a licensed Professional Engineer, or by an individual working under the supervision of such Engineer. Documentation of engineering judgment is not required but is desirable when determining if ADA accessibility facilities cannot be designed to the maximum extent feasible.

**11.** Intersection. A roadway area formed by the connection of lateral curb lines or the lateral roadway boundaries of two or more highways or streets that join each other. Alley or driveway junctions normally do not constitute an intersection.

**12.** Island. A defined area between traffic lanes for control of vehicular movements or for pedestrian access and refuge. It includes all end protection and approach treatments. A median located within an intersection area is also considered to be an island. See Refuge Island.

**13.** Landing. An approximately level [1V:50H (2.00%) maximum in longitudinal slope and cross slope] part of a pedestrian accessible route or walkway that provides a space for performing turning maneuvers, resting or accessing pushbuttons.

**14.** *MUTCD*. Manual on Uniform Traffic Control Devices (2009 Edition)
mutcd.fhwa.dot.gov

**15.** New Construction Projects. A highway new construction project is the construction of a transportation facility where none existed, in a location without existing site constraints, where it is technically feasible to fully meet the standards for accessibility.

**16.** Pedestrian. A person traveling on foot or using assistive devices, such as wheelchairs, for mobility.

**17.** Pedestrian Access Route (PAR). A continuous and unobstructed walkway within a pedestrian circulation path that provides accessibility. Pedestrian accessible routes may include parking access aisles, curb ramps, crosswalks at vehicular ways, walks, ramps, and lifts.
Draft Public Rights of Way Accessibility Guidelines (PROWAG)
www.access-board.gov/prowac/draft.htm

**18.** Pedestrian Facilities. A general term denoting improvements and provisions made to accommodate or encourage non-vehicular transit.

**19.** Pedestrian Grade Separation Facilities. An accessible pedestrian traffic separation structure either over or under the roadway elevation (grade) of the vehicular traffic lanes providing a safe pathway access across the roadway.

**20.** Physical Barrier. A physical obstruction (i.e. fence, planter, guide rail, etc.) which prohibits a pedestrian movement. Placement of intentional physical barrier to deter pedestrian movements must be outside the vehicular line of sight and clear zone.

**21.** Public Right-of-Way. Consists of everything between the highway right-of-way limits, including travel lanes, medians, refuge islands, planting strips, sidewalks and other facilities of a roadway system.

**22.** Ramp. Any part of a constructed pedestrian pathway with a slope greater than 1V:20H (5.00%).

**23.** Refuge Island. A specifically defined area (most often raised above the street level) between vehicular traffic lanes intended as a pedestrian refuge location for persons unable to cross the entire roadway width at one time.

**24.** Running Slope, also known as longitudinal slope. The slope that is parallel to the direction of travel.

**25.** Sidewalk. A portion of a roadway between curb lines or the lateral line of a roadway and the adjacent property line or easement of private property that is paved or improved and intended for use by pedestrians.

**26.** Shoulder. A section of a roadway system adjacent to the traveled way that may be shared by motorized vehicles, horse drawn vehicles, bicycles, and pedestrians. The shoulder facilitates drainage, supports the roadway and provides a buffer between vehicles and pedestrians.

**27.** Site Infeasibility. Existing physical or site constraints which prohibit the incorporation of elements, spaces or facilities that are in full and strict compliance with the minimum requirements for new construction and which are necessary to provide pedestrian access, circulation and use.

**28.** Technically Infeasible. A finding that alterations to an existing facility cannot fully meet the standards because of existing site conditions that would require additional work, right-of-way acquisition or impacts, not included in the original scope or limits of the alteration project. Existing site constraints such as limited right-of-way, existing utilities, existing structures, environmental/historic impacts or other site constraints may also prohibit modification or addition of elements, spaces, or facilities that are in full and strict compliance with the standards (e.g., curb ramps may be constructed with slopes greater than 1V:12H (8.33%) where space limitations prohibit the use of flatter slopes). Where full compliance is found to be technically infeasible, these curb ramps must use slopes that provide access to the maximum extent feasible.

**29.** Traffic Control Device. A sign, signal, pavement marking, or other device used to regulate, warn, or guide traffic that is placed on, over, or adjacent to a street, highway, pedestrian facility, or shared-use path by authority of a public agency having jurisdiction.

**30.** Transition Plan. The Transition Plan should identify all current physical obstacles that limit accessibility to individuals with disabilities, describe in detail the methods that will be used to make the facilities accessible, specify a schedule for taking steps necessary to achieve compliance and identify the official responsible for implementing the plan. The District Transition Plan Items list will typically not have existing curb ramps that are noncompliant or technically infeasible curb ramps listed. Missing curb ramps will not be added to the District Transition Plan Items list as they will be updated with the next alteration plan. Complaints may result in facilities being added to the District Transition Plan Items list. Rarely, curb ramps that are required as part of an alteration project cannot be completed with that project and must be added to the District Transition Plan Items list. The District Transition Plan Items list is submitted to Central Office for inclusion in the Department Transition Plan. A public entity with 50 or more employees is required to have a Transition Plan.

**31.** Traveled Way. The portion of the roadway for the movement of vehicles, exclusive of roadway shoulders, berms, sidewalks and parking lanes.

**32.** Walkway. The continuous portion of a pedestrian access route that is connected to street crossings by curb ramps or blended transitions.

## 6.2 ADA REQUIREMENTS, STANDARDS AND GUIDELINES

Under the ADA, the United States Access Board has developed and continues to maintain accessibility design guidelines for accessible buildings and facilities known as the 2010 ADA Standards and the Draft Public Rights-Of-Way Guidelines (PROWAG). The 2010 ADA Standards focus mainly on facilities on sites such as buildings and is not always applicable to the public right-of-way. PROWAG provides guidance for facilities located within the public right-of-way that could be affected by constraints posed by space limitations at sidewalks, roadway design practices, slope, and terrain.

The United States Access Board's guidelines become enforceable when they are adopted by the standard setting agency for the ADA. The agencies responsible for standards under the ADA are the Department of Justice (DOJ) and the United States Department of Transportation (US DOT). Both the DOJ and US DOT have accepted the 2010 ADA Standards as standards. <u>It should be noted; the standards and guidelines serve as a means to achieve and/or measure ADA compliancy but are not requirements of ADA.</u>

The requirements of ADA include:

- New construction must be accessible and usable by persons with disabilities. Technical infeasibility should not usually be a factor in its design.
- Alterations to existing facilities, within the scope or limits of a project, must provide usability to the maximum extent feasible.
- Existing facilities that have not been altered shall not deny access to persons with disabilities.

Both the 2010 ADA Standards and PROWAG provide means to meet the requirements of ADA. Facilities located outside of the public right-of-way are governed by the 2010 ADA Standards; and facilities located within the public right-of-way are governed by PROWAG. This is consistent with a February 2006 FHWA memorandum that states the PROWAG will be used as a best practice for facilities located within the public right-of-way, when the 2010 ADA Standards is silent or not applicable. The 2010 ADA Standards, PROWAG and other standards and guidelines have been incorporated into PennDOT's standards and guidelines to achieve ADA compliance.

**A. New Construction Projects.** All new construction projects that have pedestrian needs will incorporate appropriate pedestrian facilities to be accessible and usable by persons with disabilities. New construction projects for highways and bridges are generally built on new locations where construction space or other existing restrictions are rare. Project cost is not an acceptable reason to fail to construct or delay completing an ADA required improvement for accessibility compliance.

PennDOT's design development process will assess and ensure that accessibility requirements are addressed during the earliest stages possible to reduce or prevent potential conflicts with various planning, right-of-way, environmental, utilities, or other highway design related issues. Project scopes may also need expanded to meet pedestrian needs.

**B. Alteration Projects and Removing Existing Pedestrian Access Barriers.** A highway alteration project is a change to any portion of an existing facility (space, site, structure, or improvement of a pedestrian or vehicular route) located in the highway right-of-way that affects or could affect usability, access, circulation, or use of the facility. Alterations could affect the structure, grade, function and use of the roadway. Projects such as reconstruction, major rehabilitation, milling, resurfacing, widening, traffic signal installation and pedestrian signal installation all affect access, circulation or use of a facility.

As per Title II of ADA, when a facility is altered, it must be improved or upgraded to meet the latest standards. Where it is technically infeasible to meet the latest standards, access must be provided to the maximum extent possible. See Section 6.2.B.4 for additional discussion on Technically Infeasible. At a minimum, only the altered facilities are required to be improved or upgraded to current standards. It may be cost beneficial to improve unaltered facilities while construction forces are mobilized. Additional improvements may be unavoidable due to the improvement of one facility affecting the use of an adjacent facility. Coordinate with the local municipality or property owner to obtain right-of-way or temporary construction easements for altered facilities located outside of PennDOT right-of-way.

As the ADA standards or PennDOT standards change, a state-wide upgrade of all facilities is not required. Instead, it is systematically initiated by alteration projects. Meaning, if a facility was constructed to an older standard and provides access but has not been altered since construction, the facility does not need to be upgraded. For example, a curb ramp was constructed according to standards before the DWS requirement. If the curb ramp has not been altered and provides access, the curb ramp is technically compliant. Only when the curb ramp, or the pedestrian crossing, is altered must it fully meet the latest standard and in this case include the DWS. Some sidewalk alteration projects may trigger curb ramp upgrades as well.

All alteration type projects must assess pedestrian needs and must improve or upgrade altered existing facilities to the latest standards. See Section 6.6 for tools available to help assess pedestrian needs. The ADA Law, 28 CFR Part 35.151(e) - New construction or alterations provides the general direction for the placement of curb ramps: (1) Newly constructed or altered streets, roads and highways must contain curb ramps or other sloped areas at any intersection having curbs or other barriers to entry from a street level pedestrian walkway. (2) Newly constructed or altered street level pedestrian walkways must contain curb ramps or other sloped areas at intersections to streets, roads, or highways.

During alteration projects curb ramps must be installed or upgraded and must be provided at all street crossings and signalized entrances. "T" intersections may provide only one crossing of the through roadway based on pedestrian needs. Plus intersections may provide only one crossing of the through roadway in the event existing utilities, drains, severe slopes, etc…that are not in the scope of work, make providing an accessible crossing Technically Infeasible. In the rare cases where safety concerns, such as sight distance, warrant pedestrian crossing be prohibited on one or more legs of an intersection, the TE-672 should be completed, see Section 6.6. "No Pedestrian Crossing" signs are only required if crossing is prohibited.

Where existing site constraints limit the ability to fully meet the latest standards, the improvements or upgrades must be done to provide access to the maximum extent feasible within the scope or limits of the designated project. Projects altering the usability of the roadway must incorporate accessible pedestrian improvements at the same time as the alterations to the roadway are performed.

All alteration projects require the removal of the existing pedestrian access barriers, such as missing curb ramps, when they are located within the limits of work. Only in rare situations may the pedestrian access barrier remain and the location of the barrier added to the Transition Plan to be addressed at a later time. Alterations at signalized intersections must follow appropriate traffic signal policies and procedures.

**1.** Major Alteration Projects. Major alteration projects can affect access, circulation, or use of existing facilities within the existing right-of-way. These alterations can include 4R projects such as resurfacing, restoration, rehabilitation and reconstruction and other alterations such as major widening, bridge projects, interstate safety rest area / welcome center restorations and certain transportation enhancements.

**a.** Transportation Enhancements (TE) and other Federal-aid Programs. Transportation Enhancements are special projects related to ground transportation facilities that improve the quality of life in Pennsylvania. The TE program includes project categories such as Hometown Streets and other enhancements such as bicycle and pedestrian paths, streetscapes, scenic overlooks, rest areas and rehabilitation of historic transportation related buildings such as train stations.

All Federal-aid special transportation programs such as TE projects involving pedestrian accessibility must include current applicable pedestrian accessibility facilities whether or not the project is located within the public right-of-way. The 2010 ADA Standards include special guidelines for building alterations and historic preservation projects.

**b.** Highway Occupancy Permits. The need to provide new or additional pedestrian access along and across existing highways as a result of new adjacent property development must require the approval and issuance of a PennDOT Highway Occupancy Permit (HOP) to the local government or adjacent property owner. The HOP may include the requirement that ADA compliant pedestrian facilities be made a part of the permit conditions.

The permittee shall be responsible to continuously maintain the facilities including curbs, sidewalks and curb ramps so as to conform to the permit and so as not to interfere or be inconsistent with the design, maintenance, and drainage of the highway, or the safe and convenient passage of traffic upon the highway. Curb ramps are an integral part of the entire sidewalk system.

For ADA facilities in PennDOT ROW, PennDOT should complete, or verify the completed, Curb Ramp Inspection Forms (CS-4401) and approve the Technically Infeasible Forms for all ADA Curb Ramps and pedestrian facilities that are appurtenant and integral to the function and operation of driveways / local roads where they intersect the State Route. If ADA facilities are located outside PennDOT ROW and are deemed integral to the function / operation of a driveway / local road at the intersection of a State Route, the HOP applicant should prepare and submit any Technically Infeasible Forms for ADE approval.

This includes all curb ramps crossing State Routes, curb ramps crossing local roads at the intersection of State Routes, and curb ramps constructed as part of commercial / residential / industrial driveways that provide access to or from State Routes.

Pedestrian facilities that are not appurtenant and integral to the function of driveways / local roads do not require PennDOT approval or oversight. When permit plans indicate the construction of any pedestrian facilities, the following note should be included on the plans.

"CONSTRUCT ALL PROPOSED PEDESTRIAN FACILITIES ON THESE PLANS TO COMPLY WITH THE AMERICANS WITH DISABILITITES ACT, PUBLIC RIGHT-OF-WAY ACCESSIBILITY GUIDELINES (PROWAG), AND THE 2010 ADA STANDARDS."

Appropriate accessibility guidelines, construction standards and specifications or other approved construction details must be used in the preliminary and final design stages of all projects to ensure accessibility facilities are constructed where required in the project.

**2.** Minor Alteration Projects. Minor or Betterment alteration projects can affect access, circulation, or use of existing facilities within the existing right-of-way. Minor or Betterment Projects that could affect existing pedestrian access and trigger the need for installation of or upgrading of accessibility facilities are listed below.

- Milling, resurfacing, restoration, rehabilitation and reconstruction for pavement improvements and widening, intersection improvements and utility adjustments
- Roadway signalization – Placement of poles and control panels
- Pedestrian signalization – Placement of poles and control panels
- Signing – Placement of poles or posts
- Roadway lighting – Placement of poles, junction boxes and control panels
- Construction of grade separation structures – Overpasses and underpasses
- Rehabilitation or replacement of any length bridge structure
- Shoulder rebuilding and widening – Adjoining or part of a pedestrian access route
- Inlet replacement – Inlet locations affecting pedestrian routes
- Guide rail replacements – Adjoining or part of a pedestrian access route
- Fringe parking areas – Parking and pedestrian circulation
- Safety rest areas and welcome centers – Work affecting parking and pedestrian circulation
- Transportation Enhancements – Projects relating to public use of highway facilities and streetscapes

Resurfacing is an alteration that improves the vehicular paths of the roadway. It is also an alteration to pedestrian paths that cross the altered roadway; therefore the pedestrian paths must be upgraded to the latest ADA requirements. A federal court case ruled the curb ramps at the end of the altered pedestrian path must also be considered altered and must be upgraded. Source: Kinney v. Yerusalim, 9 F.3d 1067 (3d Cir. 1993), cert. denied, 511 U.S. 1033 (1994).

These minor alteration projects are general examples only and each operation must be assessed individually in relation to any existing pedestrian accessibility feature.

**3.** Non-alteration Projects. Minor or Betterment Projects that in all likelihood will not affect access, circulation, or use of existing facilities within the existing right-of-way are listed below:

- Truck escape ramps
- Guide rail removal or replacement not affecting pedestrian access routes
- Roadside slope flattening
- Pavement markings and line striping
- Shoulder rebuilding in areas not affecting pedestrian access routes
- Signal maintenance / signal head replacement
- Sign maintenance / replacement
- Roadway lighting maintenance including luminaire and bracket arm replacements
- Truck weigh stations
- Wetland replacement mitigation
- Safety hardware upgrades
- Drainage – replacement of manholes, endwalls, pipes, culverts and inlets not affecting pedestrian access routes
- Bridge painting

Normal maintenance activities are not considered alterations and do not require simultaneous improvements to pedestrian accessibility under the ADA. Maintenance activities include actions that are intended to preserve the roadway system, retard future deterioration and maintain the functional condition of the roadway without increasing the structural capacity. Maintenance activities can include seal coats, slurry seals, and other preventive maintenance items such as crack sealing / joint repair, pavement / pothole patching, shoulder repair, repair to drainage systems, emergency repairs and pipe cleaning.

**4.** Technically Infeasible. All construction must meet PennDOT's standards. For existing sites where it is technically infeasible to construct facilities fully to current PennDOT's standards, as determined by using sound engineering judgment, a "Technically Infeasible Form" documentation must be prepared. This must be submitted and approved before construction to document that access has been designed to the maximum extent feasible. The Technically Infeasible Form (similar to a design exception) must include the following:

- Project site constraints that would adversely affect installing the appropriate access feature
- Reasons why the access feature cannot be designed to the desired standards
- The design solution derived to provide access to the maximum extent feasible

Project site constraints may include but are not limited to:

- Limited right-of-way
- Existing utilities
- Existing buildings, walls or vaults
- Environmental impacts
- Historic impacts
- Safety
- Roadway profile slope

Project scope, not cost, will determine when existing site constraints justify the use of the Technically Infeasible Form. In certain situations, existing site constraints may justify the use of a design that provides access to the maximum extent feasible if removing the existing site constraints would require additional work that is not included as part of the project scope. For example, a resurfacing project may not include removal of existing site constraints in the project scope and may be justification for installing a facility that provides access to the maximum extent feasible. However, for a widening project that includes right-of-way acquisition, utility relocations and removing underground vaults as part of the project scope, these constraints will not be satisfactory justification for installing a facility that does not meet PennDOT's standards since they are part of the project scope. The existing site constraints must be evaluated on a case-by-case basis using sound engineering judgment before submitting a Technically Infeasible Form.

**a.** Technically Infeasible Scenario #1. For an overlay project, the designer suggests that an existing Type 1 curb ramp without a landing provides the maximum access possible since the curb ramp is located within limited right-of-way and is part of a narrow sidewalk. In this situation the designer is incorrect. A Type 2 curb ramp may be installed and provide full access, the Type 1 curb ramp design is not appropriate because the level of access can be improved. The Type 2 curb ramp must be installed to provide access fully meeting the standards.

**b.** Technically Infeasible Scenario #2. For an overlay project, the designer suggests that an existing Type 2 curb ramp with a ramp slope of 1V:10H (10.00%) provides the maximum access feasible after evaluating all possible design alternatives within the project scope. The existing site constraints included narrow sidewalk width and limited right-of-way. In certain situations the designer may reach the conclusion that a curb ramp cannot be improved without going beyond the project scope and may not be required to upgrade the facility. For this scenario it is important to evaluate if the facility is accessible. The 1V:10H (10.00%) curb ramp slope is greater than the maximum curb ramp slope but still provides a general accessible solution.

**c.** Technically Infeasible Scenario #3. For an overlay project, the designer suggests that an existing Type 1 diagonal curb ramp should be replaced with a Type 4A curb ramp with a slope slightly exceeding the standards due to limited sidewalk width. An evaluated alternative that included the installation of two fully compliant Type 2 curb ramps was dismissed by the designer because it required the adjustment of an existing electric box where one of the curb ramps would be placed. In this situation, utility adjustments are not part of the project scope. However the utility adjustment would not have a major impact on the project and is not suitable justification for installing a curb ramp that does not fully meet the standards. Relocating existing utilities, obtaining right-of-way, or performing other out-of-scope work in order to fully meet the standards must be evaluated on a case-by-case basis.

**d.** Technically Infeasible Scenario #4. For an off-alignment project, the designer suggests that an existing Type 1 curb ramp without a landing provides the maximum access possible due to proposed utility locations and limited right-of-way. New construction projects are held to the highest degree of PennDOT's standards since the project scope provides the greatest flexibility to provide accessible facilities. In the above scenario, the site constraints listed are part of the project scope and are not valid. Additional right-of-way or alternate placement of proposed utilities will be required to meet PennDOT's standards.

The Technically Infeasible Form will be reviewed prior to construction by the District ADA Review Committee. It is recommended that the District ADA Review Committee have the following members or disciplines: Traffic, Bike/Pedestrian Coordinator, Safety, Maintenance, and Community Relations Coordinator. The District ADA Review Committee will make a recommendation for approval to the ADE of Design or delegate. Once approved by the ADE of Design or delegate, the Technically Infeasible Form will be submitted as part of the contract documents. For Design/Build projects, the Technically Infeasible Form will become part of the contract documents upon approval. The District will be responsible for maintaining a copy of all Technically Infeasible Forms. An electronic copy must be sent to the ADA Coordinator at Central Office where the data will be archived into a database.

See Chapter 6, Appendix A, *Technically Infeasible Form,* for additional information.

**C. Unaltered Existing Facilities.** As per the Title II requirements under the ADA, existing facilities and programs, even though they have not been altered, must not deny access to persons with disabilities. A range of methods are available to ensure that people who have disabilities are not denied access to public facilities and programs. In many situations, an operational solution may achieve program accessibility without the need for construction.

In fact, existing facilities do not have to be made accessible if other methods of providing access are effective. Except for the installation of curb ramps, which are specifically required for program access, structural changes are an option of last resort.

A pedestrian circulation system (sidewalks, street crossings, shared-use paths in the public right-of-way) is a facility that a local government provides for its citizens. It is the general availability of this facility to people with disabilities that must be evaluated when considering the existing pedestrian environment. Full compliance with facility standards developed for new construction and alterations may not be required to achieve access.

Facility accessibility can be thought of as providing a basic level of usability. It targets high-priority access improvements (curb ramps) that eliminate major barriers to the use of existing facilities, so that people with disabilities are not excluded from participation. Program accessibility requires careful planning to identify those efforts that will provide the greatest access to the available resources. Non-construction approaches may include alternate accessible routes, relocation of services or activities to accessible locations, or providing the service or benefit directly to the individual.

Jurisdictions should consider whether such operational solutions would be sustainable over the long term. For some rights-of-way elements, structural changes may be more economical. In an existing right-of-way that is not otherwise being altered, the minimum requirement for achieving program accessibility is the installation of curb ramps at selected locations where existing pedestrian walkways cross curbs. This work must be identified in the transition plan.

## 6.3 PROJECT TYPE EXAMPLES

**A. Maintenance Type Projects.** The following examples represent projects that include routine maintenance and repair work that generally does not impact, disturb or modify pedestrian usability. Note: Resurfacing projects are not considered routine maintenance and are not represented with the following examples.

- Repair of drainage pipes or inlets that result in a small portion of sidewalk being removed and replaced. This type of work will require only that the sidewalk be repaired in-kind and no additional installation / upgrade of sidewalk or curb ramps would be required. However this project would not be considered a maintenance type project if a significant length (equal to or greater than 30 m or 46 $m^2$ (100 ft or 500 $ft^2$)) of sidewalk is removed.

- Utility repairs or relocations that result in a small portion (less than 30 m and less than 46 $m^2$ (less than 100 ft and less than 500 $ft^2$)) of sidewalk being removed and replaced would require only repair in kind and would not trigger any new installation or upgrades to existing sidewalk or curb ramps. The placement of utilities may not decrease the accessible path width to less than 1220 mm (4 ft).

- Repair of damaged traffic barrier adjacent to sidewalk in an urban area would not require upgrade of the adjacent sidewalk or curb ramps.

- Repair of potholes, spot patching of roadway or crack sealing of roadway would not require any installation or upgrades to adjacent sidewalks or curb ramps.

- Modifications to existing traffic signals (non-structural) such as repair, replacement and maintenance of traffic signal head modules, pedestrian signal head modules, loop detectors, video detectors, microwave detectors, signal controller features, wiring, junction boxes, traffic control signage, roadway lighting or cameras would not require any installation or upgrades to adjacent sidewalks or curb ramps. However, if the modification creates a negative impact to the existing sidewalk or existing pedestrian push buttons are not accessible, improvements or upgrades must be installed.

- Re-striping or modifications to the pavement markings on a roadway would not require installation or upgrade of existing sidewalk or curb ramps. If new striping is installed to designate a crossing to curbs without curb ramps at the crossing, it will be necessary to install curb ramps.

- Spot patching or repair of existing sidewalk to correct buckling, cracking or other severely deteriorated conditions would not require installation of new or upgrade of existing sidewalk. However, as a rule of thumb, if more than 50% of a run of sidewalk is being repaired, the entire length should be upgraded to PennDOT's standards. This work may include installing or upgrading curb ramps.

- Slurry seals to correct surface friction or seal entire roadway to address cracking would not require upgrade of the curb ramps. These applications must be feathered into the curb ramp to provide a flush transition.

- Emergency repairs would not require upgrade or installation of curb ramps. Emergency repairs include interim pavement patching or thin overlays for severely distressed pavement due to a harsh winter, natural or man-made disasters.

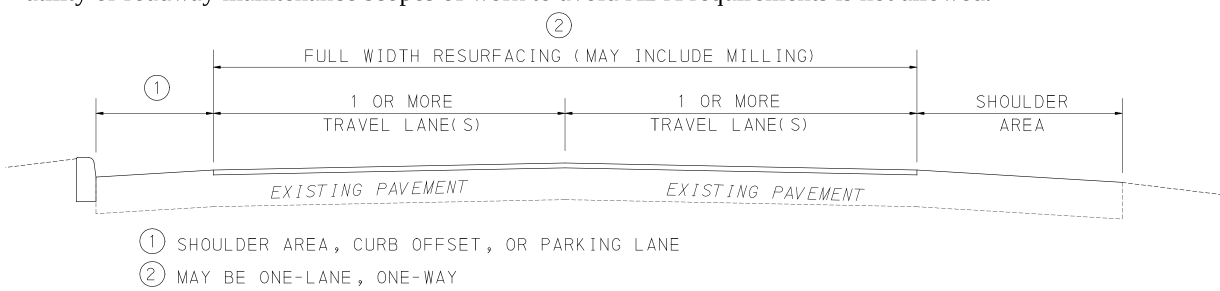
- Traffic signal timing modifications, repair or maintenance of pedestrian pushbuttons and the addition or modification of a closed loop system would not require modifications to meet PennDOT's standards.

**B. Alteration Type Projects.** The following projects include alterations that affect pedestrian usability. That is, when an existing element is replaced, it must either meet current PennDOT's standards or have an approved Technically Infeasible Form for any element that does not meet full compliance. The work does not require any additional work beyond the altered facilities; however, it may be beneficial to upgrade other unaltered pedestrian facilities as part of the project to improve access. Resurfacing is considered an alteration. Examples of Alteration Type Projects include:

- A resurfacing project, including maintenance resurfacing, affects the usability of pedestrian paths that cross the resurfacing area. This alteration project must install new curb ramps where any pedestrian route crosses a curb and upgrade existing curb ramps to the latest PennDOT standards. Provide access to pedestrian push buttons to the maximum extent feasible. The resurfacing project would not require the existing sidewalks or driveways within the limits of the project to meet PennDOT's standards since the sidewalk and driveways are not altered as part of the project.

- When utility or roadway maintenance work such as mechanized patching requires the resurfacing of the full width of the roadway and that resurfacing goes through a Pedestrian Accessible Route (PAR), it is considered an alteration and the curb ramps on both ends of the PAR must be in compliance with ADA standards to the maximum extent feasible. Full width of the roadway is defined as the outside travel lane edge to outside travel lane edge. See figure below.

  When utility or roadway maintenance work requires resurfacing of one or more travel lanes, but not the full width of the roadway, and the resurfacing does not extend the pavement lifecycle, curb ramp upgrades will not be triggered. Documentation should be put into the file indicating the pavement resurfacing schedule has not been affected due to the lane resurfacing required by the utility or roadway maintenance work. Adjusting the utility or roadway maintenance work resurfacing requirements or other utility or roadway maintenance scopes of work to avoid ADA requirements is not allowed.




- A signal project includes installing a new signal pole and push buttons on one corner of an intersection. Part of a curb ramp flare must be sawcut and removed in order to install the signal pole foundation. The installation of a signal pole is an alteration to the pedestrian push button but not an alteration to the sidewalk or street even though a small portion of the curb ramp is impacted and therefore the curb ramp does not need to be upgraded as a part of this project. If the pole is placed where it has a negative impact on the pedestrian access route, the negative impact must be addressed.

- A signal project included removing an existing signal pole, installing a new signal pole and installing push buttons on one corner of an intersection. The corner of the intersection has sidewalk but is missing a curb ramp. The installation of the pedestrian push button and signal pole is not an alteration to the sidewalk or street; however, PennDOT may not deny access to the push button and must provide access to the push button.

- Traffic signal mast arm modifications/relocations, addition/upgrade/relocation of the pedestrian detection system (push buttons, audible system, etc.), addition of a new pedestrian signal system that was not previously incorporated into the intersection, lane widening that modifies the existing pedestrian system (relocation of pedestrian poles, timing modifications, etc.) are all alterations that would require the altered facility to meet PennDOT's standards.

- A utility company decides to relocate its utility lines underground, requiring the reconstruction of a substantial length [equal to or greater than 30 m (100 ft)] of existing sidewalk. The newly constructed sidewalk will need to meet PennDOT's standards. The limits of the sidewalk to be replaced must be extended to meet logical termini. Curb ramps must be installed or upgraded and must be provided at all street crossings and signalized entrances unless a pedestrian study determines accommodations are not warranted. The limits will be determined by the Assistant District Executive (ADE of Design, ADE Services, or their designate using sound engineering judgment, considering factors such as ownership of the sidewalk, degree of impact, complexity of the solution and overall project scope. If the work disturbs 50% or more of the sidewalk width and the limit of sidewalk reconstruction is within 15 ft of a pedestrian crossing, curb ramp upgrades will be required for that corner or mid-block crossing. For projects over 300 ft, if a pedestrian crossing or curb ramp is within 5% of the total disturbed length of sidewalk, curb ramp upgrades will be required for that corner or mid-block crossing. For example, a 572 ft sidewalk disturbance would be required to extend 28.6 ft to upgrade a crosswalk or install a required crosswalk. The measurement will be from the end of disturbance to the edge of the existing (or missing) landing or ramp or crosswalk line.

- Striping (not restriping) of a crosswalk improves the pedestrian crossing and is an alteration. Alterations to the pedestrian path must also upgrade curb ramps at the crossing.

- Minor widening or geometric improvements are being made to a non-curbed section of roadway in a rural area with no evidence of existing pedestrian activity (i.e., worn dirt paths, visual observation of people walking in roadway, adjacent bus stops, adjacent pedestrian destinations such as schools or shopping centers, etc.). The project would not require the installation of new sidewalks if it is not within a designated growth area or if a pedestrian study does not support the need.

- A substantial section of sidewalk is to be reconstructed under an area-wide sidewalk contract. The entire section will be required to be replaced to PennDOT's standards. The sidewalk must extend to logical termini. As a rule of thumb, if more than 50% of a run of sidewalk is being replaced, the entire length should be upgraded to PennDOT's standards.

**C. Reconstruction and New Construction Type Projects.** The following projects are typically major projects including new construction, reconstruction, retrofit projects, sidewalk retrofit projects and community enhancement projects. These projects will be held to the highest standards regarding pedestrian usability and ADA compliance. A Technically Infeasible Form will be required for any reconstructed pedestrian facility that does not meet PennDOT's standards. Technically Infeasible justification may only be applied to New Construction in very limited circumstances. These projects must evaluate the need for pedestrian circulation paths, including PAR's between logical termini. Pedestrian needs should be evaluated in the planning phase (Pre-TIP), refined and/or reevaluated in scoping and preliminary engineering. Coordination with the local municipality is critical to this process.

- New construction or reconstruction of a curbed roadway must evaluate adding new or upgraded sidewalks and curb ramps to PennDOT's standards at all street crossings and signalized entrances.

- New construction or reconstruction of a bridge in an urban area or an area with evidence of existing pedestrian activity (i.e., worn dirt paths, visual observation of people walking in roadway, adjacent bus stops, adjacent pedestrian destinations such as schools or shopping centers, etc.) must evaluate adding new or upgraded sidewalks and curb ramps to PennDOT's standards.

- A community enhancement project must evaluate including new sidewalk or improve the existing sidewalk and curb ramps to PennDOT's standards within the project limits and extending the limits to logical termini. If aerial utilities are to be moved to support the project, they must be either relocated entirely outside of the new sidewalk or, if necessary, within the sidewalk (last resort) outside of the PAR where they will not become obstructions to ensure access for all pedestrians to the maximum extent possible.

- A park and ride lot or an expansion to an existing park and ride lot must evaluate providing or upgrading sidewalks and curb ramps that meet PennDOT's standards to access adjacent sidewalks, bus stops or transit stations. When transit loading areas are within the park and ride lot, they must meet the requirements of the proposed 2011 PROWAG.

- When it is determined through a pedestrian study that sidewalk is to be included in the project scope, the municipality will be responsible for future maintenance. A sidewalk maintenance agreement must be signed or sidewalk will not be installed or reconstructed. See Section 6.6.

- Minor widening or geometric improvements are being made at an intersection with curb, but no existing sidewalk. If a pedestrian study determines there is a need to accommodate pedestrians (i.e., local or regional plans, worn dirt paths, visual observation of people walking in roadway, adjacent bus stops, adjacent pedestrian generators and attractions such as schools or shopping centers, etc.) new sidewalk meeting PennDOT's standards should be evaluated for construction in the area of the widening and extend to logical termini. Curb ramps must also be installed or upgraded where pedestrian paths cross curbs.

- A resurfacing project includes the addition of new sidewalk within the project limits. All new sidewalk and curb ramps within the project limits must meet PennDOT's standards.

- A developer widens the roadway to provide an auxiliary lane. As a result, the existing sidewalks are impacted. The developer must replace the impacted sidewalk along their frontage, and may need to replace the remaining pedestrian facilities within the project limits to PennDOT's standards.

- A developer wants to modify their existing access onto PennDOT right-of-way. There currently is no sidewalk along the property frontage and there is evidence of existing pedestrian activity and/or existing sidewalk along the frontage of adjacent businesses. The developer must install curb ramps meeting PennDOT's standards at all street crossings and signalized entrances along the property frontage. The developer may be required to install new sidewalk along the property frontage and extend the improvements beyond the frontage to logical termini in accordance with municipal ordinance to provide pedestrian continuity and connectivity.

- New construction or reconstruction of shared use paths must meet PennDOT's standards, which includes providing curb ramps wherever a trail crosses a curb.

- Placement of a new signalized intersection or complete upgrade of an existing signalized intersection must meet PennDOT's standards.

**D. Connections to Existing Facilities.** All construction must meet PennDOT's standards. At the limits of the project or limits of construction, connections to the existing sidewalk or other facilities will be required. At these tie in locations, deviation from the standards may be necessary to match the existing facility. For example, as part of a curb ramp upgrade, a small portion of sidewalk has been reconstructed at a width equal to 1525 mm (60 in). The existing sidewalk width is equal to 915 mm (36 in) at the tie in location. In this example the sidewalk width will transition from the proposed width to the existing width. See Publication 72M, *Roadway Construction Standards*, RC-67M for Transition to Existing Sidewalk Detail. A Technically Infeasible Form is not required for transitions required to connect to existing facilities.

## 6.4 LIAISON WITH LOCAL GOVERNMENT AND PRIVATE PROPERTY OWNERS

Maintaining the proper liaison with local governments and school districts concerning the installation and funding of accessibility facilities is an important part of this policy. Local governments must be kept informed of any adjacent roadway project scope of work that entails accessibility facilities that may affect their facilities or require their participation in funding or maintenance responsibilities.

**A. Americans with Disabilities Act: Reimbursement and Maintenance for Curb Ramps with Local Municipalities.** Resurfacing projects, including overlay, wearing course resurfacing and mill and fill projects, are considered an alteration to the roadway and to any pedestrian path that is crossed. As per Title II requirements under the ADA, when a facility is altered, the facility must meet the current standards. A federal court decision (Kinney v. Yerusalim, 1993) determined the pedestrian crossing and the curb ramps are to be considered as a single unit. Therefore, when the pedestrian crossing is altered, the curb ramp is also considered altered and must be reconstructed or upgraded to meet the current standards by the entity performing the alteration. If PennDOT performs the resurfacing project or impacts the pedestrian path, PennDOT is ultimately responsible to see that all curb ramps meet the current PennDOT standards.

Coordination must be completed with the local municipality to discuss financial and maintenance responsibilities.

**1.** 100% Federal Funded Projects.
- PennDOT will not seek any reimbursement from the municipality.

**2.** 100% State Funded Projects.
- Pedestrian facilities that provide access across state routes – PennDOT will fully fund.
- Pedestrian facilities that provide access across local roads – Municipality will fully fund.
- Pedestrian facilities that provide access across both state routes and local roads – 50/50 cost sharing.

**3.** Federal State and Local Funded Projects.
- Each party will be responsible for their percentage of the total project cost.
  - See Chapter 6, Appendix B, for Charts 1-6, funding scenarios.

As per State Highway Law of 1945, local municipalities will be responsible for maintaining all structures located outside of the curb lines. A maintenance agreement will be required for all sidewalk installation and replacement projects, except projects performed under an HOP. The maintenance agreement process is to be completed in the design phase of the project, prior to advertising. Maintenance agreements will not be required for installation or replacement of curb ramps and/or level landings where such installation or replacement is done to provide ADA compliant facilities.

According to the State Highway Law of 1945, Sections 502, 513, 522 and 542, the Secretary of Transportation has determined that the Department will perform roadway maintenance between curblines and will not perform maintenance for pedestrian structures such as, but not limited to, curb, sidewalks, curb ramps and level landing areas. This includes level landings providing access to pedestrian pushbuttons. These pedestrian structures located outside of the curb lines will be maintained by municipalities. The only exceptions to this allocation of maintenance responsibilities are those set forth specifically by agreement [or for such structures on bridges maintained by the Department].

Curb ramps and level landings are portions of the sidewalk system that provide ADA compliant pedestrian accessibility across the roadway and to pedestrian pushbuttons. Curb ramps and level landings are installed pursuant to ADA requirements, not Section 670-416 of the State Highway Law.

With respect to sidewalk installation or replacement projects, if a municipality chooses not to sign the maintenance agreement, the Department can (a) cancel the project; (b) reduce the scope of work for the project, or (c) program a project in another municipality that is willing to sign the agreement. As part of the cooperation, a local government or group of local governments may choose to meet with the Department to map out long range plans.

A series of coordination letters and a reimbursement and maintenance agreement has been developed to expedite coordination with municipalities (See Chapter 6, Appendix C). The municipality has several methods of reimbursement:

**1.** The municipality must make payment to the Commonwealth in full within thirty (30) days of receipt of such invoice.

**2.** The municipality, after receipt of such invoice, must make monthly payments to the Commonwealth for a period of one (1) year. The payments must be in equal amounts and total all costs.

**3.** The municipality must make payment to the Commonwealth in full after receiving the necessary funds from a Pennsylvania Infrastructure Bank (PIB) loan. The municipality must make payment to the Commonwealth in full within thirty (30) days of receipt of such loan, which must be no longer than sixty (60) days after completion of the Project.

**4.** The municipality authorizes the Commonwealth to withhold and apply a portion of the municipality's Liquid Fuels Tax Fund allocation as necessary to reimburse the Commonwealth in full for all costs.

Should municipalities choose not to participate in funding their curb ramps, the Department will adjust the project limits of work. The Department will address curb ramps along state routes only and adjust milling and resurfacing operations to follow along the face of curb thereby not impacting the curb ramps along the local roads. In some cases it will be necessary to upgrade the curb ramps along the local road in order to correctly upgrade the curb ramps along the state route. If the municipality chooses not to participate in funding curb ramps, the Department will fund the local curb ramps in order to comply with ADA regulations.

**B. Installing Curb Ramps Located Outside of the Public Right-of-Way.** The acquisition of right-of-way for the construction of curb ramps is dependent on the scope of work for the project. If the project scope includes right-of-way acquisition, then right-of-way must be acquired where applicable for curb ramp construction. However, if the project scope does not include right-of-way acquisition, then right-of-way will not be acquired for curb ramp installations. The following should be noted:

**1.** PennDOT typically does not have maintenance responsibility beyond the face of curb but still may have right-of-way that extends beyond the face of curb.

**2.** Municipal right-of-way is public right-of-way. Curb ramps and other pedestrian facilities may be installed or upgraded within the municipal right-of-way.

For sidewalk or curb ramp construction on private property (sidewalk area is in public use and project scope that does not include right-of-way acquisition), perform the following coordination with the property owner:

**1.** Send initial certified letter (Authorization to Enter Introduction) to the property owner explaining the scope of the project and the affect on their property. See Chapter 6, Appendix D, Attachment A. Include Form RW-397A, Authorization to Enter (Waiver of Claim).

**2.** Set up an appointment with the property owner and **PennDOT personnel** to have property owner sign off on Form RW-397A, Authorization to Enter (Waiver of Claim).

**3.** Outcome 1. Property owner signs Form RW-397A, Authorization to Enter (Waiver of Claim).
- Construct curb ramp to current standards.

**4.** Outcome 2. Property owner refuses to sign Form RW-397A, Authorization to Enter (Waiver of Claim).
- Send a second certified letter (Authorization to Enter Failure to Respond) notifying the property owner of their liability. See Chapter 6, Appendix D, Attachment B.
- Depending on available right-of-way:
  - Install new or upgrade existing curb ramp to the maximum extent feasible.
  - Do not install new or upgrade the curb ramp, and add the existing curb ramp to the ADA Transition Plan to be addressed in the future.
  - Document that authorization to enter has been denied from the property owner (with the Technically Infeasible Form).

## 6.5 PEDESTRIAN ACCESS ROUTE

The pedestrian access route (PAR) as defined by PROWAG is a continuous and unobstructed walkway within a pedestrian circulation path that provides accessibility. Pedestrian accessible routes may include parking access aisles, curb ramps, crosswalks at vehicular ways, walks, ramps, roadway shoulders, water table on bridge decks, and lifts. The following sections will discuss many of these facilities separately; however, these facilities share the common requirements of the PAR.

**A. PAR General Requirements.**

**1.** Surface Requirements. The surface must be stable and firm with a slip resistant textured finish. A standard test has not been identified for measuring slip resistance; therefore sound engineering judgment must be used in the determination.

**2.** Elevation Differences. For elevation differences located within the PAR (excluding depressed curb for curb ramps) existing changes in level up to 6.4 mm (0.25 in) in height may remain without any edge treatment. Changes in level greater than 6.5 mm (0.25 in) and less than or equal to 13 mm (0.5 in) height must be beveled with no slope greater than 1V:2H (50.00%). Changes in level greater than 13 mm (0.5 in) height must be accomplished by means of a sloped surface such as a ramp or curb ramp.

**3.** Grate Openings and Horizontal Gaps.

**a.** Expansion Joints. The use of expansion joints should be minimized and their size should be less than 13 mm (0.5 in) in width. Expansion joint material is required where the curb ramp adjoins any rigid pavement, sidewalk, curb or structure. The top of the joint filler must be flush with the adjacent concrete surface.

**b.** Inlet Grates. Inlet grates located within the pedestrian access route must have spaces no greater than 13 mm (0.5 in) wide in one direction. If gratings have elongated openings, then they must be placed so that the long dimension is perpendicular to the dominant direction of pedestrian travel.

**4.** Longitudinal Slopes. The least possible slope must be used for the PAR. The maximum desirable slope is 1V:20H (5.00%); however, when the PAR is located within the public right-of-way, including vehicular bridges, the longitudinal slope may match the adjacent roadway profile slope. It may be necessary to temporarily exceed the roadway profile when crossing driveways or providing curb ramps. Where an overpass, underpass, bridge, or similar structure is designed for pedestrian use only and the approach slope to the structure exceeds 5 percent, a ramp, elevator, limited use/limited application elevator, or platform lift shall be provided. Elevators and platform lifts shall be unlocked during the operating hours of the facility served.

**5.** Cross Slopes. Cross slopes may not exceed 1V:50H (2.00%). The cross slope of curb ramps, blended transitions, and turning spaces shall be 2 percent maximum. At pedestrian street crossings without yield or stop control and at midblock pedestrian street crossings, the cross slope shall be permitted to equal the street or highway grade. See 2011 PROWAG R304.5.3 for more information.

**6.** Unobstructed Width. Minimum unobstructed widths of 1220 mm (48 in) provide the necessary room for pedestrians using wheelchairs. This is consistent with PROWAG and exceeds the 2010 ADA Standards minimum clear widths of 915 mm (36 in). See Figure 6.1.

Note: The 2010 ADA Standards allow for a 915 mm (36 in) minimum clear width with provisions to allow an 815 mm (32 in) clear width if the obstruction (such as a street sign) is less than 610 mm (24 in). The Department's standards exceed this width. Appropriate application of the 2010 ADA Standards minimum clear width is acceptable in determining if existing facilities are accessible.

**a.** Protruding Objects. Refer to Figure 6.3. Objects projecting from walls such as signs, telephones, canopies, etc. with their leading edges between 685 mm and 2030 mm (27 in and 80 in) above the finished sidewalk must protrude no more than 100 mm (4 in) into any portion of a sidewalk (Figure 6.3(a)). Objects mounted with their leading edges located less than 685 mm (27 in) or more than 2030 mm (80 in) above the finished sidewalk may project any amount provided they do not reduce the required continuous passage along the sidewalk (Figures 6.3(a) and (b)). Free standing objects mounted on posts may overhang their mountings a maximum of 305 mm (12 in) when located between 685 mm and 2030 mm (27 in and 80 in) above the ground or finished sidewalk provided they do not reduce the required continuous passage along the sidewalk (Figures 6.3(c) and (d)). Note: The 2010 ADA Standards and PROWAG depict overhead clearance as 2030 mm (80 in); **however, refer to the *MUTCD* for traffic signal mounting requirements.**

**b.** Headroom. Guide rail, handrail or other barriers must be provided when the vertical clearance of an area along or adjoining a sidewalk or continuous passage is less than 2030 mm (80 in) high. The leading edge of such barriers must be located a maximum of 685 mm (27 in) above the finished sidewalk (Figures 6.3(a) and (c-1)).

**7.** Landing Requirements.

**a.** Size. A minimum 1220 mm × 1220 mm (48 in × 48 in) landing must be provided where pedestrians perform turning maneuvers or require resting areas. When the turning area is confined by walls, curbs or other obstructions, the landing must be 1525 mm × 1525 mm (60 in × 60 in). See Figure 6.2 for the 2010 ADA Standards wheelchair turning space requirements for confined spaces.

**b.** Slope. The surface slope of the landing must not exceed 1V:50H (2.00%) in longitudinal slope or cross slope.

**8.** Detectable Warning Surfaces (DWS). The PAR must also have a standardized detectable warning surface comprised of truncated domes as detailed in Publication 72M, *Roadway Construction Standards*, RC-67M. For pedestrians with vision impairments, detectable warnings can provide a confirming cue of the street edge. Normally the DWS is installed as part of a curb ramp; however, a DWS must be installed where the PAR crosses streets, alleys or railroads. Detectable warning surfaces should not be provided at crossings of residential driveways since the pedestrian right-of-way continues across residential driveway aprons. However, where commercial driveways are provided with yield or stop control, detectable warning surfaces should be provided at the junction between the pedestrian route and the vehicular route. DWS must be bid as "either/or" items. The contractor can choose from any of the product types listed in Publication 35, *Approved Construction Materials* (Bulletin 15). Requests to use a specific type must be approved by the Bureau of Project Delivery, Highway Delivery Division, Project Schedules, Specifications and Constructability Section.

**a.** Contrast. Many colors are available for the DWS. It is recommended that the color selection is coordinated with in-place DWS. The DWS must contrast light-on-dark or dark-on-light. Currently a standard test has not been defined to measure the contrast; therefore, contrast must be determined using sound engineering judgment.

**b.** Dome Arrangement. The domes must be aligned in parallel and perpendicular rows and columns in relation to the edge of the tile or unit. This dome arrangement allows the truncated domes to be installed in the direction of the PAR, path of the wheelchair travel and perpendicular to the grade break at the toe of the ramp or curb ramp. This will provide pedestrians using wheelchairs the ability to maneuver between the domes rather than travelling over them. Older versions of the truncated domes are arranged in diagonal rows in relation to the edge of the tile or unit. This older configuration is still detectable as a warning surface for existing in-place applications, but should not be used for future construction.

**c.** DWS in Roadway Shoulders. Roadway shoulders are designed and constructed to support the roadway and, as a general rule, are not constructed as a PAR and are not required to comply with ADA requirements. DWS should not be installed in the shoulder. At intersections without sidewalks, connecting trails, or other accessible pedestrian circulation paths systems, marked or unmarked crosswalks to shoulders do not require DWS in the shoulder. In the rare case the shoulder is intended to be a PAR, it should be constructed with a 2% cross slope and DWS will be required in the shoulder at crosswalks. Central Office ADA Coordinator approval is required for construction of shoulders as a PAR. See Section 6.5.B.4.

**d.** Pedestrian Pushbutton Access. Ramps and level landings to access pedestrian pushbuttons, located behind the shoulder, will still have DWS. DWS should be placed in the ramp or level landing, outside the shoulder, at the back edge of the shoulder. Intersection raised islands that intersect a crosswalk are considered barriers to access and require curb ramps and DWS.

**e.** At cut-through pedestrian refuge islands, detectable warning surfaces shall be placed at the edges of the pedestrian island and shall be separated by a 610 mm (2.0 ft) minimum length of surface without detectable warnings. Detectable warning surfaces are not required at pedestrian refuge islands that are cut-through at street level and are less than 6.0 ft in length in the direction of pedestrian travel. Where a cut-through pedestrian refuge island is less than 6.0 ft in length and the pedestrian street crossing is signalized, the signal should be timed for a complete crossing of the street.

## B. PAR Miscellaneous Requirements.

**1.** Algebraic Grade Difference. The algebraic grade difference between any two surfaces, such as the road surface and curb ramp, must not exceed 13.33%. Where the algebraic grade difference exceeds 13.33%, a 610 mm (24 in) transition strip must be used to create a more gradual change in grade. Transition strip slope must not exceed 1V:20H (5.00%). See Publication 72M, *Roadway Construction Standards*, RC-67M for details.

**2.** Driveway Aprons. This information will supplement the information presented in Chapter 7, Driveways. Excessive cross slope on driveway aprons can be a significant barrier for pedestrian use. A level area with minimal cross slope is necessary for accessible passage across a driveway. Driveway aprons that are constructed like ramps, with steep, short side flares, can render a section of sidewalk impassable, especially when encountered in series, as in residential neighborhoods. Compound cross slopes, such as those that occur at the flares of a driveway apron or curb ramp, may cause tipping and falling if one wheel of a wheelchair loses contact with the ground or the tip of a walker or crutch cannot rest on a level area. Even with narrow sidewalks along the curb, it is possible to design a sidewalk to pass across the driveway apron without exceeding a cross slope limitation of 1V:50H (2.00%). Sidewalks that cross multiple driveways that are close together can create a rollercoaster effect as the sidewalk ramps up and down to cross the driveways. Consider keeping the top of sidewalk at driveway elevation until all driveways have been crossed. Another option is to use a reduced height sidewalk between driveways while trying to keep the ramp slopes under 5%, with 8.33% as a maximum. See Chapter 7, Driveways.

**3.** Utilities. Existing utilities, such as electric boxes, manholes, inlets, fire hydrants and electric poles, may remain in the PAR given the utility meets the previously mentioned requirements. Proposed utilities should be placed outside of the PAR where feasible or at a minimum where they do not obstruct the PAR.

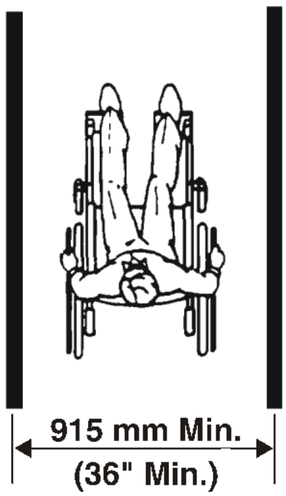
**4.** Roadway shoulders and the water table on bridge decks are not constructed to be pedestrian facilities and are therefore not required to comply with ADA requirements, although pedestrians are permitted to use them. Roadway shoulders and water tables on bridge decks should be constructed according to current design standards. If pedestrian needs are such that sidewalks are warranted along the corridor, but cannot be constructed; construct the shoulders according to current standards and, if practical, grade the area adjacent to the shoulder to facilitate future sidewalk installation. In the rare case pedestrian needs warrant construction of shoulders at 2%, Central Office ADA Coordinator approval is required. An executive summary of the pedestrian study and plans needed to give a corridor overview should be submitted with the approval request.

**5.** When replacing an existing bridge that has sidewalk, and there is no sidewalk on either approach to the bridge, the new bridge may not require sidewalk. The pedestrian study should check to see if there are future plans for sidewalk on the bridge approaches. If both approaches do not have sidewalk and there are no future plans for sidewalks on both approaches, then most likely sidewalk would not be warranted. The new bridge shoulders should be constructed according to current design standards, unless the bridge shoulders provide connectivity between two existing PAR's.

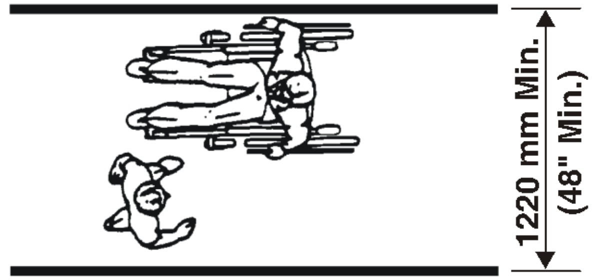
**6.** On July 26, 2011 the U.S. Access Board released for public comment proposed guidelines for accessible public rights-of-way. The guidelines provide design criteria for public streets and sidewalks, including pedestrian access routes, street crossings, curb ramps and blended transitions, on-street parking, street furniture, and other elements. The specifications comprehensively address access that accommodates all types of disabilities, including mobility and vision impairments, while taking into account conditions and constraints that may impact compliance, such as space limitations and terrain, as indicated in an overview of the rule. The 2011 proposed guidelines, or PROWAG, can be found here: www.access-board.gov/prowac/nprm.pdf.

**7.** Shared Use Paths are designed for both transportation and recreation purposes and are used by pedestrians, bicyclists, skaters, equestrians, and other users. The U.S. Access Board is currently in the process of developing guidelines for Shared Use Paths. Shared use path design is similar to roadway design but on a smaller scale and for lower speeds. Whether located within a highway right-of-way, provided along a riverbank, or established over natural terrain within an independent right-of-way, shared use paths differ from sidewalks and trails in that they are primarily designed for bicyclists and others for transportation purposes such as commuting to work.

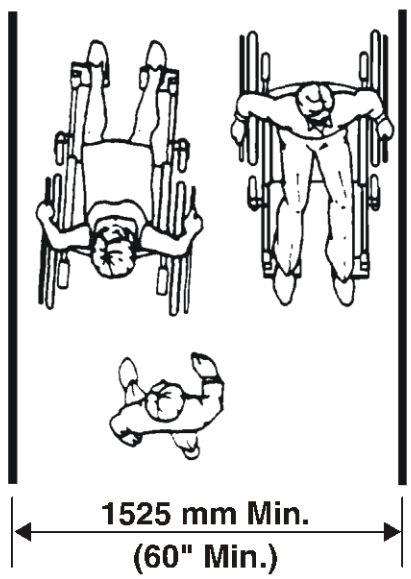
The Advanced Notice of Proposed Rulemaking (ANPRM) for Shared Use Paths, published on March 28, 2011, can be found at: www.access-board.gov/sup/anprm.pdf.




**(a)**
**Minimum Clear Width for Single Wheelchair**




**(b)**
**Minimum Passage Width for One Wheelchair and One Ambulatory Person**




**(c)**
**Minimum Clear Width for Two Wheelchairs**

*The 2010 ADA Standards **minimum clear width does not equate to sidewalk width.** Sidewalk widths must be 1525 mm (60 in) minimum. The sidewalk width may be reduced to 1220 mm (48 in) if 1525 mm × 1525 mm (60 in × 60 in) passing areas are provided every 61 m (200 ft). Consider pedestrian volume in determining required sidewalk width. Minimum accessible path must be 1220 mm (48 in) minimum. These widths exceed the 2010 ADA Standards minimum clear width of 915 mm (36 in) for a single wheel chair due to the probability of multiple pedestrians.

**FIGURE 6.1**
**Minimum Clear Width Dimensions**

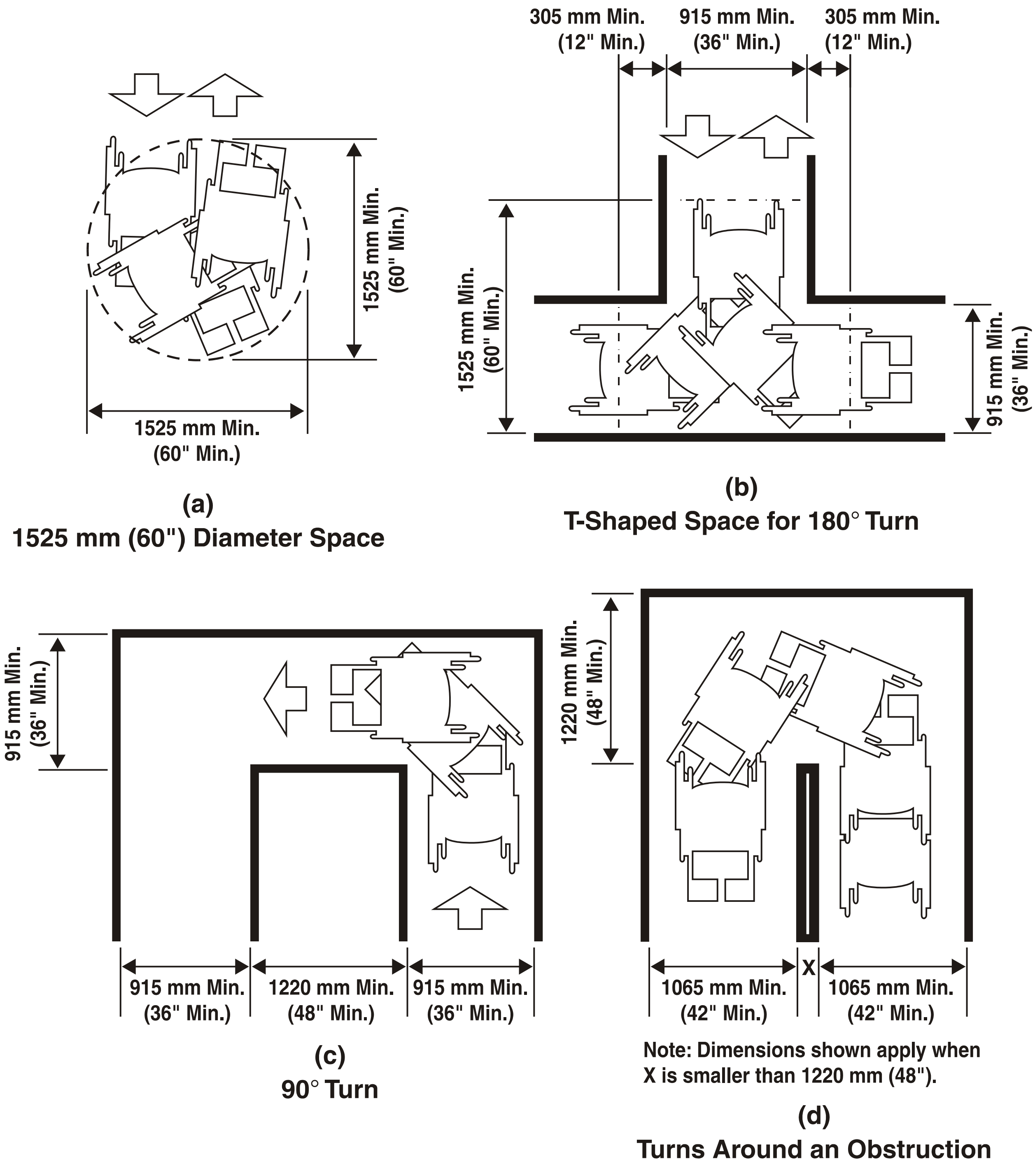
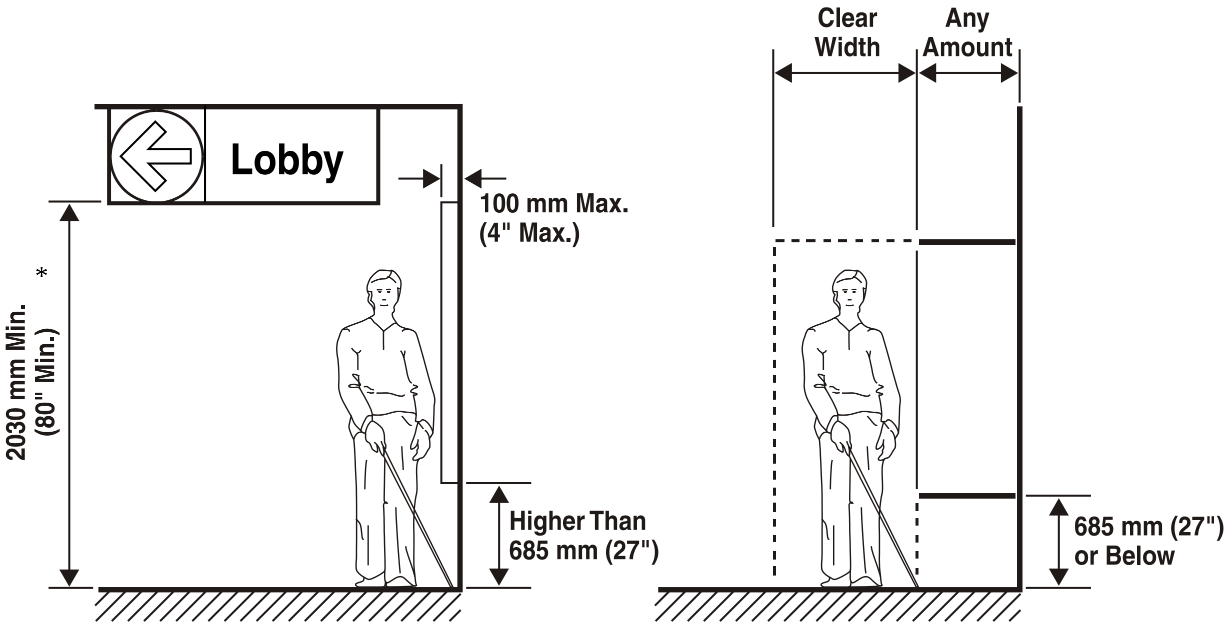


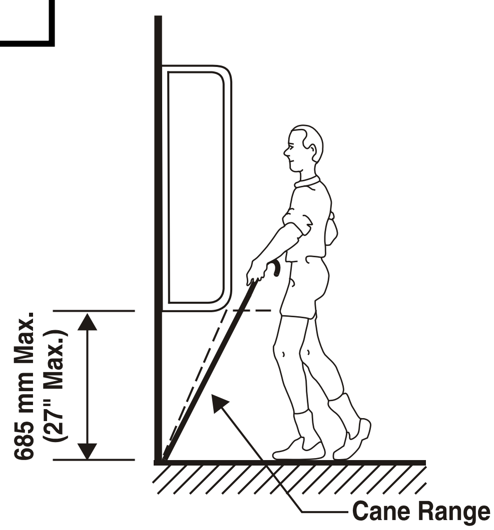

**FIGURE 6.2**

**Wheelchair Turning Space**




**(a)**
**Walking Parallel to a Wall**

*Refer to the *MUTCD* when placing traffic signals.




**(b)**
**Walking Perpendicular to a Wall**

## FIGURE 6.3
## Protruding Objects

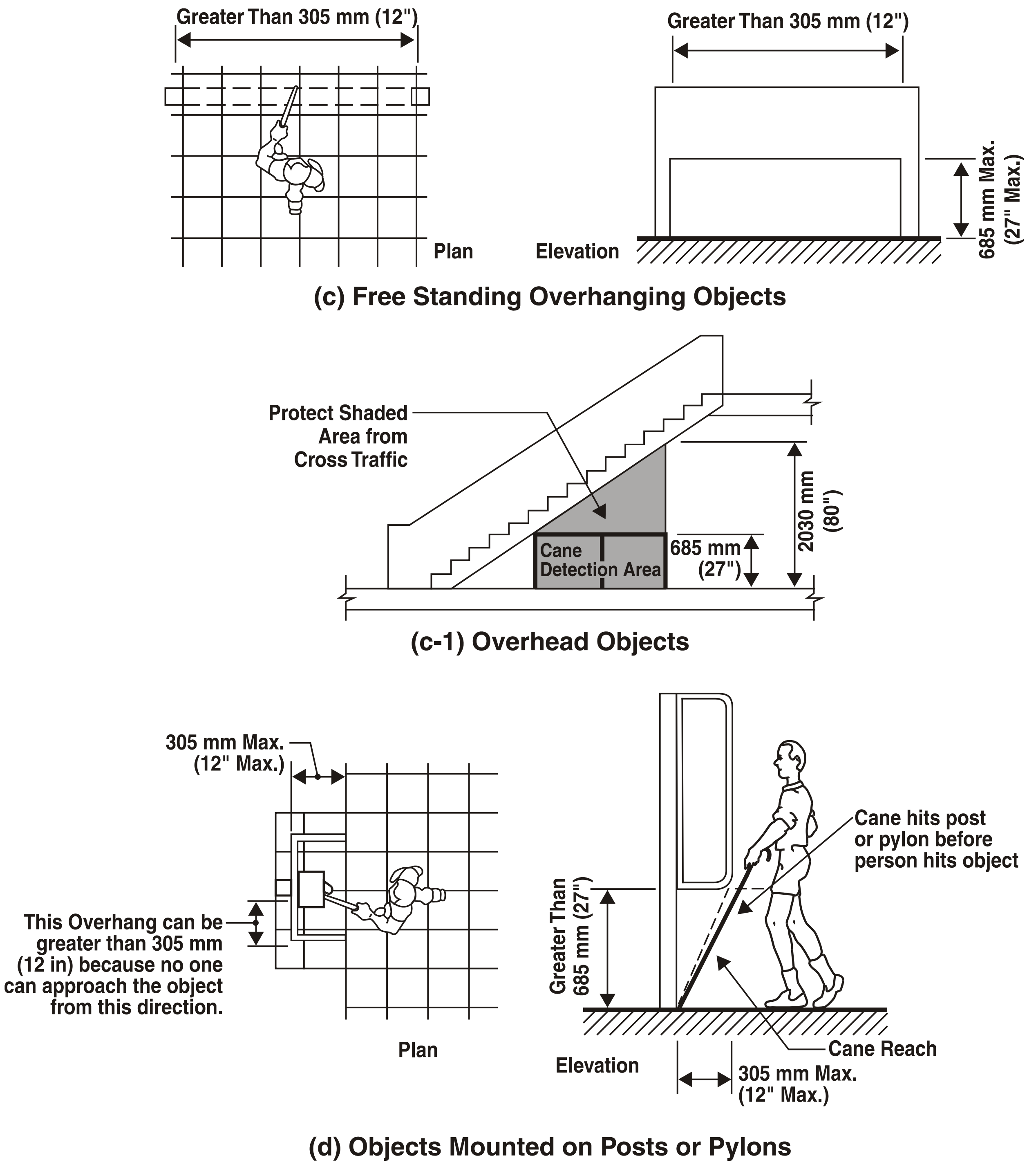



**FIGURE 6.3 (Continued)**

## Protruding Objects

**8.** On June 20, 2007, the Access Board issued a Notice of Proposed Rulemaking (NPRM) to establish accessibility guidelines pursuant to the Architectural Barriers Act (ABA) for camping facilities, picnic facilities, viewing areas, outdoor recreation access routes, trails, and beach access routes that are constructed or altered by or on behalf of the Federal government. The latest version of The Draft Final Accessibility Guidelines for Outdoor Areas can be found at: www.access-board.gov/outdoor/draft-final.pdf.

## 6.6 SIDEWALKS

Sidewalks are an essential part of the urban street cross section. In rural and suburban areas, community development such as schools, local businesses, industrial plants and recreation areas may result in pedestrian concentrations that make sidewalks a necessity. In many cases, the absence of roadway lighting and higher traffic speeds in rural areas increases the potential for vehicle and pedestrian conflicts.

In general, wherever roadside and land development conditions affect regular pedestrian movement along a highway, sidewalks should be considered. As a general practice, sidewalks should be constructed along any roadway without shoulders where there is a need to provide pedestrian accommodation. Where sidewalks are built along a high-speed highway, buffer areas should be established to separate pedestrians from the travel way.

The following policy on sidewalks is consistent with the Smart Transportation theme to consider all highway corridor modes.

The Department may construct new sidewalks when pedestrian needs have been evaluated and the needs of pedestrians have been determined as follows:

**1.** A sidewalk has been programmed as a project or project component through the Transportation Improvement Program (TIP) process.

**2.** A municipality requests the inclusion of sidewalks to be installed as part of the programmed (post TIP) Department project. The municipality has agreed to fund the sidewalk construction and any additional right-of-way costs.

**3.** The Department may replace sidewalks when an existing sidewalk is removed, relocated or altered, as a result of the Department project.

**4.** The need to accommodate critical pedestrian safety needs has been identified within the limits of a Department project. (i.e., Pedestrians are forced to walk in traffic lanes between pedestrian generators with an existing or potential crash history.)

In all of the above scenarios, the municipality is responsible for future sidewalk maintenance. A maintenance agreement must be executed or ordinances clarifying maintenance responsibilities must be in place. If a municipality refuses to accept ownership and maintenance responsibilities for a proposed sidewalk, then that sidewalk should be deleted from the scope of work. If practical, grade the area adjacent to the shoulder to facilitate future sidewalk installation. Roadway shoulders and the water table on bridge decks are not constructed to be pedestrian facilities and are therefore not required to comply with ADA requirements, although pedestrians are permitted to use them. Roadway shoulders and water tables on bridge decks should be constructed according to current design standards.

Should the need for sidewalks be identified in the scoping process and the municipality is unwilling to participate in funding and/or maintenance responsibilities, the design and construction of the project should consider features that do not preclude future sidewalk installations. Topographical limitations and funding availability must be considered in this evaluation.

There are several tools available to analyze pedestrian needs:

**1.** Pedestrian Study Determination - Chapter 6, Appendix E

**2.** Bike/Pedestrian Checklist - Publication 10X, Design Manual, Part 1X, *Appendices to Design Manuals 1, 1A, 1B, and 1C*, Appendix S.

**3.** TE-672 Pedestrian Accommodation at Intersections Checklist, see the following link:
ftp.dot.state.pa.us/public/PubsForms/Forms/TE-672.pdf

**4.** Local and Regional Planning Documents

**A. Agreements.**

**1.** Establish an agreement between jurisdictional and contributing entities (Department, municipality, developer, project sponsor, etc.) on the cost sharing responsibilities for sidewalks that address the following conditions:

**a.** A reimbursement agreement clarifies the cost to be borne by the contributing entities of the total sidewalk, curbing and incidental construction costs.

**b.** A reimbursement agreement clarifies the right-of-way acquisition and costs, and utility relocations, adjustments and cost to facilitate the sidewalk.

**c.** A reimbursement agreement is required when Federal and/or State funds in combination with local matching funds are used for a project.

**2.** An agreement is not necessary if the above responsibilities are addressed through the issuance of a Highway Occupancy Permit (HOP).

**B. Funding.**

**1.** It is Department policy not to use State funds for sidewalk construction. At the discretion of the Department, State funds may be used for a limited number of applications as described below:

**a.** ADA compliance for alterations as defined in Americans with Disabilities Act policy and design guidance in this Manual.

**b.** The construction of new sidewalks to accommodate critical pedestrian safety needs that have been identified within the limits of a Department project.

**c.** To replace sidewalk where an existing sidewalk is removed, relocated or altered as the result of a Department project.

**2**. For sidewalks within public right-of-way:

**a.** Federal funds with local matching funds may be used for construction within public right-of-way when a pedestrian need is identified.

**b.** State funds may be used for construction within the public right-of-way for those applications noted in Section 6.6.B.1.

**3.** For sidewalks outside existing public right-of-way:

**a.** Federal funds may be used on sidewalk outside public right-of-way if the sidewalk will be constructed as part of a Transportation Enhancement (TE) or Federal Safe Routes to School (SRTS) project.

**b.** Federal funds with local matching funds when applicable may be used on a right-of-way purchase required for sidewalk construction including ADA accommodations, to remediate a critical pedestrian safety need, to replace an existing sidewalk, or for new sidewalk installations. The project scope includes right-of-way acquisition.

**c.** Federal funds and/or State funds may be used on private property, when replacing an existing curb ramp or when an "Authorization to Enter (Waiver of Claim)" is in place.

**d.** State funds may be used on a right-of-way purchase to construct those applications as noted in Section 6.6.B.1.

**C. Sidewalk Maintenance.** Sidewalk maintenance is the responsibility of the municipality. The municipality may use its maintenance forces or require abutting landowners to maintain the sidewalk through municipal ordinances. Refer to the following for further guidance:

**1.** A maintenance agreement, generally between the municipality and the Department or municipal ordinances clarifying maintenance responsibilities, is required for a sidewalk on public right-of-way.

**2.** A maintenance agreement is required for a sidewalk on private property where local ordinances do not stipulate maintenance responsibilities.

**D. Additional Support Information.**

**1.** The Federal requirement for consideration of pedestrian need is provided in the Safe, Accessible, Flexible, Efficient Transportation Equity Act - a Legacy for Users (SAFETEA-LU) of 2005. Based on SAFETEA-LU, Federal funds may be used to construct sidewalks. Independent pedestrian-based projects are often funded through Transportation Enhancement, Hometown Streets, or Safe Routes to School projects. Furthermore, the Department's Smart Transportation Policy, Pennsylvania's Mobility Plan, the Statewide Bicycle and Pedestrian Plan and Context Sensitive Solutions, all strongly advocate enhanced pedestrian access and mobility.

**2.** The Department's legal authority to construct sidewalks emanates in part from the Highway Act of 1945; and Act 120.

**3.** Financing the cost of a new sidewalk to meet a critical pedestrian safety need may derive from different sources, including but not limited to the Surface Transportation Program (STP), TE, SRTS, Highway Safety Improvement Program (HSIP) funds, State funds, Act 44 funds, County funds, Bridge Bill funds, and Capital funds.

**E. Highway Occupancy Permit.** New development along existing highways may increase pedestrian traffic to the point that it is desirable to construct curbs and sidewalks. In this situation, the property owner or the local government may request a highway occupancy permit (HOP) to construct a curb and sidewalk within the Department's right-of-way. The permit should be prepared in accordance with the Department's "Highway Occupancy Permit Manual" and will be reviewed to ensure that the development plans identify appropriate curb ramp locations or other ADA accessibility requirements. The request to construct curbs on any State highway where curbs do not presently exist must be reviewed by the responsible PennDOT District Office to determine the effects of the curb on safety, capacity, drainage, and pedestrian access.

**F. General Information.** The Department should first attempt to enter into a maintenance agreement. However, sidewalks may be constructed by the Department on bridges or through tunnels with no abutting property ownership with whom to attach maintenance responsibility. In these rare cases, the Department may accept maintenance responsibility.

On projects where the Department's work requires the replacement of curbs and the sidewalk is not disturbed, the Department must replace the area of sidewalk needed to provide for curb ramp accessibility.

When the existing sidewalk width is equal to or greater than 1525 mm (60 in), the preferred width of new sidewalk connecting to existing sidewalk will equal the width of the existing sidewalk. When the existing sidewalk width is less than 1525 mm (60 in), the width and cross slope must be transitioned as indicated in Publication 72M, *Roadway*

*Construction Standards*, RC-67M. The approximate limits of sidewalk removal and replacement will be determined by the cross slope transition and the width transition, where the longest transition length controls.

Where sidewalk is to be replaced to a building line, the floor elevations and entrances will control the grade. Drainage flow must be away from the building at all points on the sidewalk.

Installing barriers such as railings, curbs, or walls along the edge of the sidewalk should be considered when adjacent ground surfaces abruptly fall away from the sidewalk elevation.

## 6.7 SIDEWALK DESIGN CRITERIA

Sidewalks must meet the following criteria:

**1.** See PAR requirements in Section 6.5.

**2.** Minimum sidewalk width of 1525 mm (60 in). The sidewalk width may be reduced to 1220 mm (48 in) if 1525 mm × 1525 mm (60 in × 60 in) passing areas are provided every 61 m (200 ft). Consider pedestrian volume in determining required sidewalk width. Minimum accessible path width may not be less than 1220 mm (48 in). These widths exceed the 2010 ADA Standards minimum clear width of 915 mm (36 in) for a single wheelchair due to the probability of multiple pedestrians. See Figure 6.1 for the 2010 ADA Standards minimum clear width dimensions associated with wheelchair accessibility.

**3.** Handrails are not required on sidewalks.

**4.** Sidewalks must be separated from vehicular travel lanes by curbs, planting strips or other barriers which will be continuous except where interrupted by driveways, alleys or connections to accessible elements.

## 6.8 PEDESTRIAN GRADE SEPARATION FACILITIES

**A. Physical Separation.** The physical separation of pedestrian and vehicular traffic and their associated control measures vary and depend largely on the following factors for consideration:

**1.** Pedestrian-generating sources in the area
**2.** Pedestrian crossing volumes
**3.** Vehicular traffic volumes to be crossed
**4.** Type of highway and number of lanes to be crossed
**5.** Location of nearest crossing facility
**6.** Number of vehicles turning at intersections

The intersection of pedestrians' access routes and vehicles may sometimes present serious problems, especially where arterial streets traverse a business district and there are intersections with high-volume cross streets. In extreme cases, grade separations for pedestrians provide the only satisfactory solution. Although separations for pedestrians are justified in some instances, at-grade crosswalks will remain the predominant form of crossing. Conflict is minimized if the crosswalks are properly placed, designed, maintained and operated. The use of other physical barriers such as median barriers, guide rail, refuge islands and fencing should also be studied to protect pedestrians at crossing locations.

In most cases, the use of a pedestrian overpass will be more acceptable than an underpass since pedestrians are more reluctant to use an underpass due to other safety considerations.

The aesthetic and economical design of pedestrian grade separation facilities should be encouraged and can best be accomplished by recognizing the need for pedestrian grade separation in the planning and preliminary design stages. This permits maximum latitude in site selection and grade line adjustments between the pedestrian grade separation facility and the highway.

**B. Access.** All pedestrian grade separation facilities must meet the following minimum accessibility criteria:

**1.** Access Provisions.

**a.** See PAR General Requirements in Section 6.5 for additional requirements unless noted otherwise below.

**b.** Provide pedestrian sidewalks and ramps at all separation structures. Where warranted and possible, a stairway can also be provided in addition to the ramp. In certain situations, access by platform lift (wheelchair lift) or elevator may be necessary. Note: Ramps are used to traverse an elevation difference at various locations such as building entrances; curb ramps are used to traverse the elevation difference of a curb. See Section 6.9 for Curb Ramp Design Considerations.

**c.** Some persons with mobility impairments may find lengthy ramps more difficult to negotiate than stairs complying with the proper design criteria. Care is necessary to avoid inadvertently creating a mobility problem for one group of people while accommodating another group.

**d.** Walkways should have a minimum 2440 mm (96 in) width.

**e.** Maximum slopes of adjoining accessible routes not to exceed a gradient of 1V:20H (5.00%).

**f.** Walkways with a slope gradient greater than 1V:20H (5.00%) will be considered ramps.

**2.** Ramps and Landings.

**a.** Use flattest gradient possible. Ramp slopes between 1V:20H (5.00%) and 1V:16H (6.25%) are preferred for easier access. Wheelchair users with disabilities affecting their arms or with low stamina have serious difficulty using inclines (ramps). Many people cannot manage a 1V:12H (8.33%) slope for a 9 m (30 ft) distance. The maximum ramp slope is 1V:12H (8.33%).

**b.** Maximum length of ramps between landings is dependent on the slope and horizontal projection as indicated in Table 6.1.

**c.** Maximum rise between landings is 760 mm (30 in).

**d.** Landing width must be at least as wide as the widest ramp run approaching the landing and have a minimum clear length of 1525 mm (60 in) due to a confined turning space.

**e.** If a ramp changes direction at a landing, the minimum landing size must be 1525 mm × 1525 mm (60 in × 60 in) due to a confined turning space.

**f.** Ramps must have level landings at the bottom and top of each run.

**g.** Circular style ramps are not recommended since they normally have non-uniform cross slopes which do not permit all wheelchair wheels to be on the ground at the same time. The lack of level landings also does not permit any resting areas for people with limited stamina.

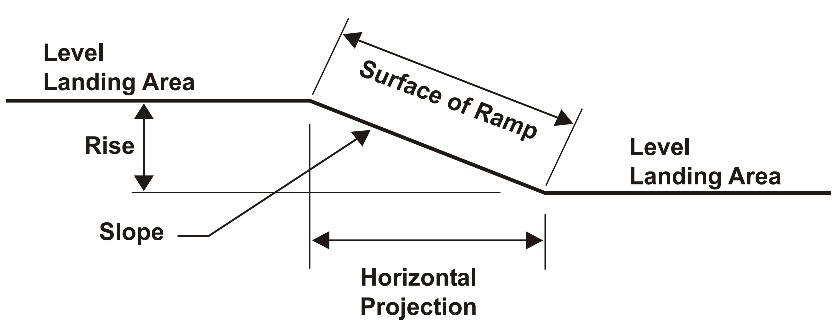


**TABLE 6.1**
**RAMPS BETWEEN LANDING AREAS**

| TYPICAL RAMP DIMENSIONAL ELEMENTS BETWEEN LANDING AREAS | | |
|---|---|---|
| **SLOPE** | **RISE (Maximum)** | **HORIZONTAL PROJECTION (Maximum)** |
| 1V:12H < 1V:16H | 760 mm (30 in) | 9 m (30 ft) |
| 1V:16H < 1V:20H | 760 mm (30 in) | 12 m (40 ft) |

**3.** Handrails (See Figures 6.4, 6.5 and 6.6).

**a.** In addition to any protective railings, parapets or fencing, provide handrail on both sides of all stairways and ramp runs exceeding a 150 mm (6 in) rise or an 1830 mm (72 in) horizontal projection in order to provide support for balance and security in ascending or descending the structure.

**b.** Top of gripping surface for handrail must be mounted between 860 mm and 965 mm (34 in and 38 in) above the ramp surface and be parallel with the ramp or landing surface.

**c.** Where handrails are not required, provide a 50 mm (2 in) minimum height curb or other vertical guard to prevent drop off from ramp or landing.

**d.** Ends of handrail must be either rounded or returned smoothly to floor, wall or post and should not project into any walkway.

**e.** Clear space between handrail and wall surface must be a minimum of 38 mm (1.5 in).

**f.** If handrails are not continuous, they must extend at least 305 mm (12 in) beyond the top and bottom of the ramp segment.

**g.** Handrails must not rotate within their fittings.

**h.** Avoid recessed handrail locations in vertical surfaces.

**i.** Handrail materials should be capable of withstanding bending moments of at least 1112 N (250 lb) horizontal concentrated load. Fasteners and support mounts should withstand an 1112 N (250 lb) shear load and 1112 N (250 lb) tensile load.

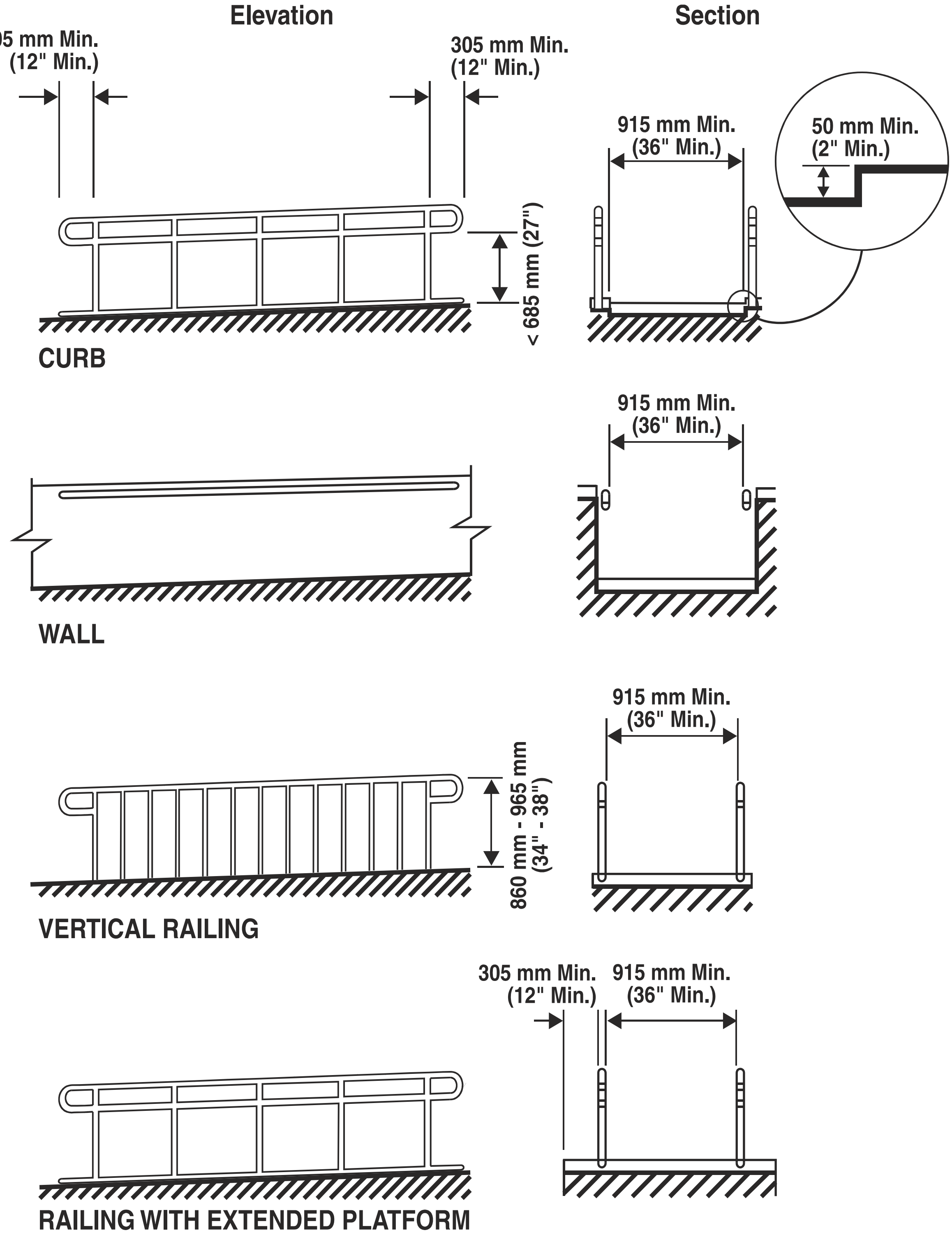
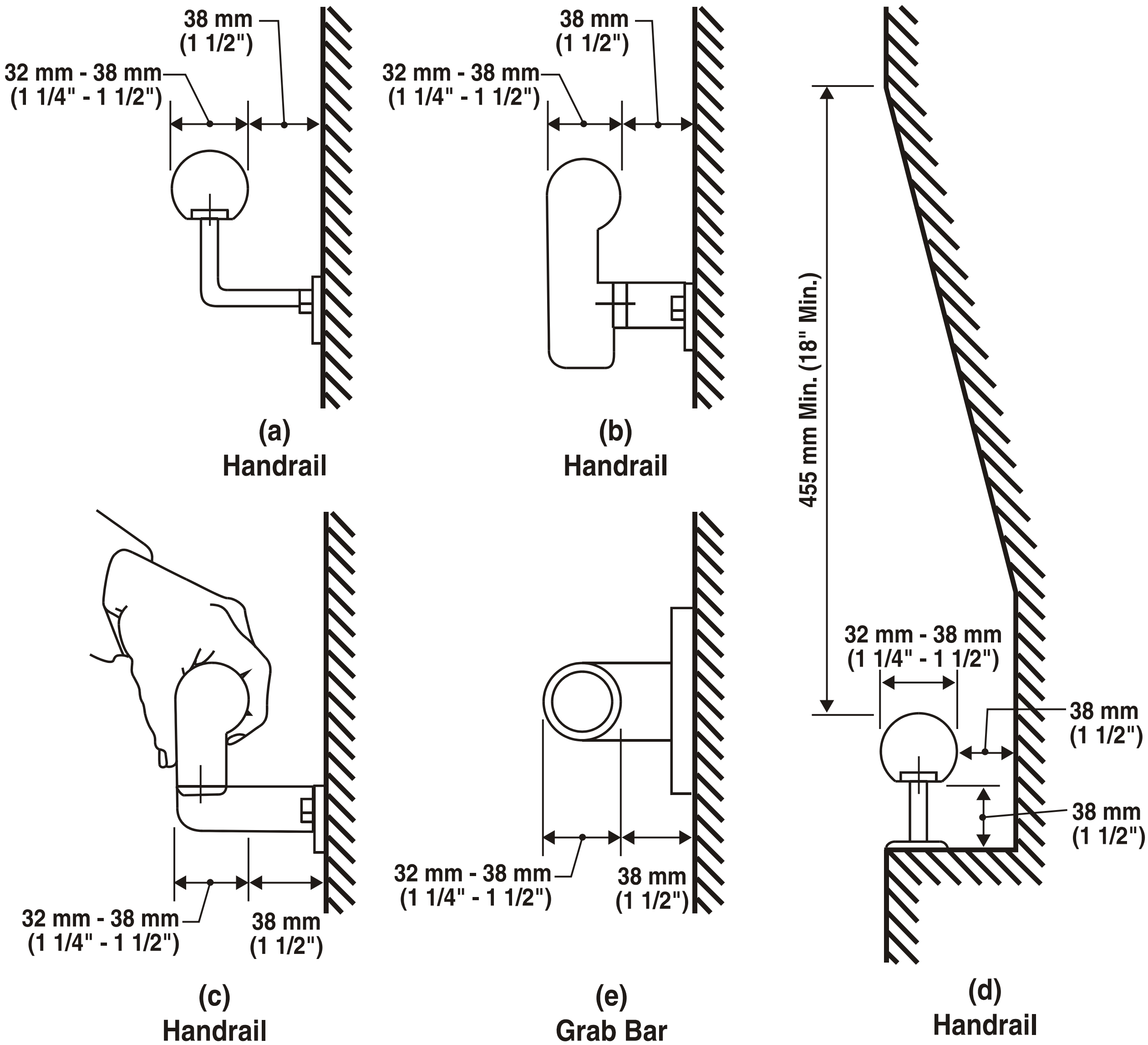
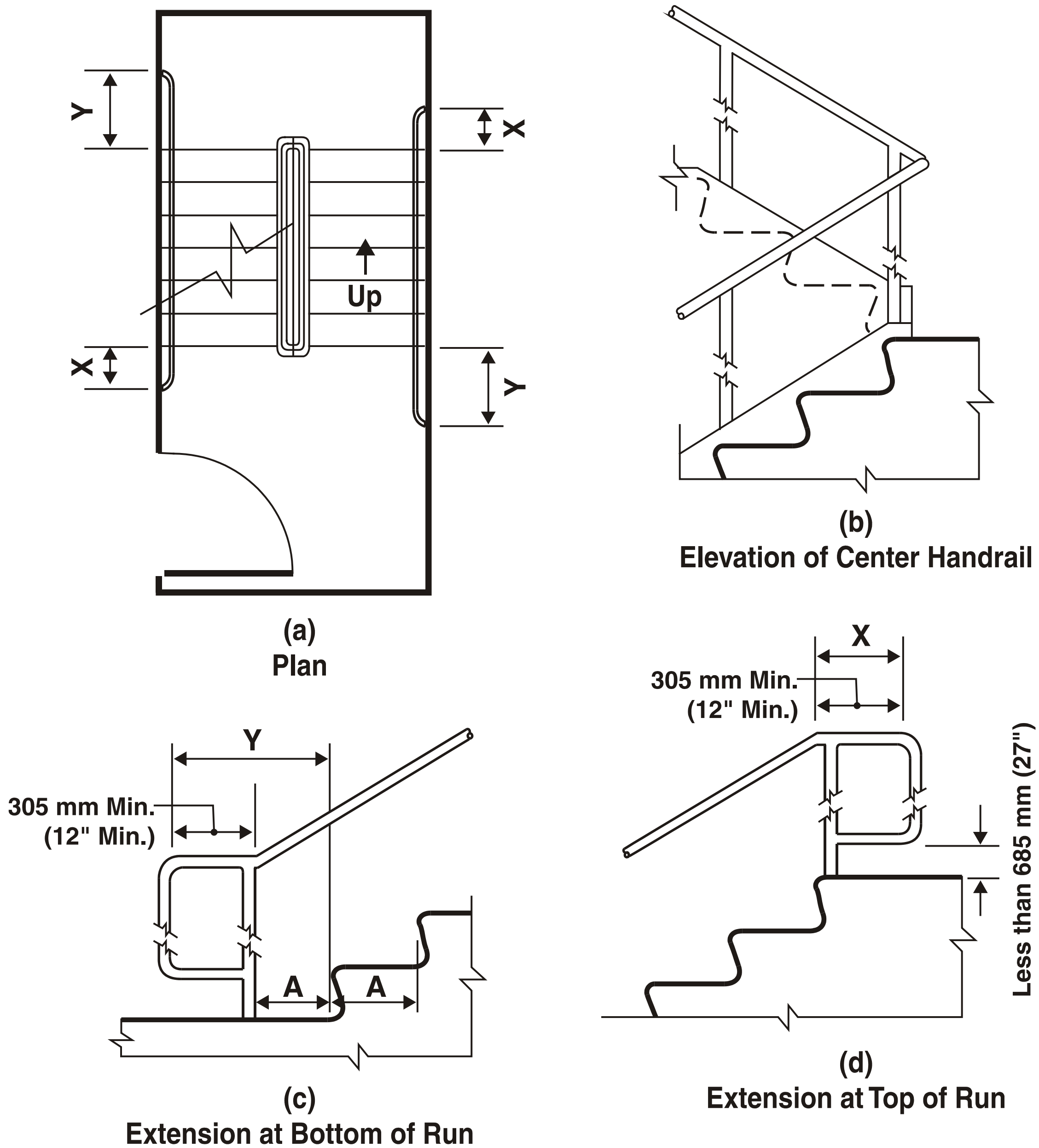



**FIGURE 6.4**

## Examples of Edge Protection and Handrail Extensions




## FIGURE 6.5
## Size and Spacing of Handrails and Grab Bars




**NOTE:**
**X is the 305 mm (12 in) minimum handrail extension required at each top riser.**
**Y is the minimum handrail extension of 305 mm (12 in) plus the width of one tread (A) that is required at each bottom riser.**

**FIGURE 6.6**
**Stair/Step Handrails**

**4.** Stairways (See Figures 6.6 and 6.7).

**a.** Maximum 180 mm (7 in) riser (R = vertical rise in millimeters (inches)), 130 mm (5 in) is preferred.

**b.** Tread (T = horizontal projection in millimeters (inches)) length designed to appropriate standard stair design formulas to achieve the needed slope as approved. Minimum tread width of 280 mm (11 in). A common stair design formula is 2R + T = 660 mm (26 in).

**c.** Use rounded tread nosing with maximum 13 mm (0.5 in) radius of curvature.

**d.** Provide landing for every 1525 mm to 1830 mm (60 in to 72 in) change in elevation and if possible avoid using over 10 steps or less than three steps per flight.

**e.** Provide handrail along both sides of the stairway.

**f.** Winding the stairway or reversing the stair direction alignment can reduce space requirements.

**g.** Pitch stairs surface so that water will not accumulate on walking surfaces. Maximum pitch is 2.00%; 1.00% pitch is recommended.

**h.** Do not use open tread steps or steps with projected nosings.

**i.** No part of a stairway should overhang a walkway at or below head height. A clear head room passageway above the walkway of 2135 mm (84 in) minimum is required.

**j.** Stairways that lead to a walkway should be setback from the edge of the stair nosing at least 585 mm (23 in) from the walkway at the bottom and at least 305 mm (12 in) at the top.

**5.** Additional Criteria. Additional design criteria for pedestrian grade separation facilities are found in the AASHTO Bridge Specifications.

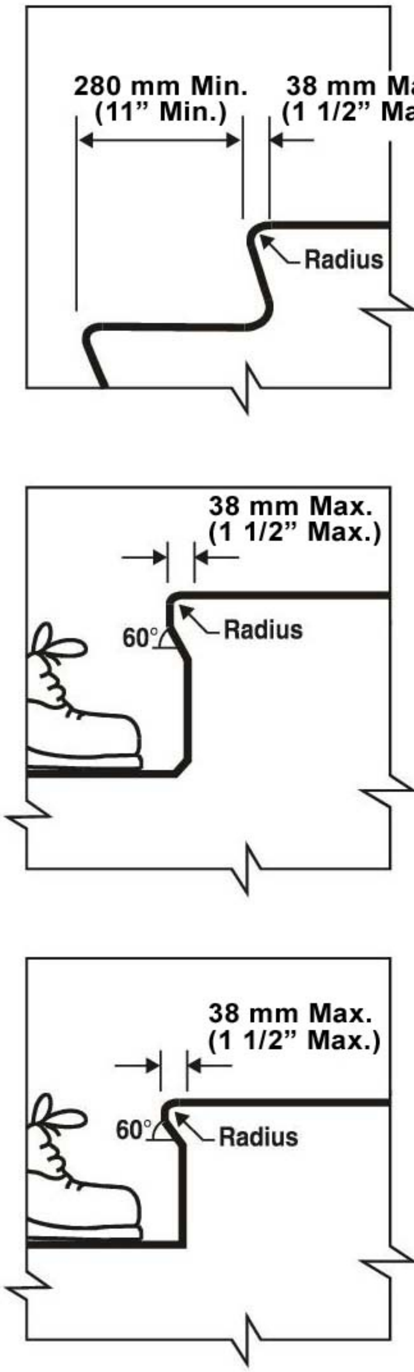
**6.** Lighting.

**a.** The installation of lighting at pedestrian grade separation structures should be carefully considered.

**b.** Stairways which have regular use should have at least shadow lighting to indicate the beginning and end and if possible the edge of each tread.

**c.** The simplest lighting approach is an overhead light placed to one side on the upper height of the stairway with the luminaires directed to shine down upon the stairway. Avoid placing landscape plant material in locations where their shadows may obscure the intended light illumination on the ramp or stairway.

**d.** An illumination guideline for ramps or stairways is to provide a minimum average of 22 lx (2.0 footcandles) of light on the intended surface.




(a)
Flush Riser

(b)
Angled Nosing

(c)
Rounded Nosing

**FIGURE 6.7**
**Usable Tread Width and Examples of Acceptable Nosings**

## 6.9 CURB RAMP DESIGN CONSIDERATIONS

**A. Existing Conditions.** Curb ramps are constructed to permit people in wheelchairs to cross a curb with ease. Design of curb ramps may vary in relation to the following existing conditions:

**1.** Sidewalk width.
**2.** Sidewalk location with respect to the back face of curb.
**3.** Height and width of curb cross section.
**4.** Design turning radius and length of curve along the curb face.
**5.** Angle of street intersection(s).
**6.** Planned or existing location of sign and signal control devices.
**7.** Stormwater inlets and public surface utilities.
**8.** Possible sight obstructions.
**9.** Street width.
**10.** Other physical obstructions such as buildings, bridges and walls.
**11.** Roadway grade.
**12.** Parking spaces.

The ADA Law, 28 CFR Part 35.151(e) - New construction or alterations provides the general direction for the placement of curb ramps: (1) Newly constructed or altered streets, roads and highways must contain curb ramps or other sloped areas at any intersection having curbs or other barriers to entry from a street level pedestrian walkway. (2) Newly constructed or altered street level pedestrian walkways must contain curb ramps or other sloped areas at intersections to streets, roads, or highways.

Resurfacing projects and "curb ramp only" projects do not typically include changes to roadway geometry, including roadway profile grade. When the roadway profile grade exceeds 2%, and profile adjustments are not in the scope of work, the depressed curb must be constructed to match the roadway profile and the curb ramp cross slope will transition to meet the roadway profile grade as gradually as possible, but not to exceed a rate of change of 3% per LF. In normal crown sections, stormwater flow must be maintained along the curb line and the roadway should not be adjusted in any way that would alter the flow line. Transitioning the curb ramp cross slope to the roadway profile allows the pedestrian to adjust to the cross slope of the crosswalk in the safety of the area behind the curb and does not push stormwater into the vehicular path. Curb ramps and the flared sides of curb ramps shall be located so that they do not project into vehicular traffic lanes, parking spaces, or parking access aisles.

**B. General Considerations.** All curb and sidewalk areas being constructed or reconstructed in the Commonwealth must provide curb ramps for persons with physical disabilities as shown in Publication 72M, *Roadway Construction Standards*. The following must be considered in the design of curb ramps.

**1.** A curb ramp must be provided at locations that meet the criteria of the referenced ADA Law, Part 28 CFR Part 35.151(e).

**2.** All slopes are measured with respect to a level plane. The upward pitch (slope) of a road profile or sidewalk away from the curb will effectively increase the total height to be negotiated by the curb ramp.

**3.** Crosswalk markings serve primarily to guide pedestrians across roadways in the proper path and also to warn the motorist of a pedestrian crossing point.

**4.** Curb ramps should be wholly contained within marked pedestrian crosswalks (excluding flared sides for non-diagonal curb ramps) to keep crosswalk widths to a minimum and to enable ramp use to be incorporated as part of the established pedestrian control at the intersection.

**5.** Separate curb ramps to provide space for curb ramp flares and landing areas. Moving the curb ramp to the side may increase the width of the crosswalk. See Figure 6.8.

**6.** Curb ramps are not limited to intersections and marked crosswalks but should also be considered at other appropriate points of pedestrian concentration or access such as refuge medians/islands, mid-block crossings, parking areas and other traffic separation islands. At uncontrolled pedestrian crossings, a warrant analysis may be required to evaluate pedestrian needs and safety. Access may also be provided at raised median, refuge and other traffic islands by providing a level street elevation crossing cut through the island. Islands or medians to be accessed by curb ramps on each side should be wide enough to have a minimum 1220 mm (48 in) level [1V:50H (2.00%)] surface between the curb ramps.

**7.** Adequate visibility is required to ensure safe pedestrian movement. A sight distance study is recommended to ensure that curb ramps are not placed at locations where motorists cannot see the low profile of people using wheelchairs. Vehicle parking must be eliminated at least 6.0 m (20 ft) from the inside pedestrian crosswalk line at intersections. Parking may also be eliminated at midblock crossings to provide access from the curb ramp and to increase the visibility of the pedestrian. See Chapter 6, Appendix F for standard letters.

**8.** Built-up curb ramps are not permitted in new construction and their use must be carefully evaluated in any alteration work location. Built-up curb ramps should not project into any vehicular traffic lane, parking space or access aisle. Built-up curb ramps are best utilized in parking lots or locations removed from vehicular traffic or major curb drainage flows. Snow removal considerations around these ramp projections must also be evaluated when considering the use of a built-up curb ramp.

**9.** Mountable curbs are not suitable for pedestrian access unless their design conforms to the curb ramp design criteria. Plain concrete gutter should not be used where curb ramps are proposed.

**10.** Raised median islands in crossing locations should not be less than 1220 mm (48 in) deep for cut through street level access openings. To allow for attendant assisted wheelchairs, 1830 mm (72 in) is required.

**11.** Curb ramps serving adjoining crosswalks should not be located too close to each other in order to avoid excessive undulating pavement surfaces which can be uncomfortable to walk on or become unsafe for pedestrians. See Figure 6.8 for the preferred design and Figure 6.9 for the non-desirable design. This situation often occurs at intersections having a curb radius less than 4.5 m (15 ft). As a last resort a continuous, wide, diagonal curb ramp may be considered in this situation for alteration work but is not permitted in new construction. Note: Diagonal curb ramps provide less pedestrian protection from turning vehicles and require ADE of Design approval.

**12.** If a curb ramp or other ADA accessibility feature cannot be designed to the appropriate standards, then a Technically Infeasible Form must be prepared describing the existing site constraints, design alternatives evaluated and the design alternative selected to provide access to the maximum extent feasible. The form must be reviewed, approved by the ADE of Design or delegate and placed in the project design document file.

**13.** Curb ramps must be oriented in such a fashion that the grade break is approachable by a pedestrian in a wheelchair. This can be accomplished by installing the curb ramp perpendicular to the curb. This allows for a wheelchair to make contact with both wheels before experiencing a change in grade. This may cause the curb ramp to not be in alignment with the crossing direction. The curb ramp may be installed in the same direction as the crossing and not perpendicular to the curb when a triangular landing is provided. This provides non-visual cues for pedestrians with visual disabilities. The triangular landing must be approximately level [1V:50H (2.00%)]. See Figure 6.11.

**14.** Narrow sidewalks may not provide the necessary space to install perpendicular curb ramps. A different curb ramp type such a Type 2 or Type 6 curb ramp must be considered. See Figure 6.12.

**15.** Where a pedestrian circulation path crosses the curb ramp, flared sides shall be sloped 10 percent maximum, measured parallel to the curb line. The use of steeper flares is acceptable provided they are protected from pedestrian traffic. See Figure 6.13.

**16.** Excessively steep curb ramps may deny access and must be reconstructed with an appropriate slope or be replaced by a different type of curb ramp. See Figure 6.14.

**17.** Vertical drops or lips located within the PAR may cause a pedestrian to trip or deny access to a pedestrian using a wheelchair. Curbed flares must be located outside of the pedestrian access route. A non-walk surface such as grass limits the PAR and will allow the installation of a curbed flare. See Figure 6.15.

**18.** Sidewalks, curb ramps and roadway drainage features must be designed and constructed to prevent surface drainage from ponding at the bottom of the curb ramp. Edge of road elevations at the flow line must be graded to ensure positive drainage. For new construction, additional inlets may be required to prevent drainage issues. See Figure 6.16.

**19.** In all cases, the designer must attempt to design using the smallest possible corner turning radius to improve overall intersection efficiency. The use of small turning radii provides many improvements such as:

Motor vehicle traffic must slow to make a turn, making it safer for pedestrians. Less head turning is required of motor vehicle drivers because they approach the intersection at closer to right angles. Crosswalks are shorter (sometime as much as 50% shorter), which decreases pedestrian crossing time, thus decreasing pedestrian green time. This is very important to persons who use walkers, canes, or otherwise have a slower crossing speed. Longer crossing distances may intimidate them into not even using the intersection. Crosswalks are closer to the intersection, improving overall sight distance. More sidewalk space is provided for pedestrians. Curb ramps can be built perpendicular to the crosswalks, enabling persons with visual disabilities to more easily navigate the intersection. Smaller radii greatly reduce the need for diagonal curb ramps. Long wheelbase vehicles may find it more difficult to turn. However, this can be addressed by pulling back the stop bar in the receiving street. If this involves a multi-lane street, pulling back the stop bar also improves safety and reduces motor vehicle/pedestrian crashes.

**20.** Diagonal curb ramps should be avoided. They offer limited guidance to the location of the crosswalk to pedestrians with visual disabilities.

**21.** The use of sidewalk bulb-outs should be considered where applicable to reduce crosswalk length and provide needed space to install curb ramps.

**22.** People with visual impairments often have difficulty using curb ramps since the curb ramp makes locating the edge of the street more difficult and the ramps and side flare surfaces may be more difficult to walk across. See Figure 6.17. Where possible, the curb ramps should be separated as far as possible but parallel to the direct line of pedestrian movement. See Figure 6.8.

**23.** The appropriate level of detail must be provided on the plans to ensure compliant construction. See Figure 6.18 for an overview of required details.

**C. New Construction.** The guidelines presented in this Chapter will apply to new construction unless specifically noted for alteration work only.

**D. Alterations.** The following should be considered for curb ramps in alteration projects.

**1.** Designing curb ramps for alteration projects will generally be more difficult than for new construction projects because existing conditions such as buildings, walls, sidewalk gradients, right-of-way width, etc. may limit the space available to provide the required accessibility. Specific curb ramp locations should be adapted to existing site conditions.

**2.** Curb ramps may necessitate the relocation of various existing features such as street signs, mailboxes, telephone booths, newspaper dispensers or other obstacles interfering with the desired accessibility. Relocating major utility conflicts such as fire hydrants, light poles, utility poles and drainage inlets should be assessed on a case by case basis.

**3.** Although existing conditions may dictate that pedestrian crosswalks be prohibited at an intersection, this restriction could possibly change at some time in the future. Appropriate measures, such as signal pole location and placement of other utilities, should be taken to allow for future curb ramps. Curb ramp design is dependent on many factors; therefore, depressed curbs will not be installed for future curb ramp locations.

**4.** In general, when an existing space in the highway right-of-way is to be altered, each element in the space within the project scope or limits must comply with applicable requirements for new construction to the maximum extent feasible.

**5.** Alteration projects must not decrease or have the effect of decreasing the accessibility of a facility or a pedestrian circulation route below the requirements for new construction in effect at the time of the alteration. However, where the nature of the existing facility to be altered makes it technically infeasible to meet PennDOT's standards through the planned alteration, the maximum access feasible must be provided. For example, for an overlay project, an existing curb ramp must be upgraded and as a result the sidewalk must be closed. The alternate route is a sub-standard width sidewalk that cannot be expanded due to limited right-of-way. Other alternatives evaluated did not provide a greater level of access than the sub-standard width sidewalk. In this case it is technically infeasible to provide access fully meeting the standards during construction; however, access is provided to the maximum extent feasible given the situation.

**6.** An alteration of an existing facility must not impose a requirement for accessibility greater than required for new construction.

**7.** Alteration projects will not be required to expand a planned scope of work to include other items of accessibility. The scope of alteration work includes only the work included in the limits, boundaries, or scope of a planned project with no obligation to expand the scope or limits of a project to include other work or adjacent areas.

**8.** Existing project site conditions may limit accessibility design choices and should be identified early in the project scope. Depending on project scope, alteration projects may not require obtaining additional right-of-way. Alterations do not require narrowing roadway widths to comply with the design standards.

**9.** Newly issued accessibility guidelines <u>will not</u> require the need to upgrade existing accessibility facilities in the highway right-of-way at the time of the new guideline issuance if the accessibility facilities were constructed using previously approved accessibility standards. However, construction upgrades to the new standards <u>will</u> apply when the existing pedestrian route or facility is to be altered as part of a new planned project improvement to the roadway.

**10.** Alteration projects that include the installation of or relocation of telephone/utility poles, posts, street trees, fire hydrants, or other types of street furniture on or near existing pedestrian pathways will provide the required accessibility clearances designated for a pedestrian access route.

**11.** Any temporary construction activities required for alterations that affect existing pedestrian circulation paths will require the provision of a safe, alternate and accessible pedestrian route around the construction activities. The alternate route must comply with all applicable design guidelines to the maximum extent feasible so that the usability of the accessible route is maintained. The alternate route will be kept in place through the duration of the construction activity. See Section 6.14, Temporary Alternate Circulation Paths at Construction Sites.

**E. Ramp Types.** Curb ramp design criteria can be adapted to provide various configurations which may allow curb ramp installations in limited space conditions. See Figure 6.10 for adaptive curb ramp installations. Publication 72M, *Roadway Construction Standards,* RC-67M provides construction details for several curb ramp types that can be adapted to both new construction and alterations.

**1.** Type 1. The Type 1 curb ramp consists of a curb ramp and level landing for turning maneuvers at the top of the ramp. This curb ramp is ideal for locations where the existing sidewalk width is wide, provides a consistent path and allows the pedestrian to bypass the curb ramp when continuing on the sidewalk. The steeper ramp slope at the depressed curb provides better drainage than other curb ramps. The drawback of this curb ramp is the relatively wider required sidewalk width needed to install the curb ramp.

**2.** Type 2. The Type 2 curb ramp contains two ramps and a level landing at the roadway elevation. This curb ramp can be used on narrow sidewalks. Drawbacks include a flat slope at the depressed curb and pedestrians must traverse the curb ramps whether or not they desire to cross the street.

**3.** Type 3. The Type 3 curb ramp consists of a ramp that brings the street up to the top of the normal or non-depressed curb. Type 3 curb ramps can be used in situations where there is insufficient or no area available beyond the curb for other types of curb ramps. Type 3 curb ramps may not be used in locations where the ramp will project into vehicle traffic lanes, parking spaces, access aisles or interfere with curb drainage flows or snow removal operations. Type 3 curb ramps are not permitted in new construction. Negatives include pedestrians with visual disabilities may be confused by the detectable warning surface on the sidewalk and possible damage during snow removal operations.

**4.** Type 4 and Type 4A. Type 4 and Type 4A curb ramps are similar to a Type 1 curb ramp but utilize a curb or a steep flare slope that is placed outside of the path of the pedestrian. A non-walk surface or permanent barrier must deter or protect the pedestrian from crossing the unexpected vertical drop of the curb or steep flare slope. These curb ramps provide flares that may be installed where utilities limit the installation of flatter slopes. Depending on turning maneuvers, a landing may still be required.

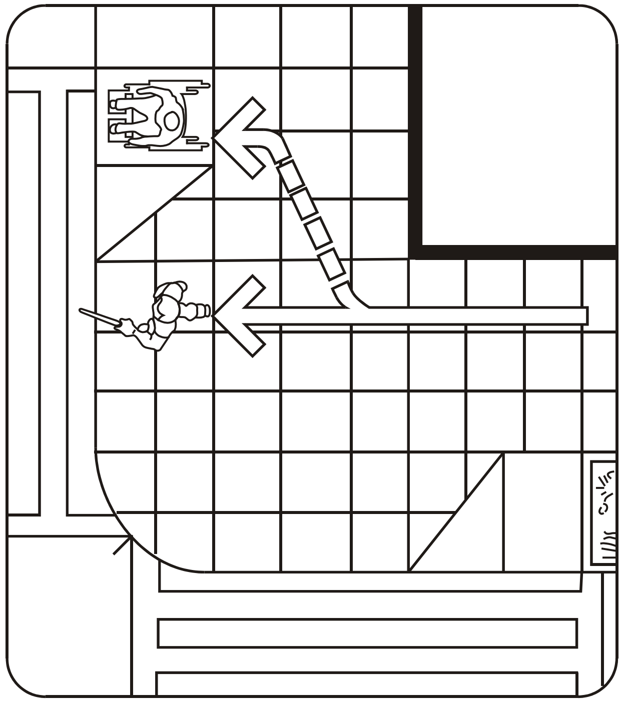
**5.** Type 6. The Type 6 curb ramp is a combination ramp that utilizes a ramp from the street leading to a landing where the pedestrian can access both left and right directions for a total of three ramps. A plain cement concrete curb cheek wall is necessary to fit the curb ramp into the adjacent ground surface. This curb ramp is ideal in residential areas where a green/planted strip separates the sidewalk from the curb. Drawbacks include the pedestrian must traverse the ramps when continuing on the sidewalk and the additional form work to construct.

**6.** Blended Transition. The blended transition pedestrian walkway is not considered a curb ramp since all surfaces slopes are less than 1V:20H (5.00%) gradient. This flat pedestrian transition connection to the level of the roadway is good for wheelchair users, but is less desirable for persons with visual impairments since locating the edge of the roadway is more difficult and less protection from turning vehicles is provided. Guidelines in Figure 6.17 must be followed when considering this type of pedestrian walkway.

**7.** Median or Refuge Island Access Openings. These openings provide access through a median or refuge island where there is need for pedestrians to walk across the median or island. The Type B detail indicates a sloped flare side to connect to the adjacent ground surface, but this flare is not designed to be an accessible slope. The median opening is only intended for narrow openings. If drainage flows through the opening, debris will collect on the truncated domes.

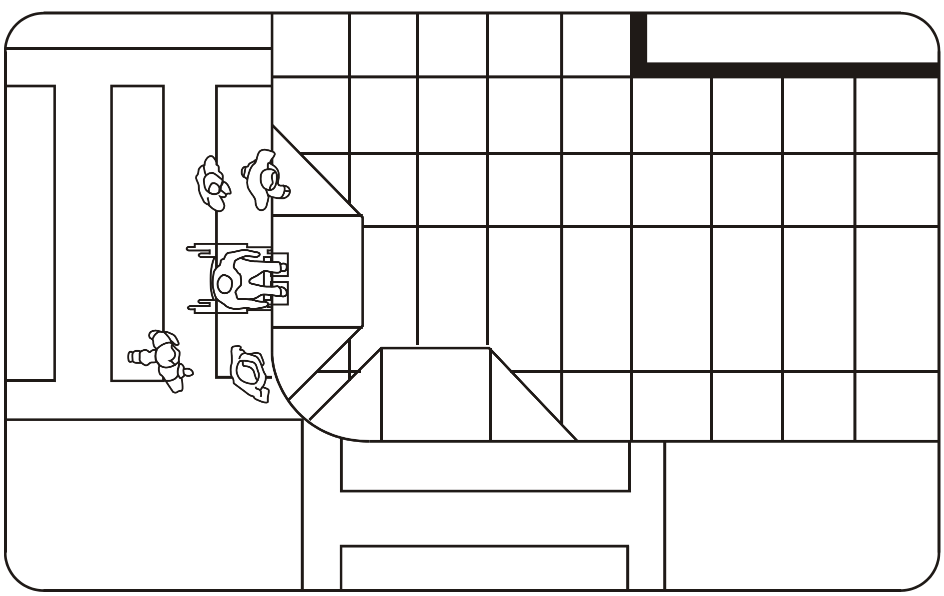
**8.** Ramped Medians or Islands. This design places back to back curb ramps separated by a landing area. The landing area is intended to provide pedestrians a resting area. The ramps as compared to an access opening will not allow drainage to flow directly through the median and thus prevents debris collection. This design is difficult to use since the median width must be wide enough to install the ramps and landing area.

**F. Non-standard Curb Ramps.** When a standard curb ramp cannot be installed due to existing conditions, a non-standard curb ramp may be needed. Non-standard curb ramps must meet the curb ramp design criteria. See Section 6.11, Curb Ramp Design Criteria. When a non-standard curb ramp is used, appropriate detail must be included in the construction plans.



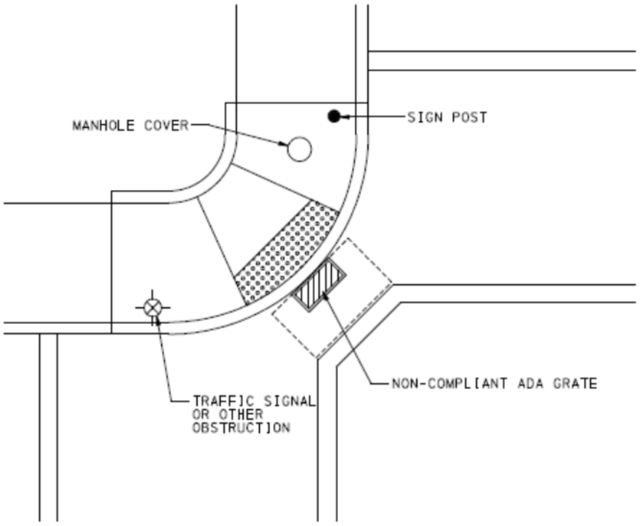
**Note: Curb ramp located to the side, away from direct line of pedestrian movement.**

**FIGURE 6.8**
## Curb Ramps at Marked Crosswalks



**Note: Avoid locating curb ramps too close together.**

**FIGURE 6.9**
## Curb Ramps at Marked Crosswalks




POTENTIAL SOLUTIONS:
FOR ALTERATIONS: UTILITIES IN THE PATH OF TRAVEL ARE ACCEPTABLE IF A 4'-0" PEDESTRIAN PATH IS MAINTAINED, THE TOP SURFACE IS FLUSH [LESS THAN 1/4" IN ELEVATION DIFFERENCE], FIRM, STABLE AND SLIP RESISTANT. INLET GRATES MUST HAVE OPENINGS NO GREATER THAN 1/2" IN DIRECTION OF TRAVEL.

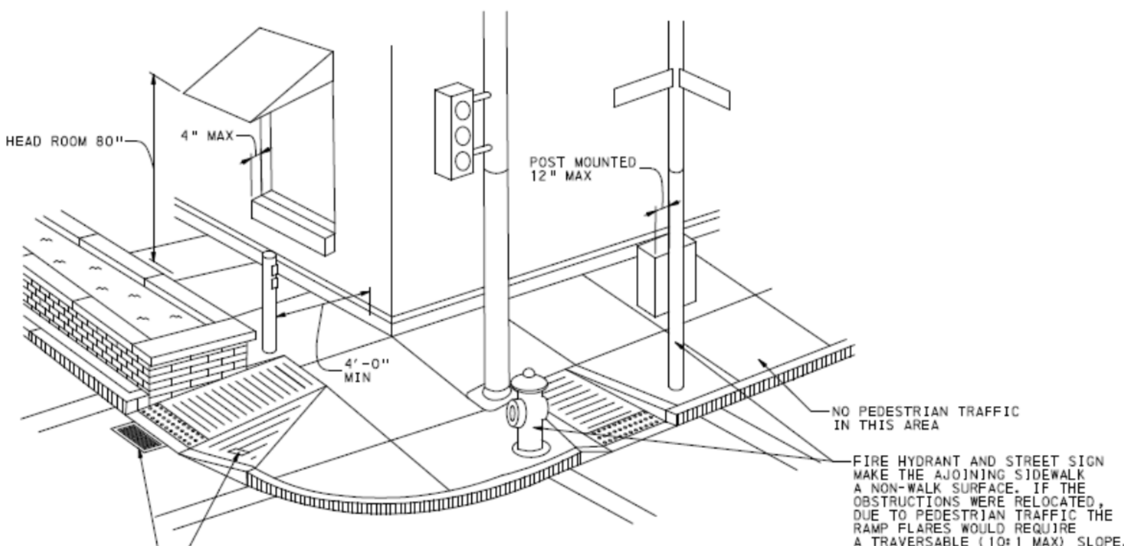
FOR NEW CONSTRUCTION: IF FEASIBLE LOCATE THE CURB RAMPS SO THAT THE UTILITIES ARE NOT IN THE PEDESTRIAN PATH OF TRAVEL.

REPLACE EXISTING GRATE WITH A GRATE WITH AN OPENING LESS THAN 1/2" IN DIRECTION OF TRAVEL. THE REPLACEMENT GRATE CAN NOT AFFECT INLET CAPACITY.

RECONFIGURE RAMPS TO UTILIZE TWO RAMPS AND AVOID EXISTING GRATE.

IF THE UTILITY AND ADJACENT SURFACE ELEVATION DIFFERENCE IS GREATER THAN 1/4", ADJUST UTILITY TO REMOVE GRADE DIFFERENCE.

POTENTIAL PROBLEM
UTILITIES IN PEDESTRIAN PATH




FOR ALTERATIONS: UTILITIES IN THE PATH OF TRAVEL ARE ACCEPTABLE IF THE TOP SURFACE IS FLUSH, FIRM, STABLE AND SLIP RESISTANT. INLET GRATES MUST HAVE OPENINGS NO GREATER THAN 1/2" IN DIRECTION OF TRAVEL.

NEW CONSTRUCTION: AT CURB RAMPS, LOCATE UTILITIES SO THAT THEY ARE NOT IN THE PEDESTRIAN PATH OF TRAVEL.

* OBJECTS PROJECTING FROM WALLS (FOR EXAMPLE, TELEPHONES) WITH THEIR LEADING EDGES BETWEEN 27" AND 80" ABOVE THE FINISHED SURFACE SHALL PROTRUDE NO MORE THAN 4" INTO PEDESTRIAN WALKWAYS.

** OBJECTS MOUNTED WITH THEIR LEADING EDGES AT OR BELOW 27" ABOVE THE FINISHED SURFACE MAY PROTRUDE ANY AMOUNT.

*** OBJECTS MOUNTED ON POSTS OR PYLONS: OVERHANG 12" MAXIMUM FROM 27" TO 80" ABOVE THE GROUND OR FINISHED SURFACE.

**** PROTRUDING OBJECTS SHALL NOT REDUCE THE CLEAR WIDTH OF AN ACCESSIBLE ROUTE OR MANEUVERING SPACE.

UTILITIES AND
VERTICAL OBSTRUCTIONS
AT CURB RAMPS

**FIGURE 6.10**
**Design Considerations:**
**Utilities in Path of Travel**

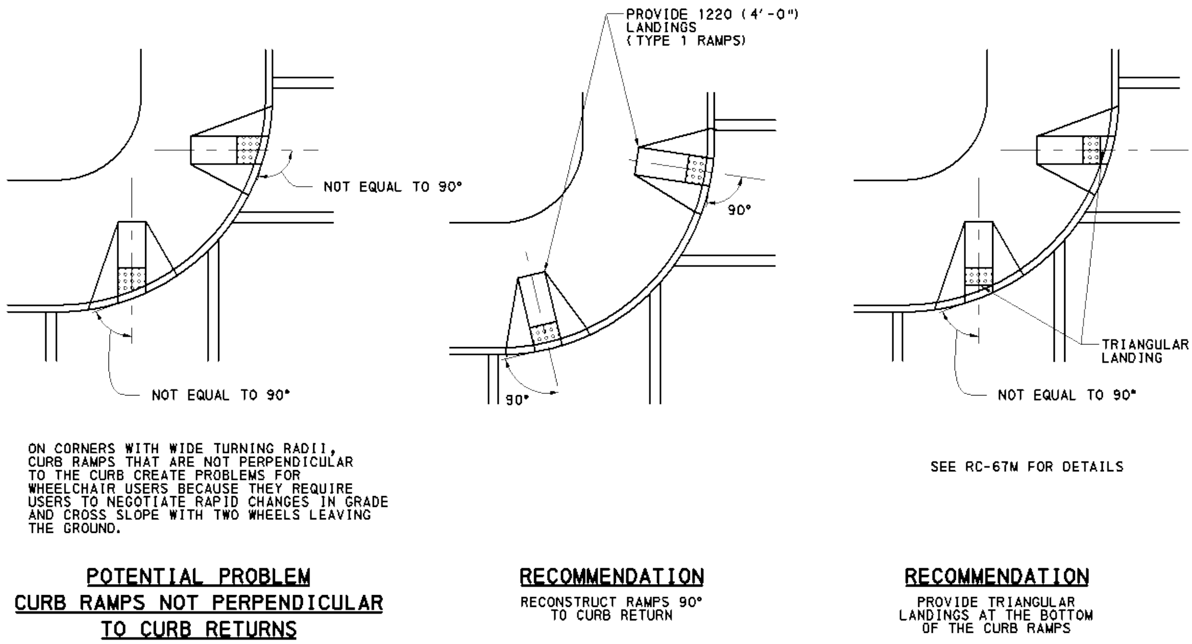



**FIGURE 6.11**
## Design Considerations:
## Non-Perpendicular Type 1 Curb Ramps

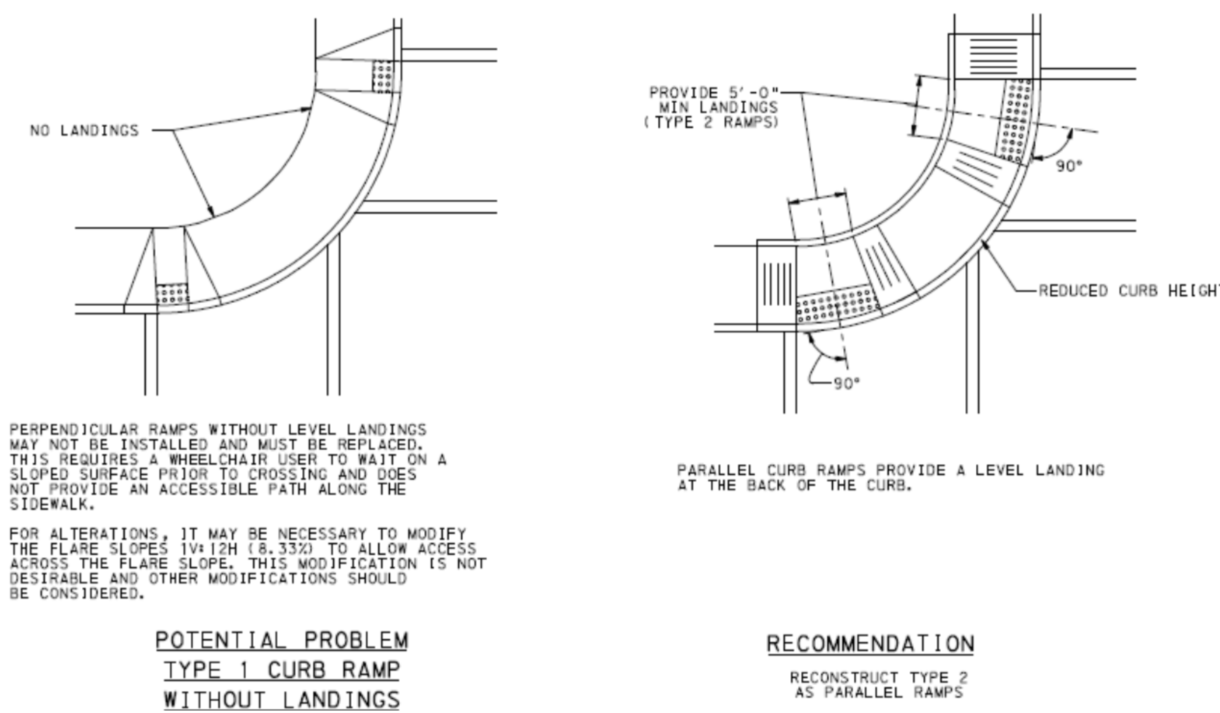
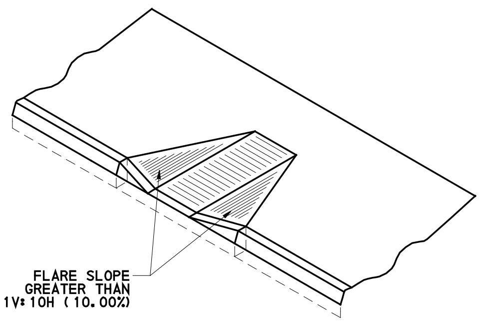
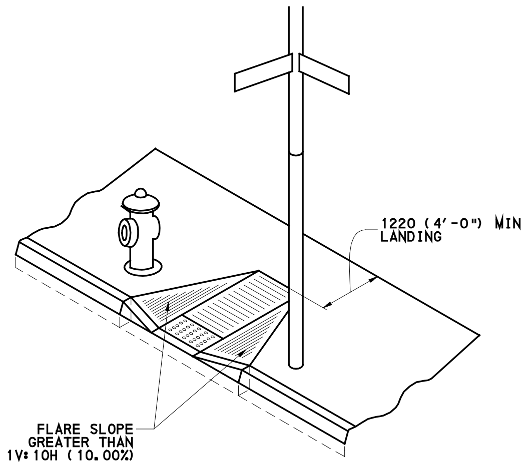



**FIGURE 6.12**
## Design Considerations:
## Type 1 Curb Ramps Without Landings



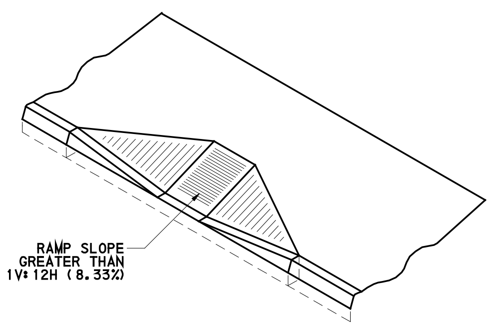

**POTENTIAL PROBLEM CURB RAMPS WITH STEEP FLARED SIDE SLOPES**



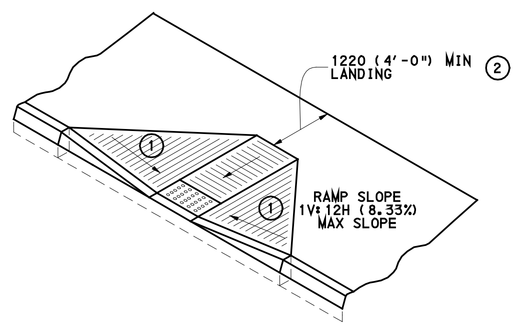

WHEN OBSTRUCTIONS THAT DETER AND LIMIT THE PEDESTRIAN PATH AND A MIN 1225 (4'-0") LANDING IS PROVIDED, STEEPER FLARE SLOPES ARE ACCEPTABLE.

**OBSTRUCTION-PROTECTED CURB RAMP WITH STEEP FLARED SIDE SLOPES**

## FIGURE 6.13
## Design Considerations: Steep Flares in PAR




**POTENTIAL PROBLEM CURB RAMPS WITH STEEP RAMP SLOPES**




RECONSTRUCT EXISTING RAMP WITH REQUIRED SLOPES.

**RECOMMENDATION**

(1) SIDE FLARES 1V:10H (10.00%) MAX
(2) SIDE FLARES 1V:12H (8.33%) MAX FOR RAMPS WITH A LANDING LESS THAN 1220 (4'-0").

## FIGURE 6.14
## Design Considerations: Steep Curb Ramps

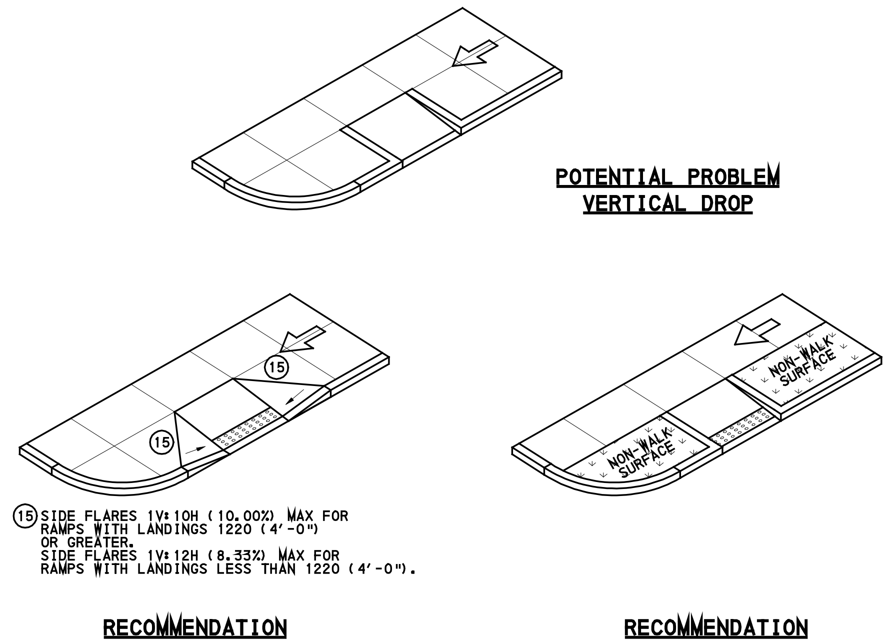



**FIGURE 6.15**
**Design Considerations: Vertical Drops in PAR**

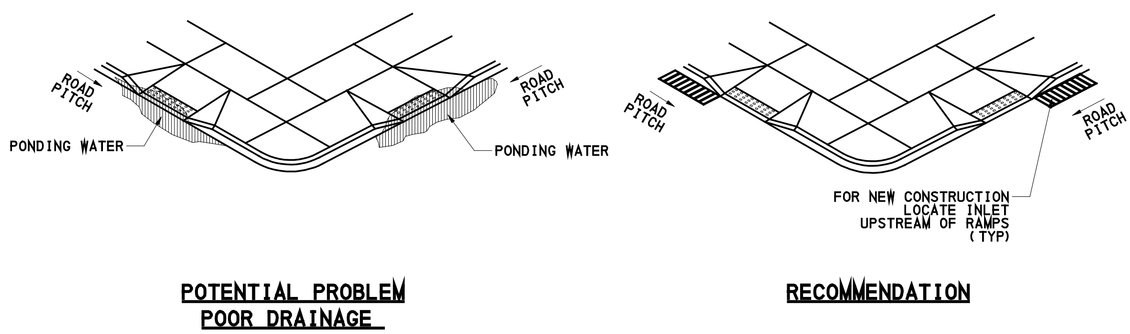
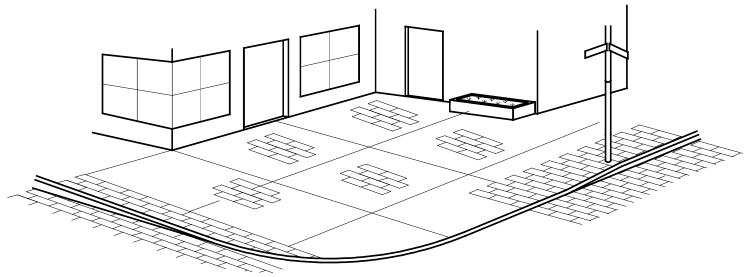
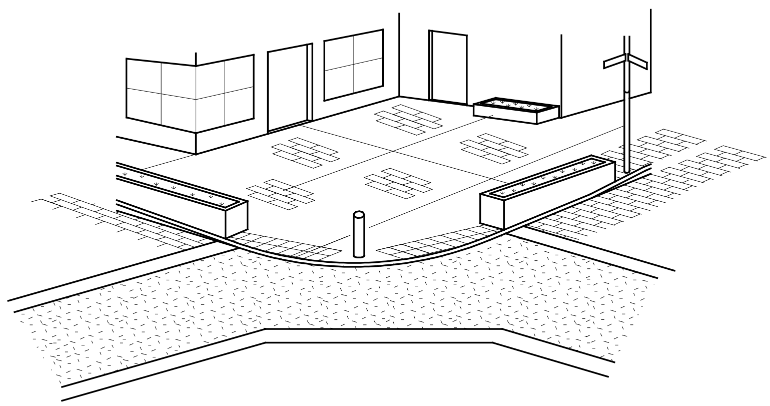



**FIGURE 6.16**
**Design Considerations: Ponding at Curb Ramps**



DECORATIVE PATTERNS USED AT DEPRESSED CURBS, SUCH AS BRICK PATTERN, CREATE A CONTINUOUS PATHWAY. PEOPLE WITH VISION AND COGNITIVE IMPAIRMENTS HAVE DIFFICULTY DETECTING WHERE THE STREET BEGINS AND ENDS.

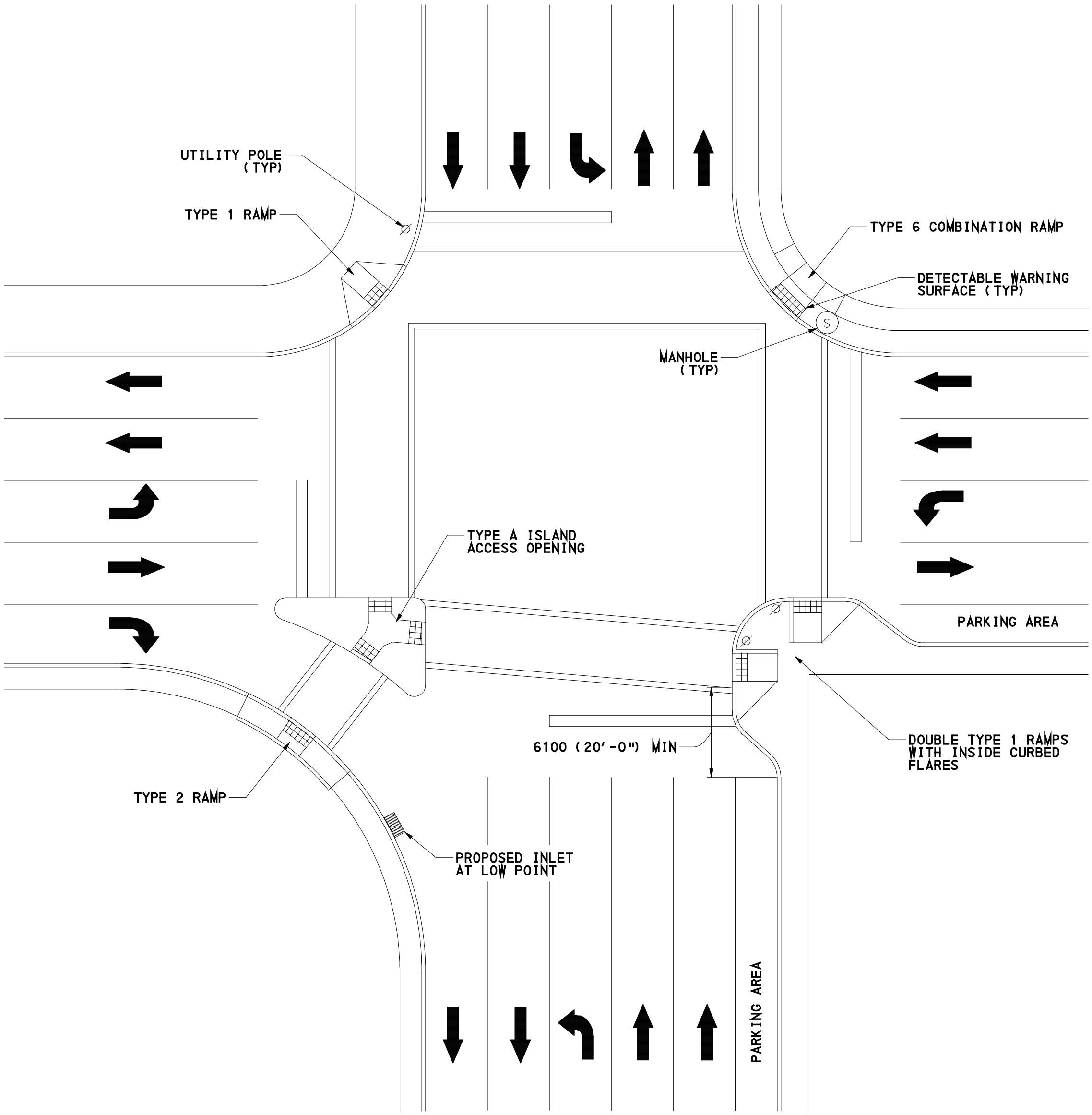
POTENTIAL PROBLEM
LARGE BLENDED TRANSITIONS



DETECTABLE WARNING SURFACES, CONTRASTING SURFACE MATERIALS, AND BARRIER POSTS ARE MEASURES THAT CAN BE UTILIZED TO CONVEY THE TRANSITION BETWEEN STREET AND SIDEWALK AT DEPRESSED CORNERS. THIS CORNER WOULD BE A GOOD LOCATION FOR ACCESSIBLE SIGNALS.

RECOMMENDATION

**FIGURE 6.17**
## Design Considerations:
## Depressed Curb and Blended Transitions




DESIGN CONSIDERATIONS:

LOCATIONS OF DRAINAGE, UTILITY OR OTHER POSSIBLE OBSTRUCTIONS.

LOCATIONS OF PEDESTRIAN PUSH BUTTONS.

CROSSWALK LOCATIONS CLEARLY AND ACCURATELY SHOWN.

LOCATIONS OF LOWPOINTS AND FLOW LINE ELEVATIONS.

CURB RAMPS LEAD TO A 1220 (4'-0") MIN ACCESSIBLE PATH WITH A MAX 2.00% CROSS SLOPE.

CURB RAMP AND FLARE SLOPES CALCULATED BASED ON ROAD PITCH AND RECOMMENDED SLOPES.

DOCUMENTATION OF NOT MEETING DESIGN REQUIREMENTS IF NOT TECHNICALLY FEASIBLE.

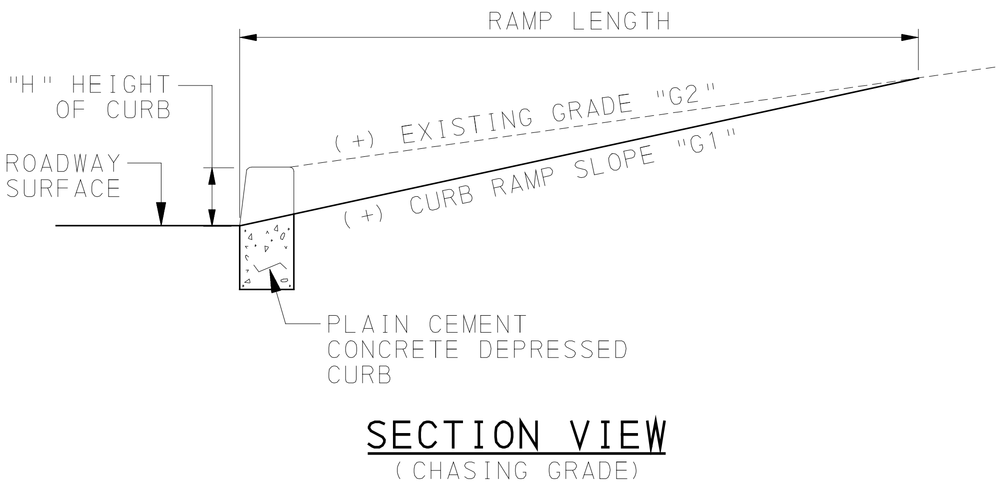
LEVEL OF DETAIL:

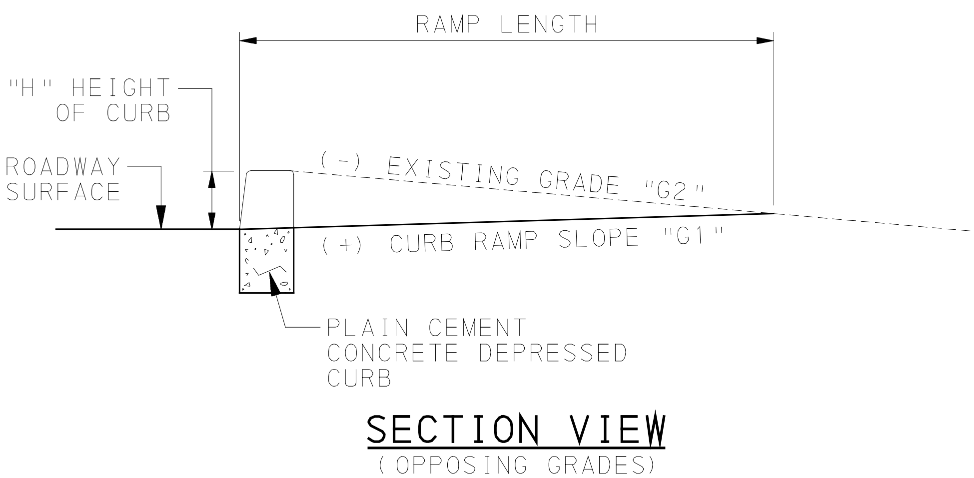
CURB RAMP AND FLARE EDGES ACUURATELY SHOWN.

DETECTABLE WARNING SURFACE CLEARLY AND ACCURATELY SHOWN.

CURB RAMP LOCATIONS AND TYPES CLEARLY IDENTIFIED.

**FIGURE 6.18**
## Design Considerations: Plan Details




To calculate ramp length:
"G1" Proposed Curb Ramp Slope (%)
"G2" Existing Grade (%)
"H" Height of Curb (ft)

$$\text{Ramp Length (ft)} = \frac{H}{(G1 - G2)/100}$$

Example #1 $\frac{0.67}{(5 - -3)}$ = 8.4'     Example #2 $\frac{0.5}{(5-2)/100}$ = 16.7' Use Steeper Slope

**FIGURE 6.19**

## Design Considerations: Ramp and Flare Calculations

APPROXIMATE RAMP LENGTH (MM)

"G1" 5% SLOPE

| | | | "H" CURB HEIGHT (MM) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| "G2" EXISTING GRADE (%) | | | 25 | 50 | 75 | 100 | 125 | 150 | 175 | 200 | 225 | 250 | 275 | 300 |
| | CHASING GRADE | 12 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 11 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 10 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 9 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 8 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 7 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 6 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 5 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 4 | 2500 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 3 | 1250 | 2500 | 3750 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 2 | 834 | 1667 | 2500 | 3334 | 4167 | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 1 | 625 | 1250 | 1875 | 2500 | 3125 | 3750 | 4375 | n/a | n/a | n/a | n/a | n/a |
| | | 0 | 500 | 1000 | 1500 | 2000 | 2500 | 3000 | 3500 | 4000 | 4500 | n/a | n/a | n/a |
| | OPPOSING GRADE | -1 | 417 | 834 | 1250 | 1667 | 2084 | 2500 | 2917 | 3334 | 3750 | 4167 | n/a | n/a |
| | | -2 | 358 | 715 | 1072 | 1429 | 1786 | 2143 | 2500 | 2858 | 3215 | 3572 | 3929 | 4286 |
| | | -3 | 313 | 625 | 938 | 1250 | 1563 | 1875 | 2188 | 2500 | 2813 | 3125 | 3438 | 3750 |
| | | -4 | 278 | 556 | 834 | 1112 | 1389 | 1667 | 1945 | 2223 | 2500 | 2778 | 3056 | 3334 |
| | | -5 | 250 | 500 | 750 | 1000 | 1250 | 1500 | 1750 | 2000 | 2250 | 2500 | 2750 | 3000 |
| | | -6 | 228 | 455 | 682 | 910 | 1137 | 1364 | 1591 | 1819 | 2046 | 2273 | 2500 | 2728 |
| | | -7 | 209 | 417 | 625 | 834 | 1042 | 1250 | 1459 | 1667 | 1875 | 2084 | 2292 | 2500 |
| | | -8 | 193 | 385 | 577 | 770 | 962 | 1154 | 1347 | 1539 | 1731 | 1924 | 2116 | 2308 |
| | | -9 | 179 | 358 | 536 | 715 | 893 | 1072 | 1250 | 1429 | 1608 | 1786 | 1965 | 2143 |
| | | -10 | 167 | 334 | 500 | 667 | 834 | 1000 | 1167 | 1334 | 1500 | 1667 | 1834 | 2000 |
| | | -11 | 157 | 313 | 469 | 625 | 782 | 938 | 1094 | 1250 | 1407 | 1563 | 1719 | 1875 |
| | | -12 | 148 | 295 | 442 | 589 | 736 | 883 | 1030 | 1177 | 1324 | 1471 | 1618 | 1765 |

Use the above chart to determine the approximate ramp length.

Step 1: Find the appropriate curb height along the top row.
Step 2: Follow the curb height down to the existing grade slope.
Step 3: The intersecting value is the approximate ramp length at the given slope.
Step 4: "n/a" indicates that a steeper slope must be used. The current slope produces a ramp length greater than 4500 mm.

**FIGURE 6.20 (METRIC)**

## Design Considerations: Ramp and Flare Length Charts

APPROXIMATE RAMP LENGTH (MM)
"G1" 6% SLOPE

| | "G2" EXISTING GRADE (%) | "H" CURB HEIGHT (MM) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 25 | 50 | 75 | 100 | 125 | 150 | 175 | 200 | 225 | 250 | 275 | 300 |
| CHASING GRADE | 12 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | 11 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | 10 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | 9 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | 8 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | 7 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | 6 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | 5 | 2500 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | 4 | 1250 | 2500 | 3750 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | 3 | 834 | 1667 | 2500 | 3334 | 4167 | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | 2 | 625 | 1250 | 1875 | 2500 | 3125 | 3750 | 4375 | n/a | n/a | n/a | n/a | n/a |
| | 1 | 500 | 1000 | 1500 | 2000 | 2500 | 3000 | 3500 | 4000 | 4500 | n/a | n/a | n/a |
| | 0 | 417 | 834 | 1250 | 1667 | 2084 | 2500 | 2917 | 3334 | 3750 | 4167 | n/a | n/a |
| OPPOSING GRADE | -1 | 358 | 715 | 1072 | 1429 | 1786 | 2143 | 2500 | 2858 | 3215 | 3572 | 3929 | 4286 |
| | -2 | 313 | 625 | 938 | 1250 | 1563 | 1875 | 2188 | 2500 | 2813 | 3125 | 3438 | 3750 |
| | -3 | 278 | 556 | 834 | 1112 | 1389 | 1667 | 1945 | 2223 | 2500 | 2778 | 3056 | 3334 |
| | -4 | 250 | 500 | 750 | 1000 | 1250 | 1500 | 1750 | 2000 | 2250 | 2500 | 2750 | 3000 |
| | -5 | 228 | 455 | 682 | 910 | 1137 | 1364 | 1591 | 1819 | 2046 | 2273 | 2500 | 2728 |
| | -6 | 209 | 417 | 625 | 834 | 1042 | 1250 | 1459 | 1667 | 1875 | 2084 | 2292 | 2500 |
| | -7 | 193 | 385 | 577 | 770 | 962 | 1154 | 1347 | 1539 | 1731 | 1924 | 2116 | 2308 |
| | -8 | 179 | 358 | 536 | 715 | 893 | 1072 | 1250 | 1429 | 1608 | 1786 | 1965 | 2143 |
| | -9 | 167 | 334 | 500 | 667 | 834 | 1000 | 1167 | 1334 | 1500 | 1667 | 1834 | 2000 |
| | -10 | 157 | 313 | 469 | 625 | 782 | 938 | 1094 | 1250 | 1407 | 1563 | 1719 | 1875 |
| | -11 | 148 | 295 | 442 | 589 | 736 | 883 | 1030 | 1177 | 1324 | 1471 | 1618 | 1765 |
| | -12 | 139 | 278 | 417 | 556 | 695 | 834 | 973 | 1112 | 1250 | 1389 | 1528 | 1667 |

Use the above chart to determine the approximate ramp length.

Step 1: Find the appropriate curb height along the top row.
Step 2: Follow the curb height down to the existing grade slope.
Step 3: The intersecting value is the approximate ramp length at the given slope.
Step 4: "n/a" indicates that a steeper slope must be used. The current slope produces a ramp length greater than 4500 mm.

**FIGURE 6.20 (METRIC) (CONTINUED)**

## Design Considerations:
## Ramp and Flare Length Charts

| APPROXIMATE RAMP LENGTH (MM) "G1" 7% SLOPE | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | "H" CURB HEIGHT (MM) | | | | | | | | | | |
| "G2" EXISTING GRADE (%) | | 25 | 50 | 75 | 100 | 125 | 150 | 175 | 200 | 225 | 250 | 275 | 300 |
| | CHASING GRADE | 12 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 11 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 10 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 9 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 8 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 7 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 6 | 2500 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 5 | 1250 | 2500 | 3750 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 4 | 834 | 1667 | 2500 | 3334 | 4167 | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 3 | 625 | 1250 | 1875 | 2500 | 3125 | 3750 | 4375 | n/a | n/a | n/a | n/a | n/a |
| | | 2 | 500 | 1000 | 1500 | 2000 | 2500 | 3000 | 3500 | 4000 | 4500 | n/a | n/a | n/a |
| | | 1 | 417 | 834 | 1250 | 1667 | 2084 | 2500 | 2917 | 3334 | 3750 | 4167 | n/a | n/a |
| | | 0 | 358 | 715 | 1072 | 1429 | 1786 | 2143 | 2500 | 2858 | 3215 | 3572 | 3929 | 4286 |
| | OPPOSING GRADE | -1 | 313 | 625 | 938 | 1250 | 1563 | 1875 | 2188 | 2500 | 2813 | 3125 | 3438 | 3750 |
| | | -2 | 278 | 556 | 834 | 1112 | 1389 | 1667 | 1945 | 2223 | 2500 | 2778 | 3056 | 3334 |
| | | -3 | 250 | 500 | 750 | 1000 | 1250 | 1500 | 1750 | 2000 | 2250 | 2500 | 2750 | 3000 |
| | | -4 | 228 | 455 | 682 | 910 | 1137 | 1364 | 1591 | 1819 | 2046 | 2273 | 2500 | 2728 |
| | | -5 | 209 | 417 | 625 | 834 | 1042 | 1250 | 1459 | 1667 | 1875 | 2084 | 2292 | 2500 |
| | | -6 | 193 | 385 | 577 | 770 | 962 | 1154 | 1347 | 1539 | 1731 | 1924 | 2116 | 2308 |
| | | -7 | 179 | 358 | 536 | 715 | 893 | 1072 | 1250 | 1429 | 1608 | 1786 | 1965 | 2143 |
| | | -8 | 167 | 334 | 500 | 667 | 834 | 1000 | 1167 | 1334 | 1500 | 1667 | 1834 | 2000 |
| | | -9 | 157 | 313 | 469 | 625 | 782 | 938 | 1094 | 1250 | 1407 | 1563 | 1719 | 1875 |
| | | -10 | 148 | 295 | 442 | 589 | 736 | 883 | 1030 | 1177 | 1324 | 1471 | 1618 | 1765 |
| | | -11 | 139 | 278 | 417 | 556 | 695 | 834 | 973 | 1112 | 1250 | 1389 | 1528 | 1667 |
| | | -12 | 132 | 264 | 395 | 527 | 658 | 790 | 922 | 1053 | 1185 | 1316 | 1448 | 1579 |

Use the above chart to determine the approximate ramp length.

Step 1: Find the appropriate curb height along the top row.
Step 2: Follow the curb height down to the existing grade slope.
Step 3: The intersecting value is the approximate ramp length at the given slope.
Step 4: "n/a" indicates that a steeper slope must be used. The current slope produces a ramp length greater than 4500 mm.

**FIGURE 6.20 (METRIC) (CONTINUED)**

## Design Considerations:
## Ramp and Flare Length Charts

APPROXIMATE RAMP LENGTH (MM)

"G1" 8.33% SLOPE

| "G2" EXISTING GRADE (%) | | | "H" CURB HEIGHT (MM) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 25 | 50 | 75 | 100 | 125 | 150 | 175 | 200 | 225 | 250 | 275 | 300 |
| | CHASING GRADE | 12 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 |
| | | 11 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 |
| | | 10 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 |
| | | 9 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 |
| | | 8 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 |
| | | 7 | 1880 | 3760 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 |
| | | 6 | 1073 | 2146 | 3219 | 4292 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 |
| | | 5 | 751 | 1502 | 2253 | 3004 | 3754 | 4505 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 |
| | | 4 | 578 | 1155 | 1733 | 2310 | 2887 | 3465 | 4042 | 4575 | 4575 | 4575 | 4575 | 4575 |
| | | 3 | 470 | 939 | 1408 | 1877 | 2346 | 2815 | 3284 | 3753 | 4222 | 4575 | 4575 | 4575 |
| | | 2 | 395 | 790 | 1185 | 1580 | 1975 | 2370 | 2765 | 3160 | 3555 | 3950 | 4345 | 4575 |
| | | 1 | 342 | 683 | 1024 | 1365 | 1706 | 2047 | 2388 | 2729 | 3070 | 3411 | 3752 | 4093 |
| | | 0 | 301 | 601 | 901 | 1201 | 1501 | 1801 | 2101 | 2401 | 2702 | 3002 | 3302 | 3602 |
| | OPPOSING GRADE | -1 | 268 | 536 | 804 | 1072 | 1340 | 1608 | 1876 | 2144 | 2412 | 2680 | 2948 | 3216 |
| | | -2 | 243 | 485 | 727 | 969 | 1211 | 1453 | 1695 | 1937 | 2179 | 2421 | 2663 | 2905 |
| | | -3 | 221 | 442 | 662 | 883 | 1104 | 1324 | 1545 | 1766 | 1986 | 2207 | 2428 | 2648 |
| | | -4 | 203 | 406 | 609 | 812 | 1014 | 1217 | 1420 | 1623 | 1825 | 2028 | 2231 | 2434 |
| | | -5 | 188 | 376 | 563 | 751 | 938 | 1126 | 1313 | 1501 | 1688 | 1876 | 2064 | 2251 |
| | | -6 | 175 | 349 | 524 | 698 | 873 | 1047 | 1222 | 1396 | 1571 | 1745 | 1920 | 2094 |
| | | -7 | 164 | 327 | 490 | 653 | 816 | 979 | 1142 | 1305 | 1468 | 1631 | 1794 | 1957 |
| | | -8 | 154 | 307 | 460 | 613 | 766 | 919 | 1072 | 1225 | 1378 | 1531 | 1685 | 1838 |
| | | -9 | 145 | 289 | 433 | 578 | 722 | 866 | 1010 | 1155 | 1299 | 1443 | 1587 | 1732 |
| | | -10 | 137 | 273 | 410 | 546 | 682 | 819 | 955 | 1092 | 1228 | 1364 | 1501 | 1637 |
| | | -11 | 130 | 259 | 388 | 518 | 647 | 776 | 906 | 1035 | 1164 | 1294 | 1423 | 1552 |
| | | -12 | 123 | 246 | 369 | 492 | 615 | 738 | 861 | 984 | 1107 | 1230 | 1353 | 1476 |

Use the above chart to determine the approximate ramp length.

Step 1. Find the appropriate curb height along the top row.
Step 2. Follow the curb height down to the existing grade slope.
Step 3. The intersecting value is the approximate ramp length at the given slope.

**FIGURE 6.20 (METRIC) (CONTINUED)**

## Design Considerations:
## Ramp and Flare Length Charts

APPROXIMATE RAMP LENGTH (MM)

"G1" 10% SLOPE

| "G2" EXISTING GRADE (%) | | "H" CURB HEIGHT (MM) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 25 | 50 | 75 | 100 | 125 | 150 | 175 | 200 | 225 | 250 | 275 | 300 |
| CHASING GRADE | 12 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 |
| | 11 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 |
| | 10 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 |
| | 9 | 2500 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 |
| | 8 | 1250 | 2500 | 3750 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 |
| | 7 | 834 | 1667 | 2500 | 3334 | 4167 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 | 4575 |
| | 6 | 625 | 1250 | 1875 | 2500 | 3125 | 3750 | 4375 | 4575 | 4575 | 4575 | 4575 | 4575 |
| | 5 | 500 | 1000 | 1500 | 2000 | 2500 | 3000 | 3500 | 4000 | 4500 | 4575 | 4575 | 4575 |
| | 4 | 417 | 834 | 1250 | 1667 | 2084 | 2500 | 2917 | 3334 | 3750 | 4167 | 4575 | 4575 |
| | 3 | 358 | 715 | 1072 | 1429 | 1786 | 2143 | 2500 | 2858 | 3215 | 3572 | 3929 | 4286 |
| | 2 | 313 | 625 | 938 | 1250 | 1563 | 1875 | 2188 | 2500 | 2813 | 3125 | 3438 | 3750 |
| | 1 | 278 | 556 | 834 | 1112 | 1389 | 1667 | 1945 | 2223 | 2500 | 2778 | 3056 | 3334 |
| | 0 | 250 | 500 | 750 | 1000 | 1250 | 1500 | 1750 | 2000 | 2250 | 2500 | 2750 | 3000 |
| OPPOSING GRADE | -1 | 228 | 455 | 682 | 910 | 1137 | 1364 | 1591 | 1819 | 2046 | 2273 | 2500 | 2728 |
| | -2 | 209 | 417 | 625 | 834 | 1042 | 1250 | 1459 | 1667 | 1875 | 2084 | 2292 | 2500 |
| | -3 | 193 | 385 | 577 | 770 | 962 | 1154 | 1347 | 1539 | 1731 | 1924 | 2116 | 2308 |
| | -4 | 179 | 358 | 536 | 715 | 893 | 1072 | 1250 | 1429 | 1608 | 1786 | 1965 | 2143 |
| | -5 | 167 | 334 | 500 | 667 | 834 | 1000 | 1167 | 1334 | 1500 | 1667 | 1834 | 2000 |
| | -6 | 157 | 313 | 469 | 625 | 782 | 938 | 1094 | 1250 | 1407 | 1563 | 1719 | 1875 |
| | -7 | 148 | 295 | 442 | 589 | 736 | 883 | 1030 | 1177 | 1324 | 1471 | 1618 | 1765 |
| | -8 | 139 | 278 | 417 | 556 | 695 | 834 | 973 | 1112 | 1250 | 1389 | 1528 | 1667 |
| | -9 | 132 | 264 | 395 | 527 | 658 | 790 | 922 | 1053 | 1185 | 1316 | 1448 | 1579 |
| | -10 | 125 | 250 | 375 | 500 | 625 | 750 | 875 | 1000 | 1125 | 1250 | 1375 | 1500 |
| | -11 | 120 | 239 | 358 | 477 | 596 | 715 | 834 | 953 | 1072 | 1191 | 1310 | 1429 |
| | -12 | 114 | 228 | 341 | 455 | 569 | 682 | 796 | 910 | 1023 | 1137 | 1250 | 1364 |

Use the above chart to determine the approximate ramp length.

Step 1: Find the appropriate curb height along the top row.
Step 2: Follow the curb height down to the existing grade slope.
Step 3: The intersecting value is the approximate ramp length at the given slope.

**FIGURE 6.20 (METRIC) (CONTINUED)**

## Design Considerations:
## Ramp and Flare Length Charts

| APPROXIMATE RAMP LENGTH "G1" 5% SLOPE | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | "H" CURB HEIGHT (IN) | | | | | | | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| "G2" EXISTING GRADE (%) | CHASING GRADE | 12 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 11 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 10 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 9 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 8 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 7 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 6 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 5 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 4 | 8.4 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 3 | 4.2 | 8.4 | 12.5 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 2 | 2.8 | 5.6 | 8.4 | 11.2 | 13.9 | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 1 | 2.1 | 4.2 | 6.3 | 8.4 | 10.5 | 12.5 | 14.6 | n/a | n/a | n/a | n/a | n/a |
| | | 0 | 1.7 | 3.4 | 5.0 | 6.7 | 8.4 | 10.0 | 11.7 | 13.4 | 15.0 | n/a | n/a | n/a |
| | OPPOSING GRADE | -1 | 1.4 | 2.8 | 4.2 | 5.6 | 7.0 | 8.4 | 9.8 | 11.2 | 12.5 | 13.9 | n/a | n/a |
| | | -2 | 1.2 | 2.4 | 3.6 | 4.8 | 6.0 | 7.2 | 8.4 | 9.6 | 10.8 | 12.0 | 13.1 | 14.3 |
| | | -3 | 1.1 | 2.1 | 3.2 | 4.2 | 5.3 | 6.3 | 7.3 | 8.4 | 9.4 | 10.5 | 11.5 | 12.5 |
| | | -4 | 1.0 | 1.9 | 2.8 | 3.8 | 4.7 | 5.6 | 6.5 | 7.5 | 8.4 | 9.3 | 10.2 | 11.2 |
| | | -5 | 0.9 | 1.7 | 2.5 | 3.4 | 4.2 | 5.0 | 5.9 | 6.7 | 7.5 | 8.4 | 9.2 | 10.0 |
| | | -6 | 0.8 | 1.6 | 2.3 | 3.1 | 3.8 | 4.6 | 5.4 | 6.1 | 6.9 | 7.6 | 8.4 | 9.1 |
| | | -7 | 0.7 | 1.4 | 2.1 | 2.8 | 3.5 | 4.2 | 4.9 | 5.6 | 6.3 | 7.0 | 7.7 | 8.4 |
| | | -8 | 0.7 | 1.3 | 2.0 | 2.6 | 3.3 | 3.9 | 4.5 | 5.2 | 5.8 | 6.5 | 7.1 | 7.7 |
| | | -9 | 0.6 | 1.2 | 1.8 | 2.4 | 3.0 | 3.6 | 4.2 | 4.8 | 5.4 | 6.0 | 6.6 | 7.2 |
| | | -10 | 0.6 | 1.2 | 1.7 | 2.3 | 2.8 | 3.4 | 3.9 | 4.5 | 5.0 | 5.6 | 6.2 | 6.7 |
| | | -11 | 0.6 | 1.1 | 1.6 | 2.1 | 2.7 | 3.2 | 3.7 | 4.2 | 4.7 | 5.3 | 5.8 | 6.3 |
| | | -12 | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.4 | 5.9 |

Use the above chart to determine the approximate ramp length.

Step 1: Find the appropriate curb height along the top row.
Step 2: Follow the curb height down to the existing grade slope.
Step 3: The intersecting value is the approximate ramp length at the given slope.
Step 4: "n/a" indicates that a steeper slope must be used. The current slope produces a ramp length greater than 15'-0".

**FIGURE 6.20 (ENGLISH)**

## Design Considerations:
## Ramp and Flare Length Charts

| APPROXIMATE RAMP LENGTH "G1" 6% SLOPE | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | "H" CURB HEIGHT (IN) | | | | | | | | | | | |
| "G2" EXISTING GRADE (%) | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| | CHASING GRADE | 12 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 11 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 10 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 9 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 8 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 7 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 6 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 5 | 8.4 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 4 | 4.2 | 8.4 | 12.5 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 3 | 2.8 | 5.6 | 8.4 | 11.2 | 13.9 | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 2 | 2.1 | 4.2 | 6.3 | 8.4 | 10.5 | 12.5 | 14.6 | n/a | n/a | n/a | n/a | n/a |
| | | 1 | 1.7 | 3.4 | 5.0 | 6.7 | 8.4 | 10.0 | 11.7 | 13.4 | 15.0 | n/a | n/a | n/a |
| | | 0 | 1.4 | 2.8 | 4.2 | 5.6 | 7.0 | 8.4 | 9.8 | 11.2 | 12.5 | 13.9 | n/a | n/a |
| | OPPOSING GRADE | -1 | 1.2 | 2.4 | 3.6 | 4.8 | 6.0 | 7.2 | 8.4 | 9.6 | 10.8 | 12.0 | 13.1 | 14.3 |
| | | -2 | 1.1 | 2.1 | 3.2 | 4.2 | 5.3 | 6.3 | 7.3 | 8.4 | 9.4 | 10.5 | 11.5 | 12.5 |
| | | -3 | 1.0 | 1.9 | 2.8 | 3.8 | 4.7 | 5.6 | 6.5 | 7.5 | 8.4 | 9.3 | 10.2 | 11.2 |
| | | -4 | 0.9 | 1.7 | 2.5 | 3.4 | 4.2 | 5.0 | 5.9 | 6.7 | 7.5 | 8.4 | 9.2 | 10.0 |
| | | -5 | 0.8 | 1.6 | 2.3 | 3.1 | 3.8 | 4.6 | 5.4 | 6.1 | 6.9 | 7.6 | 8.4 | 9.1 |
| | | -6 | 0.7 | 1.4 | 2.1 | 2.8 | 3.5 | 4.2 | 4.9 | 5.6 | 6.3 | 7.0 | 7.7 | 8.4 |
| | | -7 | 0.7 | 1.3 | 2.0 | 2.6 | 3.3 | 3.9 | 4.5 | 5.2 | 5.8 | 6.5 | 7.1 | 7.7 |
| | | -8 | 0.6 | 1.2 | 1.8 | 2.4 | 3.0 | 3.6 | 4.2 | 4.8 | 5.4 | 6.0 | 6.6 | 7.2 |
| | | -9 | 0.6 | 1.2 | 1.7 | 2.3 | 2.8 | 3.4 | 3.9 | 4.5 | 5.0 | 5.6 | 6.2 | 6.7 |
| | | -10 | 0.6 | 1.1 | 1.6 | 2.1 | 2.7 | 3.2 | 3.7 | 4.2 | 4.7 | 5.3 | 5.8 | 6.3 |
| | | -11 | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.4 | 5.9 |
| | | -12 | 0.5 | 1.0 | 1.4 | 1.9 | 2.4 | 2.8 | 3.3 | 3.8 | 4.2 | 4.7 | 5.1 | 5.6 |

Use the above chart to determine the approximate ramp length.

Step 1: Find the appropriate curb height along the top row.
Step 2: Follow the curb height down to the existing grade slope.
Step 3: The intersecting value is the approximate ramp length at the given slope.
Step 4: "n/a" indicates that a steeper slope must be used. The current slope produces a ramp length greater than 15'-0".

**FIGURE 6.20 (ENGLISH) (CONTINUED)**

## Design Considerations: Ramp and Flare Length Charts

APPROXIMATE RAMP LENGTH
"G1" 7% SLOPE

| "G2" EXISTING GRADE (%) | | | "H" CURB HEIGHT (IN) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| | CHASING GRADE | 12 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 11 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 10 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 9 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 8 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 7 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 6 | 8.4 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 5 | 4.2 | 8.4 | 12.5 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 4 | 2.8 | 5.6 | 8.4 | 11.2 | 13.9 | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | | 3 | 2.1 | 4.2 | 6.3 | 8.4 | 10.5 | 12.5 | 14.6 | n/a | n/a | n/a | n/a | n/a |
| | | 2 | 1.7 | 3.4 | 5.0 | 6.7 | 8.4 | 10.0 | 11.7 | 13.4 | 15.0 | n/a | n/a | n/a |
| | | 1 | 1.4 | 2.8 | 4.2 | 5.6 | 7.0 | 8.4 | 9.8 | 11.2 | 12.5 | 13.9 | n/a | n/a |
| | | 0 | 1.2 | 2.4 | 3.6 | 4.8 | 6.0 | 7.2 | 8.4 | 9.6 | 10.8 | 12.0 | 13.1 | 14.3 |
| | OPPOSING GRADE | -1 | 1.1 | 2.1 | 3.2 | 4.2 | 5.3 | 6.3 | 7.3 | 8.4 | 9.4 | 10.5 | 11.5 | 12.5 |
| | | -2 | 1.0 | 1.9 | 2.8 | 3.8 | 4.7 | 5.6 | 6.5 | 7.5 | 8.4 | 9.3 | 10.2 | 11.2 |
| | | -3 | 0.9 | 1.7 | 2.5 | 3.4 | 4.2 | 5.0 | 5.9 | 6.7 | 7.5 | 8.4 | 9.2 | 10.0 |
| | | -4 | 0.8 | 1.6 | 2.3 | 3.1 | 3.8 | 4.6 | 5.4 | 6.1 | 6.9 | 7.6 | 8.4 | 9.1 |
| | | -5 | 0.7 | 1.4 | 2.1 | 2.8 | 3.5 | 4.2 | 4.9 | 5.6 | 6.3 | 7.0 | 7.7 | 8.4 |
| | | -6 | 0.7 | 1.3 | 2.0 | 2.6 | 3.3 | 3.9 | 4.5 | 5.2 | 5.8 | 6.5 | 7.1 | 7.7 |
| | | -7 | 0.6 | 1.2 | 1.8 | 2.4 | 3.0 | 3.6 | 4.2 | 4.8 | 5.4 | 6.0 | 6.6 | 7.2 |
| | | -8 | 0.6 | 1.2 | 1.7 | 2.3 | 2.8 | 3.4 | 3.9 | 4.5 | 5.0 | 5.6 | 6.2 | 6.7 |
| | | -9 | 0.6 | 1.1 | 1.6 | 2.1 | 2.7 | 3.2 | 3.7 | 4.2 | 4.7 | 5.3 | 5.8 | 6.3 |
| | | -10 | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.4 | 5.9 |
| | | -11 | 0.5 | 1.0 | 1.4 | 1.9 | 2.4 | 2.8 | 3.3 | 3.8 | 4.2 | 4.7 | 5.1 | 5.6 |
| | | -12 | 0.5 | 0.9 | 1.4 | 1.8 | 2.2 | 2.7 | 3.1 | 3.6 | 4.0 | 4.4 | 4.9 | 5.3 |

Use the above chart to determine the approximate ramp length.

Step 1: Find the appropriate curb height along the top row.
Step 2: Follow the curb height down to the existing grade slope.
Step 3: The intersecting value is the approximate ramp length at the given slope.
Step 4: "n/a" indicates that a steeper slope must be used. The current slope produces a ramp length greater than 15'-0".

**FIGURE 6.20 (ENGLISH) (CONTINUED)**

## Design Considerations:
## Ramp and Flare Length Charts

APPROXIMATE RAMP LENGTH
"G1" 8.33% SLOPE

| "G2" EXISTING GRADE (%) | | "H" CURB HEIGHT (IN) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| CHASING GRADE | 12 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| | 11 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| | 10 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| | 9 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| | 8 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| | 7 | 6.3 | 12.6 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| | 6 | 3.6 | 7.2 | 10.8 | 14.4 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| | 5 | 2.6 | 5.1 | 7.6 | 10.1 | 12.6 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| | 4 | 2.0 | 3.9 | 5.8 | 7.7 | 9.7 | 11.6 | 13.5 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| | 3 | 1.6 | 3.2 | 4.7 | 6.3 | 7.9 | 9.4 | 11.0 | 12.6 | 14.1 | 15.0 | 15.0 | 15.0 |
| | 2 | 1.4 | 2.7 | 4.0 | 5.3 | 6.6 | 7.9 | 9.3 | 10.6 | 11.9 | 13.2 | 14.5 | 15.0 |
| | 1 | 1.2 | 2.3 | 3.5 | 4.6 | 5.7 | 6.9 | 8.0 | 9.1 | 10.3 | 11.4 | 12.6 | 13.7 |
| | 0 | 1.1 | 2.1 | 3.1 | 4.1 | 5.1 | 6.1 | 7.1 | 8.1 | 9.1 | 10.1 | 11.1 | 12.1 |
| OPPOSING GRADE | -1 | 0.9 | 1.8 | 2.7 | 3.6 | 4.5 | 5.4 | 6.3 | 7.2 | 8.1 | 9.0 | 9.9 | 10.8 |
| | -2 | 0.9 | 1.7 | 2.5 | 3.3 | 4.1 | 4.9 | 5.7 | 6.5 | 7.3 | 8.1 | 8.9 | 9.7 |
| | -3 | 0.8 | 1.5 | 2.3 | 3.0 | 3.7 | 4.5 | 5.2 | 5.9 | 6.7 | 7.4 | 8.1 | 8.9 |
| | -4 | 0.7 | 1.4 | 2.1 | 2.8 | 3.4 | 4.1 | 4.8 | 5.5 | 6.1 | 6.8 | 7.5 | 8.2 |
| | -5 | 0.7 | 1.3 | 1.9 | 2.6 | 3.2 | 3.8 | 4.4 | 5.1 | 5.7 | 6.3 | 6.9 | 7.6 |
| | -6 | 0.6 | 1.2 | 1.8 | 2.4 | 3.0 | 3.5 | 4.1 | 4.7 | 5.3 | 5.9 | 6.4 | 7.0 |
| | -7 | 0.6 | 1.1 | 1.7 | 2.2 | 2.8 | 3.3 | 3.9 | 4.4 | 4.9 | 5.5 | 6.0 | 6.6 |
| | -8 | 0.6 | 1.1 | 1.6 | 2.1 | 2.6 | 3.1 | 3.6 | 4.1 | 4.6 | 5.2 | 5.7 | 6.2 |
| | -9 | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 2.9 | 3.4 | 3.9 | 4.4 | 4.9 | 5.3 | 5.8 |
| | -10 | 0.5 | 1.0 | 1.4 | 1.9 | 2.3 | 2.8 | 3.2 | 3.7 | 4.1 | 4.6 | 5.1 | 5.5 |
| | -11 | 0.5 | 0.9 | 1.3 | 1.8 | 2.2 | 2.6 | 3.1 | 3.5 | 3.9 | 4.4 | 4.8 | 5.2 |
| | -12 | 0.5 | 0.9 | 1.3 | 1.7 | 2.1 | 2.5 | 2.9 | 3.3 | 3.7 | 4.1 | 4.6 | 5.0 |

Use the above chart to determine the approximate ramp length.

Step 1. Find the appropriate curb height along the top row.
Step 2. Follow the curb height down to the existing grade slope.
Step 3. The intersecting value is the approximate ramp length at the given slope.

**FIGURE 6.20 (ENGLISH) (CONTINUED)**

## Design Considerations:
## Ramp and Flare Length Charts

APPROXIMATE RAMP LENGTH

"G1" 10% SLOPE

| "G2" EXISTING GRADE (%) | | "H" CURB HEIGHT (IN) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| CHASING GRADE | 12 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| CHASING GRADE | 11 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| CHASING GRADE | 10 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| CHASING GRADE | 9 | 8.4 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| CHASING GRADE | 8 | 4.2 | 8.4 | 12.5 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| CHASING GRADE | 7 | 2.8 | 5.6 | 8.4 | 11.2 | 13.9 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| CHASING GRADE | 6 | 2.1 | 4.2 | 6.3 | 8.4 | 10.5 | 12.5 | 14.6 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| CHASING GRADE | 5 | 1.7 | 3.4 | 5.0 | 6.7 | 8.4 | 10.0 | 11.7 | 13.4 | 15.0 | 15.0 | 15.0 | 15.0 |
| CHASING GRADE | 4 | 1.4 | 2.8 | 4.2 | 5.6 | 7.0 | 8.4 | 9.8 | 11.2 | 12.5 | 13.9 | 15.0 | 15.0 |
| CHASING GRADE | 3 | 1.2 | 2.4 | 3.6 | 4.8 | 6.0 | 7.2 | 8.4 | 9.6 | 10.8 | 12.0 | 13.1 | 14.3 |
| CHASING GRADE | 2 | 1.1 | 2.1 | 3.2 | 4.2 | 5.3 | 6.3 | 7.3 | 8.4 | 9.4 | 10.5 | 11.5 | 12.5 |
| CHASING GRADE | 1 | 1.0 | 1.9 | 2.8 | 3.8 | 4.7 | 5.6 | 6.5 | 7.5 | 8.4 | 9.3 | 10.2 | 11.2 |
| CHASING GRADE | 0 | 0.9 | 1.7 | 2.5 | 3.4 | 4.2 | 5.0 | 5.9 | 6.7 | 7.5 | 8.4 | 9.2 | 10.0 |
| OPPOSING GRADE | -1 | 0.8 | 1.6 | 2.3 | 3.1 | 3.8 | 4.6 | 5.4 | 6.1 | 6.9 | 7.6 | 8.4 | 9.1 |
| OPPOSING GRADE | -2 | 0.7 | 1.4 | 2.1 | 2.8 | 3.5 | 4.2 | 4.9 | 5.6 | 6.3 | 7.0 | 7.7 | 8.4 |
| OPPOSING GRADE | -3 | 0.7 | 1.3 | 2.0 | 2.6 | 3.3 | 3.9 | 4.5 | 5.2 | 5.8 | 6.5 | 7.1 | 7.7 |
| OPPOSING GRADE | -4 | 0.6 | 1.2 | 1.8 | 2.4 | 3.0 | 3.6 | 4.2 | 4.8 | 5.4 | 6.0 | 6.6 | 7.2 |
| OPPOSING GRADE | -5 | 0.6 | 1.2 | 1.7 | 2.3 | 2.8 | 3.4 | 3.9 | 4.5 | 5.0 | 5.6 | 6.2 | 6.7 |
| OPPOSING GRADE | -6 | 0.6 | 1.1 | 1.6 | 2.1 | 2.7 | 3.2 | 3.7 | 4.2 | 4.7 | 5.3 | 5.8 | 6.3 |
| OPPOSING GRADE | -7 | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.4 | 5.9 |
| OPPOSING GRADE | -8 | 0.5 | 1.0 | 1.4 | 1.9 | 2.4 | 2.8 | 3.3 | 3.8 | 4.2 | 4.7 | 5.1 | 5.6 |
| OPPOSING GRADE | -9 | 0.5 | 0.9 | 1.4 | 1.8 | 2.2 | 2.7 | 3.1 | 3.6 | 4.0 | 4.4 | 4.9 | 5.3 |
| OPPOSING GRADE | -10 | 0.5 | 0.9 | 1.3 | 1.7 | 2.1 | 2.5 | 3.0 | 3.4 | 3.8 | 4.2 | 4.6 | 5.0 |
| OPPOSING GRADE | -11 | 0.4 | 0.8 | 1.2 | 1.6 | 2.0 | 2.4 | 2.8 | 3.2 | 3.6 | 4.0 | 4.4 | 4.8 |
| OPPOSING GRADE | -12 | 0.4 | 0.8 | 1.2 | 1.6 | 1.9 | 2.3 | 2.7 | 3.1 | 3.5 | 3.8 | 4.2 | 4.6 |

Use the above chart to determine the approximate ramp length.

Step 1: Find the appropriate curb height along the top row.
Step 2: Follow the curb height down to the existing grade slope.
Step 3: The intersecting value is the approximate ramp length at the given slope.

**FIGURE 6.20 (ENGLISH) (CONTINUED)**

**Design Considerations:**
**Ramp and Flare Length Charts**

## 6.10 CURB RAMP DESIGN REQUIREMENTS FOR ROADWAY INTERSECTIONS

**A. Separate Curb Ramps or Single "Diagonal" Curb Ramp.**

**1.** Two separate curb ramps (one curb ramp per crossing direction) must be used at each roadway intersection corner for all projects where technically feasible. This provides several advantages such as increased visibility, directional cues, decreased pedestrian crossing distance and does not require a wheelchair user to change direction when entering or leaving the curb ramp.

**2.** A single diagonal curb ramp (one curb ramp per two crossing directions at the middle of the curve) may be used where separate curb ramps are not feasible. Diagonal curb ramps are acceptable (with ADE of Design or delegate approval), provided crosswalks are constructed wide enough that a person in a wheelchair may enter either crosswalk from the ramp or the crosswalk markings provide a minimum 1220 mm (48 in) wide overrun clear zone at the bottom of the curb ramp. It is important to a visually impaired person using the sidewalk that the location of the curb ramps be as uniform as possible within a general area. See Publication 72M, *Roadway Construction Standards*, RC-67M for typical Type 1 curb ramp layouts at an intersection.

Diagonal curb ramps are not preferred and should be <u>used sparingly</u> in areas where pedestrian or vehicular traffic volumes are both moderate to high. Avoid using single ramps for large radius corner curbs. This type of location is less satisfactory for persons with visual disabilities since they are not useful to provide directional information about the crosswalk and may misdirect users.

Diagonal curb ramp locations also require pedestrians using wheelchairs to change direction when entering or leaving the curb ramp unless a diagonal intersection movement is allowed. The turning movement requires more time to cross the intersection and is performed where the pedestrian may be exposed to turning vehicular traffic.

When an existing diagonal curb ramp is altered, the existing diagonal curb ramps must be removed and replaced with separate curb ramps where technically feasible. Diagonal ramps will be acceptable for the following situations:

- Separate curb ramps cannot be installed to fully meet PennDOT standards; however, a diagonal ramp can be installed and fully meet PennDOT standards.
- When separate curb ramps would create a negative impact to:
  - Sight distance
  - Alignment with curb ramps on other side of street
  - Drainage/ponding
  - Relocated cross walk or stop bar locations would be undesirable
- Installation of separate curb ramps would require significant out of scope work that would stop construction or cancel project.
- Other factors as determined by the ADE of Design.

**B. Pedestrian Crosswalk Location.** Establish the inside pedestrian crosswalk lines by bisecting the intersection radii. The outside crosswalk lines may be placed close to the edge of the curb ramp if necessary. Sound engineering judgment is always necessary for minor adjustments in the curb ramp locations if the intersection has corners with varying radii or the corner is critical for ramp location.

**C. Flares and Crosswalks.** Single corner (Diagonal) Type 1 curb ramps must have at least a 610 mm (24 in) long segment of full height curb located on each side of the curb ramp between the flare and the nearest marked crosswalk lines.

**D. Drainage.** Curb ramps should not be located where pedestrians must cross drainage structures such as inlets and manholes. Design must consider both the location of the curb ramp and the location of the drainage structures in new construction. Locate additional drainage inlets on the upstream side of all curb ramps where applicable and locate curb ramps away from low points of the curb return.

## 6.11 CURB RAMP DESIGN CRITERIA

**A. See PAR Requirements.** Section 6.5.

**B. Depressed Curb for Curb Ramps.** The transition from curb ramp to adjacent sidewalks, streets or gutters, etc. must be flush and free of abrupt changes. For pedestrians using a wheelchair, a vertical lip at the depressed curb for curb ramps causes the pedestrian to exert additional force and may result in a backward direction fall. A vertical lip is acceptable and practical at depressed curb for driveways since it is not located within the PAR and only vehicles will travel across this change in elevation.

**C. Curb Ramp Slopes.** The least possible slope must be used for any curb ramp. However, the maximum curb ramp slope is 1V:12H (8.33%). Care should be taken to assure a uniform grade on the curb ramp free of sags and short grade changes. Position the ramp slope perpendicular to the curb to provide a grade break that may be approached perpendicularly. See Figure 6.11. It may be necessary to limit the run of a parallel or perpendicular curb ramp in order to avoid chasing grade indefinitely when traversing the height of curb. Curb ramp length not to exceed 4500 mm (15 ft). Adjust the curb ramp slope as needed to provide access to the maximum extent feasible.

**D. Curb Ramp Widths.** Minimum width of a curb ramp is 1220 mm (48 in) exclusive of flared side slopes.

**E. Flares Located Within Pedestrian Access Route.** Curb ramp side flares positioned where pedestrians can walk across them must have flared sides with a maximum slope of 1V:10H (10.00%), measured parallel along the curb. If the level landing at the top of the curb ramp is less than 4 ft deep, flares shall be 8.33% maximum. It may be necessary to limit the length of a flare in order to avoid chasing grade indefinitely when traversing the height of curb. Flare length, measured along the curb, should not exceed 4500 mm (15 ft). Adjust flare slope as needed to provide access to the maximum extent feasible. See Publication 72M, *Roadway Construction Standards*, RC-67M details for additional information.

**F. Flares and Return Curbs Located Outside of Pedestrian Circulation Path.** In locations where pedestrians would not normally walk across the flare due to sidewalk obstructions such as street furniture, poles, fire hydrants, grass or tree lawns, return curbs may be used thereby eliminating the need for flared side slope surfaces (Type 4 and 4A curb ramps, see Publication 72M, *Roadway Construction Standards*, RC-67M). Note: Objects cannot be placed where they would affect clear zone or sight distance requirements.

**G. Landing Requirements.**

**1.** Triangular Landings on Radial Curb. If a curb ramp is not installed perpendicular to the curb, a triangular landing must be installed at the bottom of the curb ramp to provide an approach to the grade break. Installing the curb ramp in the same direction as the crossing provides a directional cue for pedestrians with visual disabilities. The detectable warning surface must be installed behind the grade break.

**2.** Type 1 Curb Ramps. For a Type 1 curb ramp a landing is required at the top of the curb ramp and is connected to the continuous passage. For alterations to existing facilities where site infeasibility precludes the 1220 mm (48 in) landing length at the top of the curb ramp and other curb ramp types do not provide adequate access, then a minimum 915 mm (36 in) landing length may be provided. When the Type 1 curb ramp top landing is less than 1220 mm (48 in), the slope of the side flares must be 1V:12H (8.33%) maximum.

**H. Miscellaneous Requirements.**

**1.** Railings. Curb ramps do not require handrails.

## 6.12 TRAFFIC CONTROL REQUIREMENTS

The requirements described herein may not fit all situations and cannot replace the need for the use of sound engineering judgment in the location and design of curb ramps and crosswalk markings. Although the written guidance in this Manual does not indicate that a diagonal curb ramp requires the installation of a crosswalk, as a safety consideration, new crosswalk striping should be added to projects in medium to high pedestrian traffic areas to create the necessary clear space within the crosswalk configuration.

**1.** When the curb ramp is at the middle of curve (MC), the inside pedestrian crosswalk lines should be established by bisecting the intersecting radii and locating the crosswalk lines 1220 mm (48 in) from the MC as shown on the Standards for Roadway Construction.

**2.** Stop line markings should be used where it is important to indicate the point behind which vehicles are required to stop in compliance with a traffic signal, stop sign or other legal requirements. Markings should be placed 1220 mm (48 in) in advance of and parallel to the nearest crosswalk line.

**3.** For additional design guidance and recommendations with respect to pedestrian crosswalk markings, refer to the *MUTCD*.

## 6.13 PEDESTRIAN CROSSING CONTROLS

When provided, pedestrian-actuated crosswalk crossing controls on accessible routes must meet the following guidelines:

**1.** Controls must be raised from or flush with their housings and be a minimum of 50 mm (2 in) in the smallest dimension. The force required to activate the control must be no greater than 22 N (5 lb).

**2.** Controls must be located as close as practicable to the curb ramp serving the controlled crossing and permit operation from a clear ground space. Control location must not interfere with the movement of pedestrians on or across the curb ramp.

**3.** Controls must be a maximum height of 1065 mm (42 in) above the finished sidewalk surface.

**4.** A firm stable and slip resistant area with a minimum size of 1220 mm × 1220 mm (48 in × 48 in) must be provided to allow for a forward or parallel approach to the controls. Where a parallel approach is provided, controls must be within 255 mm (10 in) horizontally of and centered on the clear ground space. Where a forward approach is provided, controls must abut and be centered on the clear ground space.

**5.** Refer to the *MUTCD* for additional guidance.

## 6.14 TEMPORARY ALTERNATE CIRCULATION PATHS AT CONSTRUCTION SITES

Construction and alteration work within the public right-of-way that affects pedestrian circulation elements, spaces, or facilities must comply with the following provisions:

**1.** Construction or alterations affecting pedestrian pathways must require the provision of a safe, alternate and accessible pedestrian circulation path around the construction activities.

**2.** The alternate route must comply with all applicable design guidelines to the maximum extent feasible under existing conditions so that the usability of the accessible route is maintained.

**3.** The alternate route must be kept in place through the duration of the construction activity and must be clearly signed for pedestrian use. See Publication 213, *Temporary Traffic Control Guidelines*, PATA 40 and 41 and *MUTCD* Figures 6H-28 and 6H-29 for pedestrian notification signage for pedestrian route closings and detours.

**4.** The alternate route should be provided on the same side of the street as the disrupted route, to the maximum extent feasible. Where it is not feasible to provide a same-side alternate circulation path, detour the pedestrians to a similar level of accessible route as the disrupted route as close to the construction site as possible. The detour circulation path may require the installation of temporary accessible pedestrian signals, curb ramps, or other accessibility facilities.

**5.** Walking surfaces must be firm, stable, slip-resistant, at least 1525 mm (60 in) wide and be maintained free of rubble or debris that would adversely affect the movement of persons with mobility problems. The width may be reduced to 1220 mm (48 in) if passing areas 1525 mm × 1525 mm (60 in × 60 in) are provided every 61 m (200 ft).

**6.** The alternate circulation path must be protected from construction activities, drop-offs, and vehicular traffic with approved pedestrian barricades or channelizing devices. The pedestrian barriers or channelizing devices must be continuous, stable and non-flexible and consist of a wall, fence, or enclosures specified in *MUTCD* Sections 6F.63, 6F.68 and 6F.71 with detectable, continuous bottom edge 150 mm (6 in) maximum height above the walkway surface.

**7.** The barricades and channelizing devices must also provide a continuous surface or upper rail at a 915 mm (36 in) minimum height above the walkway surface and toe rail at 150 mm (6 in) maximum height above the walkway surface. Support members may not protrude into the alternate circulation path. Sidewalk barriers should be detectable by blind pedestrians or those who have low vision. Plastic tape, movable cones, and print signs at a sidewalk excavation will not generally provide adequate notice or protection. Accessibility provisions for protruding objects and construction barrier criteria in the *MUTCD* offer helpful guidance in this area.

**8.** Protrusions into the alternate circulation path are not permitted.

## 6.15 TECHNICAL Q&A INFORMATION FOR ACCESSIBILITY ISSUES

These questions and answers are general in nature and may not be inclusive of the full scope of accessibility issues at a given site. All alteration project sites must be fully evaluated on a site by site basis to determine what accessibility issues should be included in the alteration work operations.

All curb ramp details in the 2010 ADA Standards, PROWAG and other approved reference sources that have developed various curb ramp types are indicated for new construction applications. There are few specific alteration construction details since there could be innumerable existing site conditions that could require detail adjustments. However, several alteration details have been added to Publication 72M, *Roadway Construction Standards*, RC-67M for certain accessibility situations. Each curb ramp alteration will require engineering adaptation to adjust the construction detail to the alteration site conditions.

The answers to these questions have been derived from several sources related to the ADA law, ADAAG standards, PROWAG and FHWA guidelines.

### A. ADA Authority and Function.

***1. Question*** **- What's the difference between the ADA, ADA regulations and ADAAG?**
***Answer* -** The Americans with Disabilities Act (ADA) is a law passed in July 1990 that prohibits discrimination on the basis of disability. The statute required certain designated Federal agencies to develop implementing regulations, the first of which were promulgated in July of 1991. This rulemaking continues today. The regulations detail a wide range of administrative and procedural requirements, including compliance with design and construction standards; those standards are expressed in the Americans with Disabilities Act Accessibility Guidelines (ADAAG). ADAAG contains requirements for new construction and alterations. The U.S. Access Board develops the requirements as "guidelines" to serve as a basis for "standards" enforced by the Department of Justice (DOJ) and the Department of Transportation (US DOT). ADAAG derived from an earlier Federal standard, the Uniform Federal Accessibility Standards (UFAS). See Section 6.2 for additional information.

***2. Question* – Is PennDOT responsible for all ADA curb ramps for all accessible routes within our highway right-of-way regardless of who has jurisdiction for an intersecting municipal street or roadway?**
***Answer* -** Pennsylvania law does not, as a rule, require PennDOT to construct sidewalks. The Department is permitted by Pennsylvania law to install sidewalks as a part of State funded projects under certain circumstances including the need to address the safety of pedestrian traffic. Generally, sidewalk installation is at the discretion of the Secretary and requires a formal agreement with the involved municipality or local government. The installation of a sidewalk is considered a "construction improvement" with repairs and maintenance being a local government responsibility.

Similarly, the legal responsibility for maintenance of pedestrian facilities beyond the curb line, with certain exceptions, lies with either the municipality or adjoining property owners. The curb ramp is a portion of the sidewalk system that allows ADA pedestrian accessibility across the roadway.

The ADA effectively preempted PA law regarding responsibility for areas beyond the curb line by attaching liability for construction of curb ramps to the "public entity" with the responsibility or authority over streets, roads or walkways. (PennDOT is responsible to provide curb ramps that cross state roadways and local municipalities are responsible to provide curb ramps that cross their streets and other roadways.)

The ADA did not, however, assign a maintenance obligation to the "public entity" installing the curb ramp. Therefore, PA law has not been preempted concerning maintenance obligations and PennDOT is not required to maintain a curb ramp behind the curb line even though we may have originally constructed the ramp to provide access across a municipal street or roadway. See Section 6.6 for additional information.

**3. *Question* - What is the public right-of-way?**
***Answer* -** The public right-of-way consists of everything between the right-of-way limits, including travel lanes, medians, planting strips, sidewalks and other facilities.

***4. Question* - What are the elements of an accessible design?**
***Answer* -** Public agencies have the choice of whether to follow the standards in the ADA Accessibility Guidelines (ADAAG) or the Uniform Federal Accessibility Standards (UFAS). Source: 28 CFR §35.151(c); (Appendix A to 28 CFR Part 36). *FHWA encourages public agencies to use ADAAG and the United States Access Board Public Rights-of-Way Accessibility Guidelines (PROWAG) as a best practice where the current standard, ADAAG, is silent or inapplicable, according to a February 2006 Federal Highway Administration (FHWA) Memorandum.* Under the ADAAG standards, an accessible design to a highway, street, or walkway includes accessible sidewalks and curb ramps with detectable warnings. Source: 28 CFR §35.151(c) and (e) (curb ramps), ADAAG 4.3-4.5 (accessible routes), 4.7 (curb ramps with detectable warnings), 4.29 (detectable warnings). Continuously maintained sidewalks are required by the case of Barden v. City of Sacramento, 292 F.3d 1073 (9th Cir. 2002), cert. denied, 123 S.Ct. 2639 (2003).

Accessible pedestrian signals and signs must be considered, with a reasonable and consistent plan to facilitate safe street crossings. Source: 28 CFR §35.151(c); 23 U.S.C. §217(g)(2). See Section 6.2 for additional information.

***5. Question* - When should accessible design elements be incorporated into projects in the public right-of-way?**
***Answer* -** FHWA encourages the consideration of pedestrian needs in all construction, reconstruction and rehabilitation projects. If a public agency provides pedestrian facilities, those facilities must be accessible to persons with disabilities. A public agency is not relieved of its obligation to make its pedestrian facilities accessible if no individual with a disability is known to live in a particular area. This is true regardless of its funding source. Source: DOJ's ADA Title II Technical Assistance Manual, § II-5.1000, 1993. See Section 6.0 for additional information.

***6. Question* - What should a public agency do when it does not control all of the public right-of-way required to provide access for persons with disabilities?**
***Answer* -** The public agency should work jointly with all others with interests in the highway, street, or walkway to ensure that pedestrian access improvements occur at the same time as any alteration or new project. *The ADA encourages this cooperation by making each of the public agencies involved subject to complaints or lawsuits for failure to meet the ADA and Section 504 requirements.* Source: 28 CFR §§ 35.170 – 35.178. See Section 6.2.B for additional information.

***7. Question* - Does the ADA permit an individual with a disability to sue when that individual believes that discrimination is about to occur, or must the individual wait for the discrimination to occur?**
***Answer* -** The ADA permits an individual to allege discrimination based on a reasonable belief that the planned construction or alteration of a place of public accommodation, such as curb ramps, have not been adequately provided at public sidewalk crossings of a street or are non-conforming to the ADAAG. The resolution of such challenges prior to the construction of a facility is encouraged to enable any necessary remedial measures to be incorporated during the planning, design, or construction stages, when such changes can be more readily addressed. FHWA has federal oversight authority for the investigation of transportation related ADA issues.

***8. Question* - What projects must provide pedestrian access for persons with disabilities?**
***Answer* -** Any project for construction or alteration of a facility that provides access to pedestrians must be made accessible to persons with disabilities. Source: 42 U.S.C. §§ 12131 - 12134; 28 CFR §§ 35.150, 35.151; Kinney v. Yerusalim**,** 9 F.3d 1067 (3d Cir. 1993), cert. denied, 511 U.S. 1033 (1994). See Section 6.2 for additional information.

***9. Question* - How does cost factor into a public agency's decision in its transition plan concerning which existing facilities must comply with ADA and Section 504 pedestrian access requirements?**
***Answer* -** For existing facilities requiring accessibility improvements as scheduled in the transition plans, the public agency must provide accessibility improvements unless the cost of the upgrades is unduly burdensome. The test for being unduly burdensome is the proportion of the cost for accessibility improvements compared to the agency's overall budget, not simply the project cost. Source: 28 CFR Part 35, App. A, discussion at §35.150, ¶¶ 4 – 7.

The decision that pedestrian access would be unduly burdensome must be made by the head of a public agency or that official's designee, accompanied by a written statement of the reasons for the decision. Source: 28 CFR §35.150(a)(3).

***10. Question* - Can cost be a reason not to complete an ADA-required accessibility improvement for a new project planned outside of the transition plan, with ADA accessibility improvements required to make the facility readily accessible and usable by individuals with disabilities?**
***Answer* -** No. Cost may not be a reason to fail to construct or delay constructing a new facility so that the facility is readily accessible to and usable by persons with disabilities under the ADAAG standards. Source: 28 CFR §35.151(a); see DOJ Technical Assistance Manual for Title II of the ADA, II-6.3100(3). See Section 6.2.B.4 for additional information.

***11. Question* - Can cost be a reason to decide what ADA-required improvements will be completed for an alteration project planned outside of the transition plan, with ADA accessibility improvements required within the scope of the project?**
***Answer* -** No. Cost may not be a reason for a public entity to fail to complete an ADA-required improvement within the scope of an alteration project under the ADAAG standards. A public agency must complete any ADA-required accessibility improvements within the scope of an alteration project to the maximum extent feasible. Source: 28 CFR §35.151(b); DOJ Technical Assistance Manual for Title II of the ADA, II-6.3100(4). See Section 6.2.B.4 for additional information.

***12. Question* - Can a public agency delay compliance with the ADA and Section 504 on alteration projects through a systematic approach to schedule the project?**
***Answer* -** No. All pedestrian access upgrades within the scope of the project must occur at the same time as the alteration. Source: Kinney v. Yerusalim**,** 9 F.3d 1067 (3d Cir. 1993), cert. denied, 511 U.S. 1033 (1994). See Section 6.2.B for additional information.

## B. General Design Criteria.

***1. Question* - Are handrails required for curb ramps?**
***Answer* -** Handrails are not required on curb ramps. (ADAAG Section 4.8.5)

***2. Question* - Is there a minimum landing width requirement at the top of a curb ramp? *ADAAG* Figure 12 shows a dimension "X" that is related to the slope of the side flares, but does not indicate a minimum.**
***Answer* -** The ADAAG minimum landing width at the top of a curb ramp is 915 mm (36 in). PROWAG minimum landing requires a minimum of 1220 mm (48 in). It should be noted, Publication 72M, *Roadway Construction Standards*, RC-67M depicts a 1220 mm (48 in) minimum landing. A curb ramp is part of the accessible route and must maintain a maximum 1V:50H (2.00%) cross slope. Where pedestrians perform turning maneuvers, a level landing [1V:50H (2.00%) maximum longitudinal and cross slope in any direction] is required.

Figure 12 in the ADAAG is not intended to represent all of the requirements for curb ramps. The actual requirements are contained in the text of the technical specifications (*ADAAG 4.3.3 & 4.7.1).* See Section 6.11.G for additional information.

***3. Question* - Does a level landing mean a zero percent slope?**
***Answer* -** The requirement for level landings refers to ramps (ADAAG Section 4.8.5) and does not refer specifically to curb ramps. In general, "level" means having a slope no greater than 1V:50H (2.00%) in longitudinal and cross slope. Landings at the top of curb ramps are generally part of a sidewalk configuration and are permitted to have a maximum cross slope of 1V:50H (2.00%) to allow for drainage to avoid the accumulation of water on the sidewalk. Any cross slopes on sidewalks and other ground surfaces can cause considerable difficulty in maneuvering a wheelchair in a straight line. See Section 6.1 for additional information.

***4. Question* - Are curb ramps required to have detectable warnings?**
***Answer* -** Originally, ADAAG required detectable warnings, a distinctively bumpy surface (truncated dome) detectable by cane and underfoot, on the entire surface of curb ramps to provide a tactile cue for persons with vision impairments of their approach to streets. This warning was required since the sloped surfaces of curb ramps remove a tactile cue provided by curb faces. The U.S. Access Board temporarily suspended these requirements for curb ramps in 1994 due to concerns raised about the technical specifications, the availability of complying products, snow and ice removal maintenance issues, usefulness and safety. DOJ and US DOT joined in this action, which effectively removed the requirement from the enforceable standards. The suspension was extended twice (in 1996 and 1998) to accommodate the review and update of ADAAG. The ADAAG Review Advisory Committee recommended that the issue of detectable warnings at curb ramps should be resolved specifically in relation to public rights-of-ways before reinstating any requirements in ADAAG, which specifically now applies to facilities on sites. The Board agreed and did not include requirements for detectable warnings at curb ramps in its update of ADAAG. Consequently, the Board did not further extend the suspension, which expired on July 26, 2001. Since the enforcing agencies did not also extend the suspension, the detectable warning requirements *are technically part of the standards again.* New guidelines have been developed and will be presented for public street curb ramps in a forthcoming guideline covering public rights-of-way (PROW). Publication 72M, *Roadway Construction Standards*, RC-67M has been revised to incorporate the new truncated dome dimensions and alignment. See Section 6.5.A.8 for additional information.

***5. Question* - Some older curb ramps have grooved or other textured surface treatments that were to make them detectable by persons with visual impairments or create a slip-resistance surface. Are these surfaces acceptable as the detectable warning strip requirement on curb ramps and other hazardous vehicular crossings?**
***Answer* -** No. A number of other textured surfaces have been used on curb ramps, but they have not been demonstrated to be highly detectable to pedestrians who are blind, both underfoot and by the use of a long cane. Grooved cement has been found to be minimally detectable to people using a long cane as a travel aid and it is even less detectable underfoot. Other decorative surfaces that may be assumed to be detectable have not been tested for detectability. Many surfaces that look like they should be highly detectable have been found to be low in detectability. Consistency in a warning surface is essential if it is to reliably be understood as a warning by pedestrians with visual impairments. The truncated dome texture specified in ADAAG (4.29.2) is the only surface that should be considered a detectable warning. See Section 6.5.A.8 for additional information.

***6. Question* - The truncated dome warning surface is to cover the entire surface of the curb ramp in the original ADAAG. Why has this requirement been changed to require only a 610 mm (2 ft) wide strip at the bottom of the curb ramp?**
***Answer* -** The change was made to reflect the width of detectable warning strips required at transit platform edges (ADAAG 1991). The rationale for the 610 mm (2 ft) width of detectable warnings has been repeatedly demonstrated to be a sufficient width of a surface highly detectable both underfoot and by use of a long cane, to enable detection and stopping on that surface by most blind travelers. A longer width of the detectable surface can confuse pedestrians that have become accustomed to the shorter requirement and mislead them as to where the edge of the street is actually located.

***7. Question* - Why has the alignment of the truncated domes been changed? Is the older arrangement of domes on an existing curb ramp still in compliance with the ADA?**
***Answer* -** The desired current arrangement of the rows of domes is to be aligned with the path of wheelchair travel and perpendicular to the grade break at the toe of the ramp. Pedestrians encountering either configuration will find the surface pattern equally detectable and the older alignment is still in compliance with ADAAG. See Section 6.5.A.8.b for additional information.

***8. Question* - Do sidewalk crossings of residential driveways require detectable warning surfaces on either side of the driveway?**
***Answer* -** No. Generally sidewalk crossings of residential driveways will not be provided with detectable warnings, since the pedestrian right-of-way continues across most driveway aprons and overuse of detectable warning surfaces should be avoided in the interest of message clarity for persons with visual impairments. See Section 6.5.A.8 for additional information.

***9. Question* - Do sidewalk crossings of commercial driveways require detectable warnings?**
***Answer* -** Yes, in certain situations. Where commercial driveways are provided with traffic control devices or otherwise are permitted to operate like public streets, detectable warnings should be provided at the junction between the pedestrian route and the commercial driveway. See Section 6.5.A.8 for additional information.

***10. Question* - Must the dimensions indicated in ADAAG be precisely met?**
***Answer* -** Yes. Dimensions that are not marked minimum or maximum are absolute, unless otherwise indicated in the text or captions.

***11. Question* - Must the bottom of the curb ramp at the depressed curb line be flush with the adjacent roadway surface? Doesn't ADAAG allow for a 6 mm (0.25 in) vertical rise?**
***Answer* -** The ADAAG specifically states that the transition from curb ramps to walks, gutter or streets must be flush and free of abrupt changes. Any lip at the transition area can cause disruption to wheelchair movement since the small front wheels (casters) swivel freely. When the casters hit a raised lip, they swivel sideways and stop rolling. ADAAG does allow (Section 4.5.2) vertical changes in level up to 6 mm (0.25 in) without edge treatment *along an accessible route*, but the requirement for curb ramp transition to an adjacent surface requires a flush transition. See Section 6.11.B for additional information.

***12. Question* - Is environmental documentation required for curb ramps during resurfacing projects?**
***Answer -*** That is a decision that must be made based on the overall scope of the alteration project. Publication 10B, Design Manual, Part 1B, *Post-TIP NEPA Procedures*, provides two CE actions that should cover this work if there is no additional right-of-way required in the project. Resurfacing is covered by a Level 1b CE Action #1 - modernization of a highway by resurfacing. Curb ramps are covered by a Level 1a CE Action #3 - Construction of bicycle and pedestrian lanes, paths and facilities and #15 – Alterations to facilities or vehicles in order to make them accessible for the elderly and handicapped persons.

A Level 1a CE is approved by the District Environmental Manager. A Level 1b CE is approved by the District Executive.

***13. Question* - If the intersection is provided with crosswalks must the curb ramp be inside the crosswalk lines?**
***Answer -*** The curb ramps at indicated crosswalks must be contained within the crosswalk lines. For ramps that serve only one crosswalk direction, the flares may be placed outside of the crosswalk. For diagonal ramps that serve two crosswalk directions, the flares must be inside of the crosswalk lines. See Publication 72M, *Roadway Construction Standards*, RC-67M for details.

***14. Question* - Do pedestrian sidewalk crossings of curbed alleys require curb ramps?**
***Answer -*** Yes. Detectable warnings should be provided at the junction between the pedestrian route and the alley. All pedestrian crossings of a curbed roadway must be provided with accessible curb ramps complete with detectable warning surfaces since the alley represents a hazard in the line of travel for pedestrians who are visually impaired. See Section 6.5.A.8 for additional information.

***15. Question* - Should detectable warning surfaces be placed at sidewalk crossings of alleys that are at the same elevation as the sidewalk?**
***Answer -*** Yes. Detectable warnings should be provided at the junction between the pedestrian route and the alley. The sidewalk crossing of the alley presents a hazardous condition and the detectable warning surface alerts pedestrians who are visually impaired to the presence of hazards in the line of travel, indicating that they should stop and determine the nature of the hazard before proceeding further.

Also from Public Rights of Way (PROW) - Advisory R221 Detectable Warning Surfaces. "Detectable warning surfaces are required where curb ramps, blended transitions, or landings provide a flush pedestrian connection to the street." See Section 6.5.A.8 for additional information.

***16. Question* - Are existing ADA accessibility facilities constructed under previous ADA criteria required to be upgraded every time new accessibility criteria are issued?**
***Answer -*** No. Existing ADA accessibility facilities are not required to be upgraded every time new accessibility criteria are issued. However, upgrading to new criteria would be required when the existing accessibility feature is located within the project scope or limits of work of various types of alteration projects or in new construction. See Section 6.2.C for additional information.

**C. Elements of Accessible Design - Alterations.**

***1. Question* - What projects constitute an alteration to the public right-of-way?**
***Answer -*** An alteration is a change to a facility in the public right-of-way that affects or could affect access, circulation, or use. Projects altering the use of the public right-of-way must incorporate pedestrian access improvements within the scope of the project to meet the requirements of the ADA and Section 504. These projects have the potential to affect the structure, grade, or use of the roadway. Alterations include items such as reconstruction, major rehabilitation, widening, resurfacing (e.g., overlays and mill and fill), signal installation and upgrades and projects of similar scale and effect. See Section 6.1 for additional information.

***2. Question* - When does the scope of an alteration project trigger accessibility improvements for people with disabilities?**
***Answer -*** The scope of an alteration project is determined by the extent the alteration project *directly changes or affects* the public right-of-way within the project limits. *The public agency must improve the accessibility of only that portion of the public right-of-way changed or affected by the alteration.* If a project resurfaces the

street for accessibility purposes, the curb ramps, and pavement at the pedestrian crosswalk are in the scope of the project, but the sidewalks are not. Any of the facilities disturbed by the construction must be replaced so that they are accessible. All remaining access improvements within the public right-of-way must occur within the schedule provided in the public agency's planning process. See Section 6.2.B for additional information.

***3. Question* - Can my alteration project decrease or have the effect of decreasing ADA accessibility below the requirements of new construction at the time of the alteration?**
***Answer* -** No. No alteration project should be undertaken which would decrease or have the effect of decreasing accessibility or utilization of an ADA feature or facility. However, if compliance with ADA standards is *technically infeasible*, the alteration must provide accessibility to the maximum extent feasible within the scope of the alteration. See Section 6.9.D.5 for additional information.

***4. Question* - What if the ADA standards do not indicate specific details applicable for my alteration site or where full compliance to the standards would be technically infeasible?**
***Answer* -** Where ADA standards do not include detailed provisions for a specific alteration situation, the designer must determine what constitutes accessible design based on sound engineering judgment to utilize the current standards and provide accessibility to the maximum extent feasible. See Section 6.9.F for additional information.

***5. Question* - How can *technically infeasible* be better understood? Do utility and right-of-way impacts meet the definition of technically infeasible?**
***Answer* -** The highest degree of accessibility is expected in new construction. Alterations to existing facilities must observe new construction criteria where technically feasible; less stringent technical specifications may be applied where technical infeasibility is encountered. Existing facilities must achieve a level of usability that balances user needs, the constraints of existing conditions and the resources available for remedial work.

Alterations constrained by work already in place, may default to an intermediate standard when structural and site conditions prohibit full accessibility. Existing facilities must provide access to the maximum extent possible, a flexibility that permits needs to be balanced against available resources. If the alteration project scope of work involves utility relocations or additional right-of-way acquisition at the location of the pedestrian facilities, then new construction standards should be utilized. If the project scope of work does not require utility relocations or acquisition of additional right-of-way, then those elements can be considered as being constraining features or technically infeasible site conditions.

***6. Question* - What role does the "maximum extent feasible" standard play for ADA accessibility requirements in altered projects?**
***Answer* -** In an alteration project, the public agency must incorporate the ADA accessibility standards to the maximum extent feasible. Source: 28 CFR §35.151(b). The feasibility meant by this standard is physical possibility only. A public agency is exempt from meeting the ADA standards in the rare instance where physical terrain or site conditions restrict constructing or altering the facility to the standard. Source: ADA Accessibility Guidelines 4.1.6(1)(j).

Cost is not a factor in determining whether meeting standards has been completed to the maximum extent feasible. Source: DOJ's ADA Title II Technical Assistance Manual, § II-6.3200(3)-(4), 1993. *No particular decision making process is required to determine that an accessibility improvement is not technically feasible, but the best practice is to document the decision to enable the public agency to explain the decision in any later compliance review.* See Section 6.2.B.4 for additional information.

***7. Question* - Can flush mounted utility valve boxes, junction boxes, manholes, etc. be located in a curb ramp surface, side flare, or landing?**
***Answer* -** Yes, existing utilities may be located within the pedestrian access route, if necessary. However, the box cover or manhole surface must be stable, firm, slip-resistant and flush with the adjacent surface. Proposed utilities must be placed outside of the pedestrian access route. See Section 6.5.B for additional information.

***8. Question* - Can utility, signal, or sign poles, fire hydrants, etc. be located in curb ramp side flares as long as lateral clearances for accessibility are met?**
***Answer* -** If necessary, yes. All attempts to relocate vertical obstructions to provide full accessibility should be attempted and easy to relocate features such as a sign pole can be readily relocated in most cases without adversely affecting its function on the street. There is no provision in the ADA to require moving existing utilities or acquiring new right-of-way for alteration work.

There are also several curb ramp design types that do not feature side flares that may be utilized to meet existing site conditions and help to prevent keeping poles or other undesired features from being located in the pedestrian curb ramp walkway. Side flare curb ramp types are generally utilized where pedestrians would have the need to laterally cross the ramp or for a wheelchair to make a turning movement. Providing appropriate lateral accessibility clearance** at a pole (post, fire hydrant, street tree, etc.) location would be necessary. Curb ramps with returned curbs may be used where pedestrian traffic would not normally be expected to walk across the ramp.

** The minimum clear width ground space for an accessible route for single point access is 815 mm (32 in), for a maximum length of 24 in, to accommodate single wheelchair passage (ADAAG 4.2.1). The remainder of the accessible route is 915 mm (36 in) minimum clear width (ADAAG 4.3.3). PROWAG requires a minimum 1220 mm (48 in) pedestrian access route. Recommended guideline: The **1220 mm (48 in) dimension should be used** as the desired minimum single point access dimension whenever possible due to the probability of multiple pedestrians. Pedestrian access route should not be confused with sidewalk width.

Alteration projects that include the installation of or relocation of poles, posts, street trees, fire hydrants, or other types of street furniture on or near existing pedestrian pathways must provide the required accessibility clearances designated for a pedestrian access route. See Section 6.5.B for additional information.

***9. Question* - New curb ramps are being installed at an existing developed corner. New construction standards require the curb ramp to be within the crosswalk, but an existing underground utility vault is located where the ramp should be. Must the utility vault be moved?**
***Answer* -** The scope of the project will determine the answer. If utilities are being moved for other reasons within the project limits, it may be possible to alter or relocate the vault. If project construction will not involve the vault, it may be technically infeasible to position the curb ramp at an optimal location. It may also be possible to widen the crosswalk markings to include the curb ramp.

***10. Question* - What if the curb ramp can be placed over the vault, but the access cover would be located on the curb ramp?**
***Answer* -** If the access cover must be located on the curb ramp, it should meet the surface requirements of the pedestrian access route (stable, firm, slip-resistant and flush with the adjacent surface). See Section 6.5.B for additional information.

***11. Question* - If existing diagonal curb ramps are present or proposed, should crosswalk striping be included in the project?**
***Answer* -** Diagonal curb ramps should be proposed sparingly in areas where pedestrian traffic is moderate to high. All curb ramps are to have a minimum 1220 mm (48 in) clear space (overrun area) on the street at the bottom of the curb ramp in order for wheelchair users to maneuver and change direction to cross the street in the direction of pedestrian traffic. Crosswalk configurations indicated in Publication 72M, *Roadway Construction Standards*, RC-67M encompass this clear space and provide some degree of safety to the pedestrian while maneuvering across the street. Although the written guidance in this chapter does not indicate that a diagonal curb ramp requires the installation of a crosswalk, as a safety consideration, new crosswalk striping should be added to projects in medium to high pedestrian traffic areas to create the necessary clear space (overrun area) within the crosswalk configuration.

***12. Question* - Is it acceptable to retain a drainage inlet or manhole in place where a pedestrian with a disability could cross them?**
***Answer* -** If necessary, yes. The ADA does not desire to prevent these existing crossings except for new construction where they can be addressed in design. Remember that the ground surface for any accessible route must be stable, firm and slip-resistant. Grates and manhole covers must also be flush with the adjacent surface. Every effort should be made to position the ramp surface direction so that the pedestrian does not have to cross an inlet. The ADAAG makes provision for the appropriate grate type*** that is permissible in an accessible route walking surface. Note: The reduced opening size for ADA accessible grates may greatly reduce the hydraulic efficiency for the street inlet and increase the accumulation of debris at the inlet.

*** If gratings are located in walking surfaces, then they must have spaces no greater than 13 mm (0.5 in) wide in one direction. If gratings have elongated openings, then they must be placed so that the long dimension is perpendicular to the dominant direction of travel. See Section 6.5.B for additional information.

***13. Question* - Do we need to install a curb ramp at street locations where the adjacent roadway or gutter slopes exceed the ADAAG standard of 1V:20H (5.00%)?**
***Answer* -**Yes. The ADAAG is basically written for new construction where these issues can be addressed and avoided in design. In the original ADAAG, curb ramps were to be installed where an accessible route crossed a roadway; however, this provision has been greatly expanded in later years to where curb ramps are expected at every curbed roadway intersection where sidewalks enter the street. In an existing right-of-way that is not otherwise being altered, the minimum requirement for achieving program accessibility is the installation of curb ramps at selected locations where existing pedestrian walkways cross curbs. Even on steep sites, pedestrians using motorized wheelchairs or being assisted in traveling can use curb ramps and a connection to the street crossing should be available if there is a pedestrian walkway.

U.S. DOJ ADA Title II, Technical Assistance Manual Guidance – II-6.6000 Curb ramps. "When streets, roads, or highways are newly built or altered, they *must* have ramps or sloped areas *wherever there are curbs* or other barriers to entry from a sidewalk or path. Likewise, when new sidewalks or paths are built or altered, they *must* contain curb ramps or sloped areas *wherever they intersect with streets, roads, or highways*."

If it is not possible to install a curb ramp that is fully compliant with ADAAG in an existing sidewalk, each feature of accessibility should be maximized within the constraints of the site conditions at that location. Every decision must be arrived at individually, after considering the effects of contributing factors for the given site conditions based on the following guideline:

Alterations must follow the ADA Standards for Accessible Design unless compliance is technically infeasible. Where the nature of an existing facility makes it virtually impossible to comply with all of the accessibility standards applicable to planned alterations, any altered features of the facility that can be made accessible must be made accessible.

Additionally, because alterations to existing rights-of-way offer fewer opportunities to mitigate the effects of topography and to incorporate maneuvering space and other accessibility features, accessibility guidelines include less stringent technical criteria for some conditions, such as a steeper permitted slope for a curb ramp where it may be technically infeasible to meet new construction requirements. Alterations, however, may not be undertaken that have the effect of reducing existing levels of accessibility below the requirements for new construction.

***14. Question* - Curb ramp alteration work must transition to the adjacent existing sidewalk width and cross slope at some point. Is there a limit to the length of adjacent sidewalk that should be replaced?**
***Answer* -** The curb ramp must be constructed to meet the standards. The transition to the existing sidewalk width and cross slope will be as per Publication 72M, *Roadway Construction Standards,* RC-67M. The transition may not meet the standards but is intended to serve as temporary connection until the substandard sidewalk can be addressed in a subsequent project. See Section 6.3.D for additional information.

***15. Question* - A multi-block length of roadway is being resurfaced. The intersection corners have curb ramps that meet some but not all of the current design guidelines. For example, the cross slope may be too steep or the curb ramps do not have detectable warnings. Must the curb ramps be reconstructed to the latest guidelines as part of the resurfacing project?**
***Answer* -** Yes, if it is technically feasible to provide the complying facilities. The work should be done at the same time the resurfacing is being done. See Section 6.2.B for additional information.

***16. Question* - One corner of an intersection is being altered by curb and gutter reconstruction and paired curb ramps are being installed as part of this project. The other three corners of the intersection are not being altered. Must new upgraded curb ramps be provided at the unaltered corners as part of this work?**
***Answer* -** No. The scope of the project requires new upgraded curb ramps *only at the altered corner.* (Note: The ramps of the unaltered corner must be added to the transition plan.) See Section 6.2.B for additional information.

***17. Question* - What activities are not considered to be alterations?**
***Answer* -** The DOJ does not consider maintenance activities, such as filling potholes, to be alterations. The DOJ does consider *resurfacing to be an alteration.* Source: DOJ's ADA Title II Technical Assistance Manual, § II-6.6000, 1993.

The FHWA has determined that maintenance activities include actions that are intended to preserve the system, retard future deterioration and maintain the functional condition of the roadway without increasing the structural capacity. These activities include, but are not limited to, thin surface treatments (nonstructural), joint repair, pavement patching (filling potholes), shoulder repair, signing, striping, minor signal upgrades and repairs to drainage systems. See Section 6.2.B.3 for additional information.

***18. Question* - Does a project altering a public right-of-way require simultaneous accessibility improvements?**
***Answer* -** Yes. An alteration project must be planned, designed and constructed so that the accessibility improvements within the scope of the project occur at the same time as the alteration. Source: 29 CFR § 35.151; Kinney v. Yerusalim**,** 9 F.3d 1067 (3d Cir. 1993), cert. denied, 511 U.S. 1033 (1994).

The ADA does not stipulate how to perform simultaneous accessibility improvements. For example, a public agency may select specialty contractors to perform different specialized tasks prior to completion of the alteration project or concurrently with an ongoing project.

***19. Question* - Will it be necessary to modify Highway Occupancy Permit drawings if changes to curb ramps impact crosswalks and stop bar locations?**
***Answer* -** The need to provide new or additional pedestrian access along and across existing highways as a result of new adjacent property development will require the approval and issuance of a PennDOT Highway Occupancy Permit (HOP) to the local government or adjacent property owner. The HOP elements may include the need for ADA accessibility facilities. PennDOT has the oversight responsibility for ADA accessibility within our roadway right-of-way including all HOP sites. Permit approvals should include the appropriate review of proposed accessibility facilities to meet approved standards and also require appropriate construction inspection to insure all permit accessibility standards have been met.

It is recommended that alterations to an existing HOP that creates substantial revisions to the functional use of the curb ramp, crosswalk configuration, or stop bar locations should be recorded by an acceptable method and become part of the HOP file. See Section 6.2.B.1.b for additional information.

## D. Elements of Accessible Design - New Construction.

***1. Question* - Is there a specific static coefficient of friction required for a surface to be "slip resistant?"**
***Answer* -** Recommended static coefficients of friction for walking vary. OSHA recommends that walking surfaces have a static coefficient of friction of 0.5. The U.S. Access Board recommends a static coefficient of friction of 0.6 for accessible routes and 0.8 for ramps. However, there are a variety of ways to measure the coefficient of friction for different materials and no single test device or procedure has been identified by the U.S. Access Board. Without a defined test procedure, these friction values cannot be applied. It is recommended to use products that are identified by the manufacturer as having a "slip resistant" surface. See Section 6.5.A.1 for additional information.

***2. Question* - Will a standard provision be developed to require contractors to remove and replace curb ramps at their own expense if a new curb ramp installation does not meet criteria?**
***Answer* -** No. Construction inspection and approval of all construction activities remain the responsibility of the Department and ADA improvements should be given the same degree of importance as any other highway construction item. Each contract accessibility feature should be field inspected, measured and approved to ensure that the proper construction details and specifications have been appropriately met. Accessibility facilities not meeting the approved standards as determined by Department construction personnel will require the contractor to remove and replace the facility until they are in conformance to the construction standards.

For alteration projects, the ADA facilities will be constructed to the maximum extent feasible within the scope of the alteration. Construction contracts will not receive final acceptance until all accessibility facilities are approved by the Department.

## E. Temporary Routes for Alteration Project Accessibility.

***1. Question* - How will alteration construction activities affect existing ADA accessibility?**
***Answer* -** Any construction activity required for alterations that affect existing pedestrian circulation paths will require the provision of a safe, alternate and accessible pedestrian route around the construction activity. The alternate route around the work zone must comply with all applicable accessibility guidelines to the maximum extent feasible so that the usability of the accessible route is maintained. The alternate route will be kept in place through the duration of the construction activity. See Section 6.14 for additional information.

## F. Maintenance Issues.

***1. Question* - Are maintenance operations considered alterations for the purpose of the ADA?**
***Answer* -** The DOJ does not consider normal maintenance activities, such as filling potholes, to be alterations. The DOJ does consider *resurfacing beyond normal maintenance to be an alteration.* Source: DOJ's ADA Title II Technical Assistance Manual, § II-6.6000, 1993.

The FHWA has determined that maintenance activities include actions that are intended to preserve the system, retard future deterioration and maintain the functional condition of the roadway without increasing the structural capacity. These activities include, but are not limited to, thin surface treatments (nonstructural), joint repair, pavement patching (filling potholes), shoulder repair, signing, striping, minor signal upgrades and repairs to drainage systems. See Section 6.2.B.3 for additional information.

***2. Question* - Do maintenance activities require simultaneous improvements of the facility to meet ADA standards?**
***Answer* -** No. Maintenance activities do not require simultaneous improvements to pedestrian accessibility under the ADA and Section 504. However, in the development of the maintenance scope of work identified accessibility needs should be incorporated into the transition process. See Section 6.2.B.3 for additional information.

***3. Question* - What obligation does a public agency have regarding snow removal in its walkways?**
***Answer* -** A public agency must maintain its walkways in an accessible condition, with only isolated or temporary interruptions in accessibility. Source: 28 CFR §35.133. Part of this maintenance obligation includes reasonable snow removal efforts. See Section 6.6 for additional information.

***4. Question* - What day-to-day maintenance is a public agency responsible for under the ADA?**
**Answer -** As part of maintenance operations, public agencies' standards and practices must ensure that the *day-to-day operations keep the path of travel on pedestrian facilities open and usable for persons with disabilities, throughout the year. This includes snow removal, as noted above, as well as debris removal, maintenance of accessible pedestrian walkways in work zones and correction of other disruptions*. Source: ADAAG 4.1.1(4). See Section 6.6 for additional information.

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# CHAPTER 6, APPENDIX A

## TECHNICALLY INFEASIBLE FORM

(05-08)

pennsylvania
DEPARTMENT OF TRANSPORTATION

# ADA Technically Infeasible Form

***Facility Type**

- Curb Ramp
- Sidewalk
- Ped. Push Button
- Ped. Signal
- Other ______

Forward All Completed Forms to PennDOT Construction

**Justification for Technically Infeasible**

*(check all that apply)*

- ☐ Limited Right-of-Way
- ☐ Existing Utilities
- ☐ Structures, Buildings, Vaults
- ☐ Historic Areas
- ☐ Environmental Areas
- ☐ Grade Separations
- ☐ Other 1 ______
- ☐ Other 2 ______
- ☐ Other 3 ______
- ☐ Other 4 ______

**General Information**

***District:** ______
***County:** ______
***Twshp/Boro:** ______
**Project ECMS #** ______

**Submitter Information**

**Submitted By:** ______
***Submitter Company:** ______
**Street Address** ______
**City State Zip** ______
**Telephone** ______
***Date Submitted:** ______

**Project Information**

**Project Type**

- ☐ Resurfacing Project
- ☐ Signal Project
- ☐ Widening Project
- ☐ Reconstruction
- ☐ New Construction (Tech Infeasible normally N/A)
- ☐ Other ______

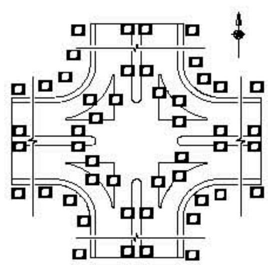
| | | |
|---|---|---|
| Pedestrian Traffic | Yes | No |
| Pedestrian Trip Generators | Yes | No |
| Safety Concerns | Yes | No |
| R9-3A "No Peds" Signs | Yes | No |
| Existing Crosswalk | Yes | No |
| Existing Sidewalk | Yes | No |
| Existing Push Buttons | Yes | No |

ADT ______

**Location Identification**

______
**SR North - Segment*
______
**SR South - Segment*
______
**SR East - Segment*
______
**SR West - Segment*
Use Graphic to ID
Location #

Northbound



| Investigated design alternatives | Why alternative was not selected |
|---|---|
| 1.) | |
| 2.) | |
| 3.) | |

**Alternative selected and description of what requirement is not met**

**ADA Review Committee Recommendation**

- Approved
- Denied

ADA Review Committee Chair - Date

**ADE of Design Approval Status**

- Approved
- Denied

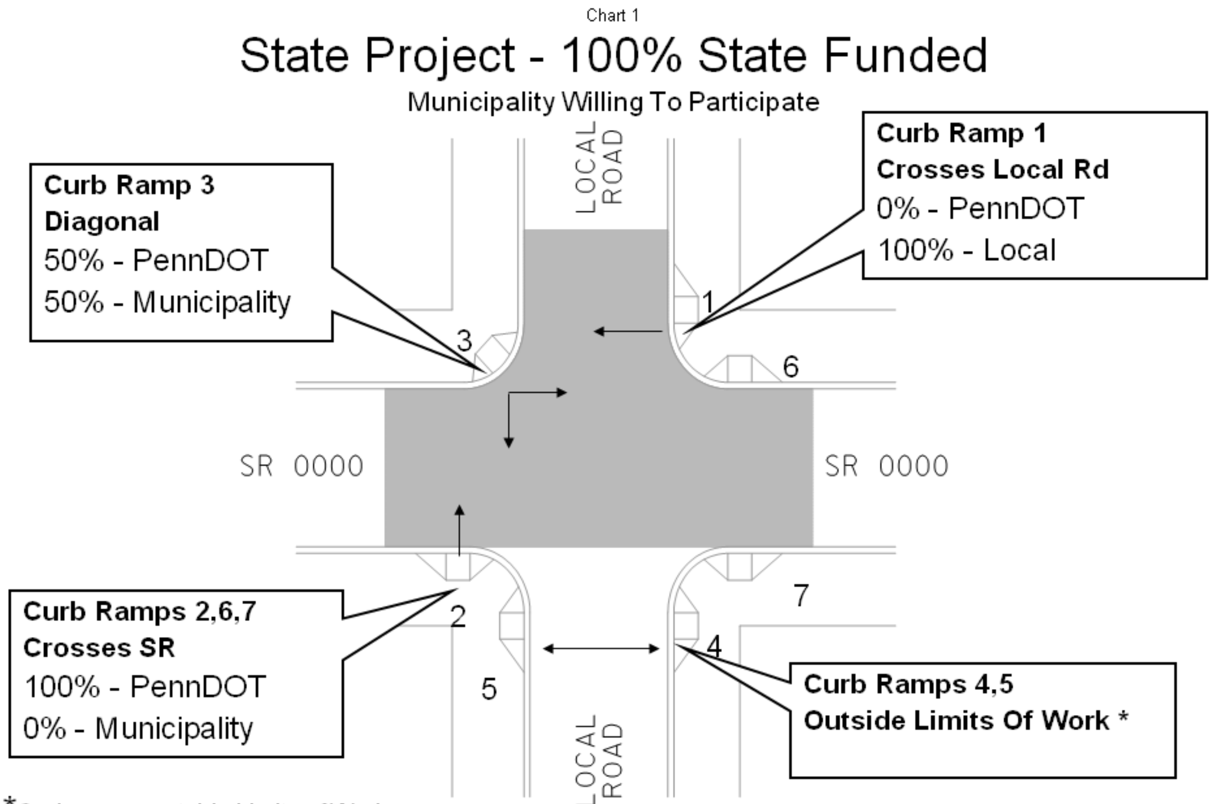
District ADE of Design - Date

**TIF #:**

*(TIF Number automatically assigned. All fields marked with * provide data for TIF #)*

# CHAPTER 6, APPENDIX B

## FUNDING SCENARIOS



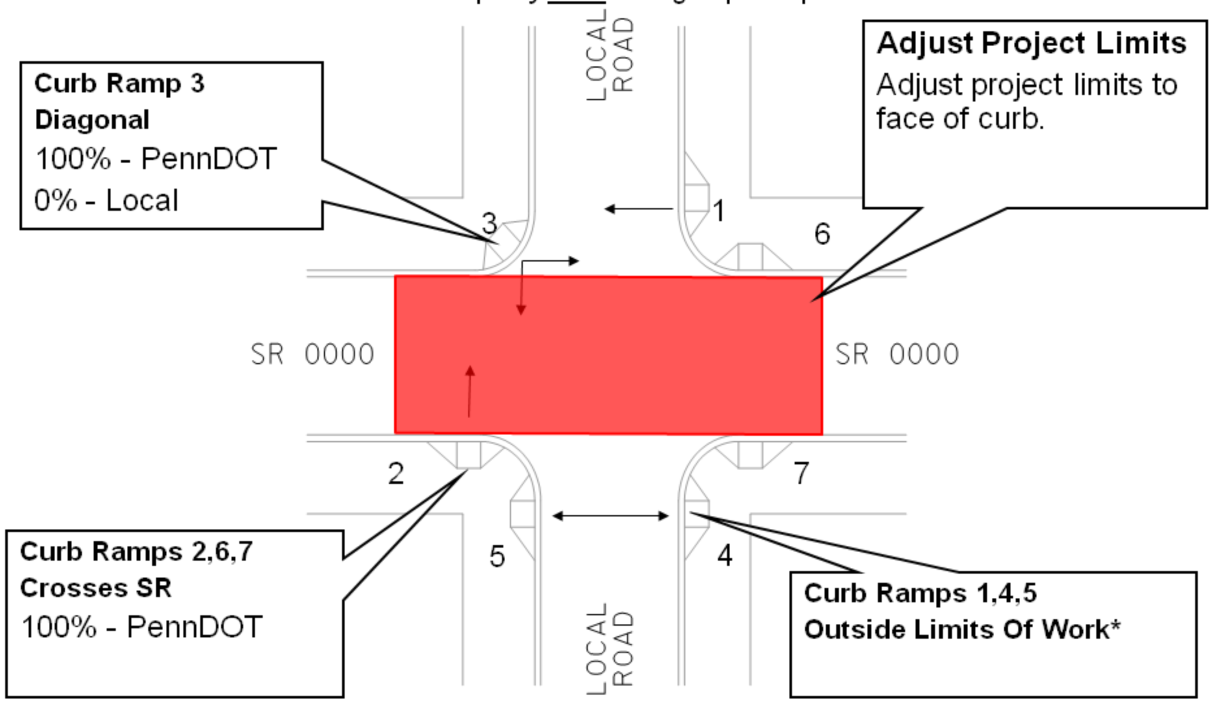

*Curb ramps outside Limits of Work:

- Are encouraged to be upgraded.
- Must be upgraded if impacted by the upgrade of other curb ramps.

Chart 2

# State Project – 100% State Funded

Municipality **NOT** willing to participate



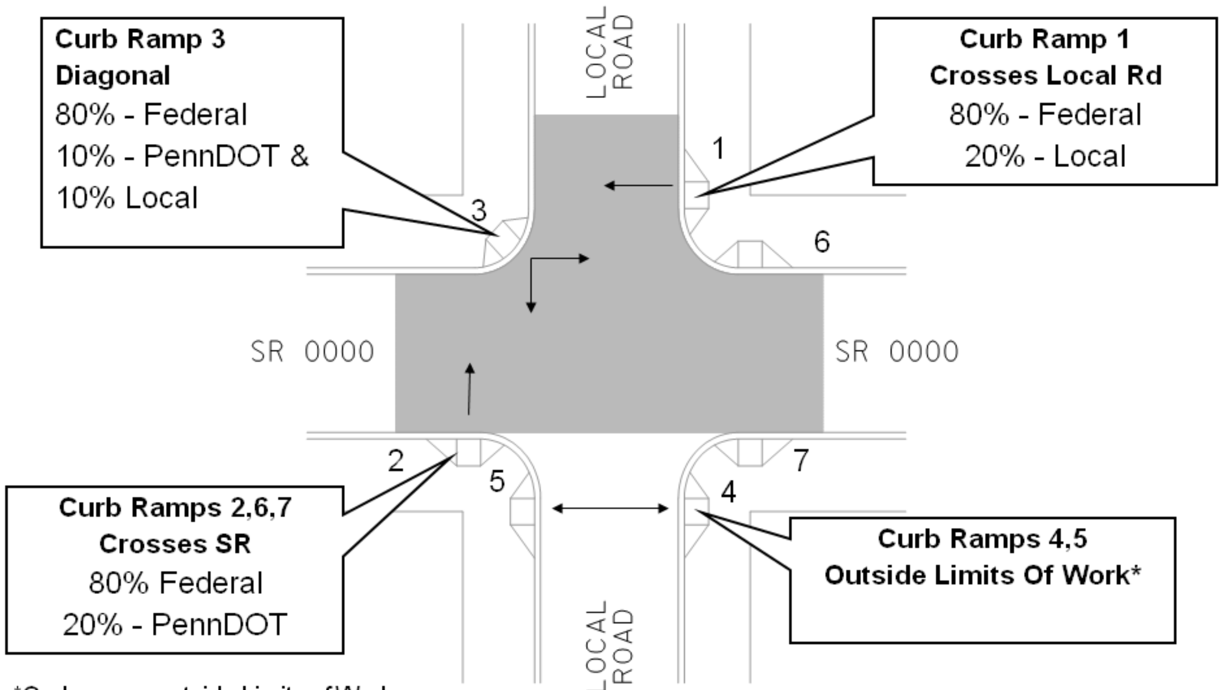

*Curb ramps outside Limits of Work:

- Are encouraged to be upgraded.
- Must be upgraded if impacted by the upgrade of other curb ramps.

Chart 3

## State Project - Federal and State Funded

Municipality willing to participate



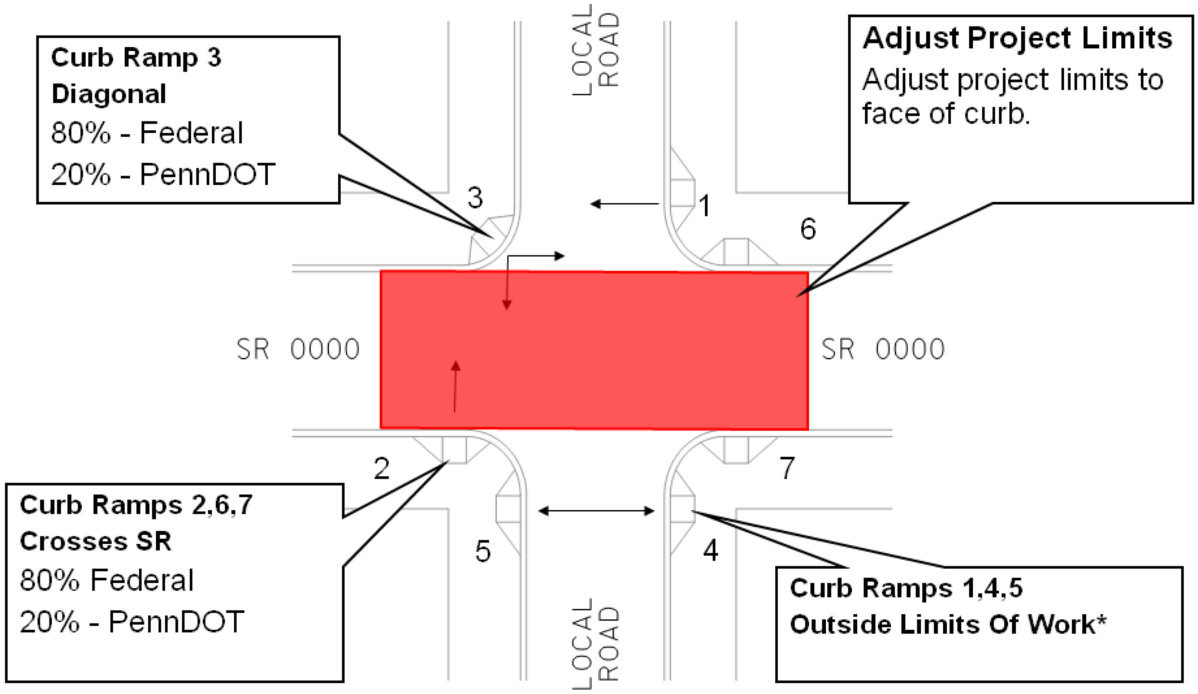

*Curb ramps outside Limits of Work:

- Are encouraged to be upgraded.
- Must be upgraded if impacted by the upgrade of other curb ramps.

Chart 4

## State Project - Federal and State Funded

Municipality **NOT** willing to participate

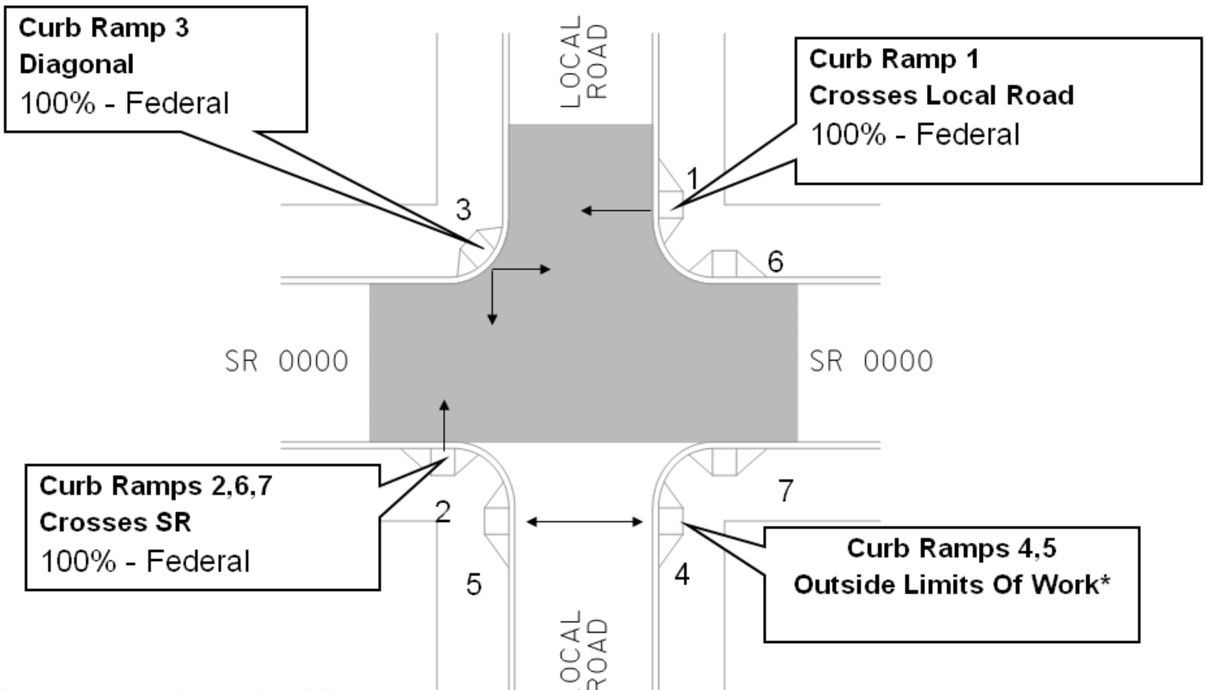



*Curb ramps outside Limits of Work:

- Are encouraged to be upgraded.
- Must be upgraded if impacted by the upgrade of other curb ramps.

Chart 5

## State Project – 100% Federally Funded

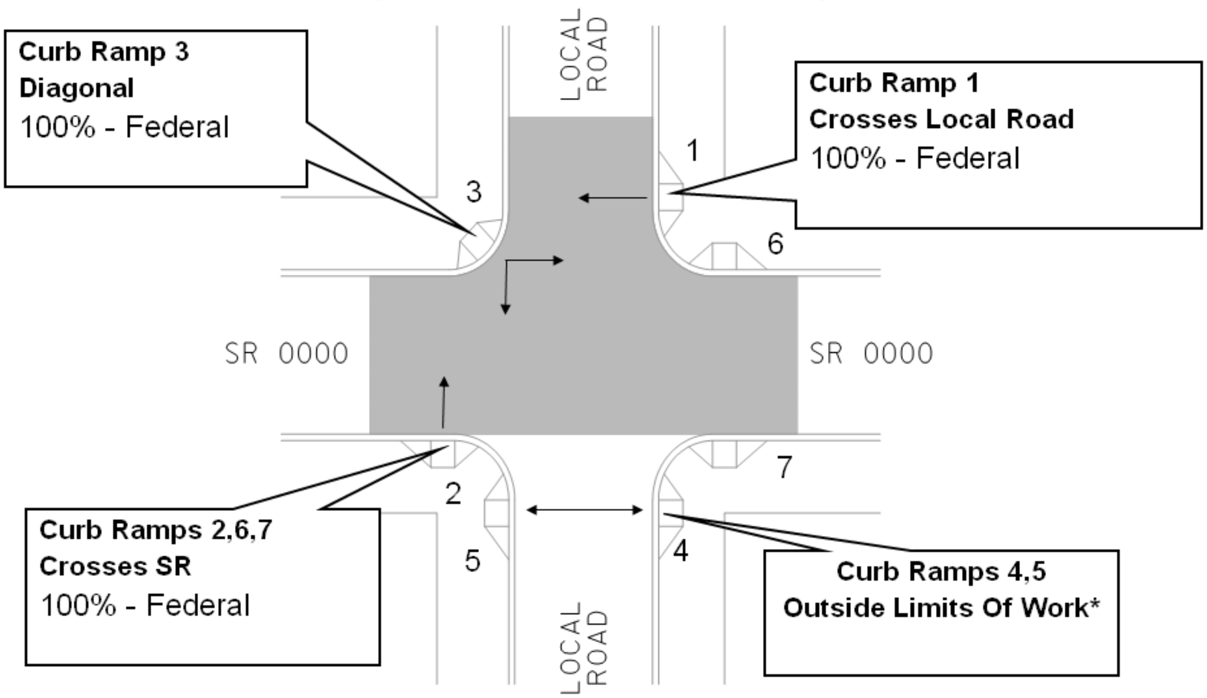



*Curb ramps outside Limits of Work:

- Are encouraged to be upgraded.
- Must be upgraded if impacted by the upgrade of other curb ramps.

Chart 6

## Local Project – 100% Federally Funded




*Curb ramps outside Limits of Work:

- Are encouraged to be upgraded.
- Must be upgraded if impacted by the upgrade of other curb ramps.

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# CHAPTER 6, APPENDIX C

## REIMBURSEMENT AND MAINTENANCE AGREEMENT

# Table 6.C.1
## Summary of Letters and Agreements

| | |
|---|---|
| **Attachment "A"** | **Notice of Future PennDOT Construction Project with Americans with Disabilities Act Accessibility Issues (standard letter).** |
| **Attachment "B"** | **Construction and Maintenance of Americans with Disabilities Act Compliant Pedestrian Facilities (standard letter).** |
| **Attachment "C"** | **Maintenance of Pedestrian Facilities to Meet Americans with Disabilities Act Requirements (standard letter).** |
| **Attachment "D"** | **Reimbursement and Maintenance Agreement (legal agreement).** |
| **Attachment "E"** | **Sidewalk Maintenance Agreement (legal agreement).** |
| **Attachment "F"** | **PennDOT/Municipality Funding Scenario Flowchart.** |

– ATTACHMENT "A" –

(Date)

Municipality Contact Person
Municipality Name
Street Address
City, State Zip Code

**Subject: Notice of Future PennDOT Construction Project with Americans with Disabilities Act Accessibility Issues**
County:
Municipality Name
SR , Section
Project Length:
Project Name:
MPMS Number:

Dear Municipality Contact Person:

The Pennsylvania Department of Transportation is planning a roadway alteration project within your city/township/borough which will affect the use of the public right-of-way.

The Americans with Disabilities Act (ADA) of 1990 is a civil rights statute that prohibits discrimination against people with disabilities. ADA implementing regulations for Title II prohibit discrimination in the provision of services, programs, and activities by state and local governments. Designing and constructing pedestrian facilities in the public right-of-way that are not usable by people with disabilities may constitute discrimination. Section 504 of the Rehabilitation Act of 1973 (504) includes similar prohibitions in the conduct of federally-funded programs.

To meet the requirements of the ADA, all projects affecting the use of pedestrian accessible routes in the public right-of-way must incorporate pedestrian access improvements within the scope of the project. Specifically, all pedestrian facilities within the scope of the project must be improved to meet the current ADA standards and any locations missing a required pedestrian facility must have a pedestrian facility installed during construction of the project.

We desire to meet with you within the next two weeks to discuss ADA accessibility issues, appropriate cost sharing, utility or right-of-way concerns, and future maintenance responsibilities for this project. The individual listed below will contact you within two weeks to set-up a meeting date.

– ATTACHMENT "A" –

Please direct all correspondence to the following contact:

PennDOT Engineering District 0-0
Contact Person
Street Address
City, State Zip Code
Telephone: (000) 000-0000
E-mail: xxxxx@pa.gov

Sincerely,

Project Manager's Name
Title

– ATTACHMENT "B" –

(Date)

Municipality Contact Person **VIA CERTIFIED MAIL**
Municipality Name
Street Address
City, State Zip Code

**RE: Construction and Maintenance of Americans with Disabilities Act Compliant Pedestrian Facilities**

Dear Municipality Contact Person:

As discussed in our meeting on (Date), the Pennsylvania Department of Transportation (Department) plans to improve SR ____ through roadway alterations or resurfacing at the intersection of (Street Name), which is under the jurisdiction of (Municipality Name). To meet current accessibility standards required by the Americans with Disabilities Act (ADA), altered pedestrian facilities must meet the latest standards.

**Scenario #1 – PennDOT and Municipal Share Construction Efforts**

☐ It was determined at the meeting referenced above that (Municipality Name) will construct or improve pedestrian facilities that service local streets on its own accord rather than have the Department include the pedestrian facilities as part of its project. The Department will construct the remaining pedestrian facilities as part of its project.

The Department acknowledges that (Municipality Name) will construct or improve pedestrian facilities at the intersection of SR _____ and (Street Name) which meet the standards for pedestrian accessibility required by the Americans with Disabilities Act Accessibility Guidelines (ADAAG), 28 CFR Part 36, as amended, and that the construction will be completed by or immediately after completion (within __ months) of the Department's project.

The Department acknowledges its intent to construct or improve pedestrian facilities at the intersection of SR ___ and (Street Name) which meet the standards for pedestrian accessibility required by the Americans with Disabilities Act Accessibility Guidelines (ADAAG), 28 CFR Part 36, as amended, and that the construction will be completed as part of the Department's project.

**Scenario #2 – PennDOT Performs All Construction**

☐ It was determined at the meeting referenced above that the Department will construct or improve all pedestrian facilities as part of its project.

The Department acknowledges its intent to construct or improve pedestrian facilities at the intersection of SR___ and (Street Name) which meet the standards for pedestrian accessibility required by the Americans with Disabilities Act Accessibility Guidelines (ADAAG), 28 CFR Part 36, as amended, and that the construction will be completed as part of

– ATTACHMENT "B" –

the Department's project.

**Scenario #3 – Municipality Performs All Construction**

☐ It was determined at the meeting referenced above that (Municipality Name) will construct or improve all pedestrian facilities as part of its project.

**(**Municipality Name**)** acknowledges its intent to construct or improve pedestrian facilities at the intersection of SR __ and (Street Name) which meet the standards for pedestrian accessibility required by the Americans with Disabilities Act Accessibility Guidelines (ADAAG), 28 CFR Part 36, as amended, and that the construction will be completed by or immediately after completion (within ___ months) of the Department's project.

**Financial Responsibilities**

The constructed or improved pedestrian facilities that service the local streets will be constructed at (Municipality Name's) expense. The constructed or improved pedestrian facilities that service state routes will be constructed at the Department's expense. The constructed or improved pedestrian facilities that service both local and state routes will be constructed at a shared 50/50 cost and expense.

**Maintenance Responsibilities**

According to the State Highway Law of 1945, as amended, (Municipality Name) is responsible for maintaining structures located outside of the highway curb lines. Therefore, (Municipality Name) will be responsible for the year-round maintenance and repair of the new pedestrian facilities. The Department in no way assumes or acknowledges any jurisdiction over the pedestrian facilities or the responsibility for the maintenance and future repair of the pedestrian facilities upon their completion.

Thank you for your attention to this matter. If you have any questions, please contact (Contact Person) at (000) 000-0000.

Sincerely,

Project Manager's Name
Title

– ATTACHMENT "C" –

(Date)

Municipality Contact Person **VIA CERTIFIED MAIL**
Municipality Name
Street Address
City, State Zip Code

**RE: Maintenance of Pedestrian Facilities to Meet Americans with Disabilities Act Requirements**

Dear Municipality Contact Person:

As indicated in the letter dated (Date), the Pennsylvania Department of Transportation (Department) plans to improve SR ___ through roadway alterations or resurfacing at the intersection of (Street Name), which is under the jurisdiction of (Municipality Name). To meet current accessibility standards required by the Americans with Disabilities Act (ADA), altered pedestrian facilities must meet the latest standards at the intersection. It has been determined that (Municipality Name) is not willing to sign an agreement with the Department to set forth cost reimbursement and maintenance obligations for the pedestrian facilities.

In the absence of an agreement, the Department will proceed with the construction of the pedestrian facilities as part of its roadway reconstruction project. PennDOT will only address curb ramps along local streets for which the pedestrian path is negatively impacted by the construction of curb ramps along state routes.

According to the State Highway Law of 1945, as amended, (Municipality Name) is responsible for maintaining structures located outside of the highway curb lines. Therefore, upon completion of construction, (Municipality Name) will be responsible for the year-round maintenance and repair of the pedestrian facilities. By constructing the pedestrian facilities to provide ADA compliance, the Department in no way assumes or acknowledges any jurisdiction over the pedestrian facilities or the responsibility for the maintenance and future repair.

Thank you for your attention to this matter. If you have any questions, please contact (Contact Person) at (000) 000-0000.

Sincerely,

Project Manager's Name
Title

– ATTACHMENT "D" –

Municipality: ____________________
Federal ID #: ____________________
SAP Vendor #: ____________________

Agreement #: ____________________
Project (SR & Sec): ________________
MPMS #: ________________________

# REIMBURSEMENT & MAINTENANCE AGREEMENT

THIS AGREEMENT, made and entered into this ______ day of ____________________, 20___, by and between the Commonwealth of Pennsylvania, acting through the Pennsylvania Department of Transportation (PENNDOT), hereinafter called the COMMONWEALTH,

a n d

_________________________, a political subdivision duly and properly formed under the laws of the Commonwealth of Pennsylvania, acting through its proper officials, hereinafter called the MUNICIPALITY.

W I T N E S S E T H:

WHEREAS, the COMMONWEALTH has under its jurisdiction SR ________, located in ______________________________, ______________ County; and,

WHEREAS, the COMMONWEALTH plans to improve SR ________, from Segment ______ Offset ______ to Segment ______ Offset ______, through roadway alterations or resurfacing, hereinafter referred to as the PROJECT, as more fully described on Exhibit "A," which is attached hereto and made part of this Agreement; and,

WHEREAS, SR_________ intersects with (a) street(s) under the jurisdiction of the MUNICIPALITY; and,

WHEREAS, all pedestrian facilities altered by a roadway alteration or construction project must be updated to current accessibility standards required by the Americans with Disabilities Act (ADA); and, WHEREAS, to meet the ADA requirements, the COMMONWEALTH will remove the existing pedestrian facility(ies) at the intersection(s) of State Route _______ and _____________, and install new pedestrian facilities as part of the PROJECT, hereinafter referred to as the PEDESTRIAN FACILITIES; and,

WHEREAS, the PEDESTRIAN FACILITIES will be installed to serve pedestrian traffic and must meet the design guideline standards for pedestrian accessibility required by the Americans with Disabilities Act Accessibility Guidelines (ADAAG), 28 CFR Part 36, as amended; and,

WHEREAS, the COMMONWEALTH is willing to construct the PEDESTRIAN FACILITIES as part of the PROJECT, subject to reimbursement by the MUNICIPALITY as set forth in Paragraph 3 below; and,

WHEREAS, the MUNICIPALITY is willing to reimburse the COMMONWEALTH for construction and inspection costs associated with the PEDESTRIAN FACILITIES, as detailed in this Agreement; and,

WHEREAS, upon completion of construction of the PEDESTRIAN FACILITIES, the MUNICIPALITY must assume year-round responsibility for maintenance of said PEDESTRIAN FACILITIES; and,

WHEREAS, the parties desire to enter into this Agreement to set forth the financial obligations and maintenance responsibilities for the PROJECT and the PEDESTRIAN FACILITIES.

NOW THEREFORE, for and in consideration of the foregoing premises and the mutual promises set forth below, the parties agree, with the intention of being legally bound, to the following:

**1.** The recitals set forth above are incorporated by reference as a material part of this Agreement.

**2.** The COMMONWEALTH, by contract or with its own forces, will construct the PROJECT and the PEDESTRIAN FACILITIES in accordance with the plans, specifications, and drawings prepared by or for the COMMONWEALTH, which are incorporated herein by reference as if physically attached hereto.

**3.** The COMMONWEALTH shall be responsible for all costs of the PROJECT other than the PEDESTRIAN FACILITIES. The MUNICIPALITY shall be responsible for the costs of the PEDESTRIAN FACILITIES as follows:

A. The MUNICIPALITY shall be solely responsible for the costs of PEDESTRIAN FACILITIES constructed to provide access across a local street under the jurisdiction of the MUNICIPALITY at the intersection of a state highway.

B. The MUNICIPALITY and the COMMONWEALTH shall be equally responsible for the costs of PEDESTRIAN FACILITIES constructed on the diagonal of an intersection which provide access across both a local street under the jurisdiction of the MUNICIPALITY and a state highway.

C. The COMMONWEALTH shall be solely responsible for the costs of PEDESTRIAN FACILITIES constructed at the intersection of two state highways.

**4.** The MUNICIPALITY shall pay to the COMMONWEALTH, by way of reimbursement, for all actual costs associated with construction of the PEDESTRIAN FACILITIES, including inspection costs, as tabulated on Exhibit "C," which is attached to and made part of this Agreement, estimated to be ________________________ ($XX,XXX.XX); and,

**5.** Upon completion of the PEDESTRIAN FACILITIES, the COMMONWEALTH shall send the MUNICIPALITY a written notice of completion and an invoice specifying the items constituting the total cost of the PEDESTRIAN FACILITIES for which it is responsible in accordance with Paragraph 3 above. The MUNICIPALITY shall make payment to the COMMONWEALTH in full through the Option circled below:

Option A:

The MUNICIPALITY shall make payment to the COMMONWEALTH in full within thirty (30) days of receipt of such invoice.

Option B:

The MUNICIPALITYshall, after receipt of such invoice, make monthly payments to the COMMONWEALTH for a period of one (1) year. The payments will be in equal amounts and total all costs due hereunder.

Option C:

The MUNICIPALITY shall make payment to the COMMONWEALTH in full after receiving the necessary funds from a Pennsylvania Infrastructure Bank (PIB) loan. The MUNICIPALITY shall make payment to the COMMONWEALTH in full within thirty (30) days of receipt of such loan, which must be no longer than sixty (60) days after completion of the Project.

Option D:

The MUNICIPALITY authorizes the COMMONWEALTH to withhold and apply so much of the MUNICIPALITY's Liquid Fuels Tax Fund allocation as necessary to reimburse the COMMONWEALTH in full for all costs due hereunder.

**6.** Upon receipt of the notice required by Paragraph 5 above, the MUNICIPALITY shall, at its sole cost and expense, be responsible for the year-round maintenance and repair of the PEDESTRIAN FACILITIES, which include, without limitation, clearing and removal of snow and ice and application of anti-skid or de-icing materials. The MUNICIPALITY may by ordinance transfer these responsibilities (both maintenance and future alteration required by ADAAG) to other parties but the MUNICIPALITY shall remain responsible for the enforcement of such ordinance. Additionally, the MUNICIPALITY shall, at its sole cost and expense, be responsible for all future alterations to the PEDESTRIAN FACILITIES required by the ADAAG. Nothing contained in this Agreement must be construed as an assumption or acknowledgement by the COMMONWEALTH of responsibility for the maintenance and future repair of the PEDESTRIAN FACILITIES.

**7.** The MUNICIPALITY, by executing this Agreement, certifies that it has on hand or will acquire sufficient funds to meet all of its obligations for the PEDESTRIAN FACILITIES as set forth in Paragraph 4.

**8.** If the MUNICIPALITY fails to perform any of the terms, conditions or provisions of this Agreement, including, but not limited to, any default of payment for a period of forty-five (45) days, the MUNICIPALITY authorizes the COMMONWEALTH to withhold so much of the MUNICIPALITY's Liquid Fuels Tax Fund allocation as may be necessary to reimburse the COMMONWEALTH in full for all costs due hereunder; and the MUNICIPALITY does hereby and herewith authorize the COMMONWEALTH to withhold such amount and to apply such funds or portion thereof, to remedy such default.

**9.** The MUNICIPALITY must indemnify, save harmless, and defend (if requested) the COMMONWEALTH, its officers, agents, and employees from all suits, actions, or claims of any character, name, or description brought for on account of any injuries to or damages received or sustained by any person, persons or property by or from the MUNICIPALITY, its contractors, their officers, agents and employees as a result of the obligations assumed by the MUNCIPALITY under this Agreement.

**10.** Nothing contained in this Agreement shall be deemed to be a waiver by the COMMONWEALTH of its discretion to abandon or postpone the PROJECT.

**11.** The MUNICIPALITY agrees to comply with the *Contractor Integrity Provisions*, the *Commonwealth Nondiscrimination/Sexual Harassment Clause*, the *Provisions Concerning the Americans with Disabilities Act*, and the *Right-to-Know Law Provisions* which are attached hereto and made part hereof as Exhibits "D," "E," "F," and "G," respectively.

**12.** The MUNICIPALITYshall enact and/or adopt such ordinances and/or resolutions as may be necessary to effect the purposes of this Agreement.

**13.** The actions that the COMMONWEALTH is either required or authorized to perform pursuant this Agreement are not intended to enlarge, and must not be construed as enlarging, its obligations regarding maintenance and operation of the state highway system under either the State Highway Law, Act of June 1, 1945, P.L. 1242, as amended, 36 P.S. § 670-101 et seq., or the Act of September 18, 1961, P.L. 1389, No. 615, as amended, 36 P.S. § 1758-101 et seq.

**14.** This Agreement will not be effective until all necessary COMMONWEALTH officials as required by law have executed it. Following full execution, the COMMONWEALTH will insert the effective date at the top of Page 1.

IN WITNESS WHEREOF, the parties have executed this Agreement the date first above written.

| ATTEST | MUNICIPALITY |
|---|---|
| ______________________________ | BY______________________________ |
| Title: DATE | Title: DATE |

***If a Corporation, the President or Vice-president must sign and the Secretary, Treasurer, Assistant Secretary or Assistant Treasurer must attest; if a sole proprietorship, only the owner must sign; if a partnership, only one partner need sign; if a limited partnership, only the general partner must sign. If a Municipality, Authority or other entity, please attach a resolution.***

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**DO NOT WRITE BELOW THIS LINE--FOR COMMONWEALTH USE ONLY**

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION

BY______________________________________
Deputy Secretary for DATE
Highway Administration

| | |
|---|---|
| APPROVED AS TO LEGALITY AND FORM | FUNDS COMMITMENT DOC. NO.____________ |
| | CERTIFIED FUNDS AVAILABLE UNDER |
| | SAP NO. ______________________________ |
| | SAP COST CENTER_________________________ |
| BY______________________________ | GL ACCOUNT______________________________ |
| for Chief Counsel Date | AMOUNT__________________________________ |
| BY______________________________ | BY______________________________________ |
| Deputy General Counsel Date | for Comptroller Date |
| BY______________________________ | |
| Deputy Attorney General Date | |

– ATTACHMENT "E" –

| | | | |
|---|---|---|---|
| County(ies): | ___________________________ | Agreement #: | _____________________________ |
| Project Short Title: | ___________________________ | MPMS #: | _____________________________ |
| Project (SR &Sec): | ___________________________ | Federal Aid ID#: | _____________________________ |

## SIDEWALK MAINTENANCE AGREEMENT

THIS AGREEMENT, made and entered into this the __________________ day of ____________________, 20___, between the Commonwealth of Pennsylvania, acting through the Department of Transportation, herein called PENNDOT,

and

_________________________, a political subdivision duly and properly formed under the laws of the Commonwealth of Pennsylvania, acting through its proper officials, hereinafter called the MUNICIPALITY.

**W I T N E S S E T H:**

WHEREAS, the need for sidewalk at the following location(s) has been determined appropriate:

| *County* | *State Road* | *Beginning Segment/Offset* | *Ending Segment/Offset* |
|---|---|---|---|

WHEREAS, the cost of constructing sidewalk at these locations is being partially or totally funded with state and/or federal funds; and,

WHEREAS, sidewalk is being installed to serve pedestrian traffic; and,

WHEREAS, the MUNICIPALITY has agreed, upon completion of the sidewalk construction, to assume year-round responsibility for maintenance of said sidewalk.

NOW, THEREFORE, in consideration of the premises, the mutual covenants hereinafter contained and with the intent to be legally bound hereby, the parties hereto agree as follows:

1. PENNDOT will, with its own forces or by contract, construct various improvements along state route ______ (____________) and install sidewalk in accordance with the plans prepared by PENNDOT, which are incorporated herein by reference as though physically attached.

2. Upon completion of said Project by PENNDOT or its contractor(s), PENNDOT will send to the MUNICIPALITY a written notice of completion.

3. Upon receipt of the notice, required by Paragraph 2 above, the MUNICIPALITY shall, at its sole cost and expense, be responsible for the year-round maintenance and repair of the sidewalk, which includes, without limitation, clearing and removal of snow and ice and application of anti-skid or de-icing materials. The MUNICIPALITY may by ordinance transfer these maintenance responsibilities to other parties but the MUNICIPALITY shall remain responsible for the enforcement of such ordinance.

4. PENNDOT shall have the right, at any given time, to terminate this Agreement by giving the MUNICIPALITY thirty (30) days' written notice. In the event of such termination, the MUNICIPALITY's responsibilities under this Agreement, except those of liability, whether financial, in tort or otherwise, shall terminate.

5. The MUNICIPALITY shall indemnify, save harmless, and defend (if requested) PENNDOT, its officers, agents, and employees from all suits, actions, or claims of any character, name, or description brought for on account of any injuries to or damages received or sustained by any person, persons or property by or from the MUNICIPALITY, its contractors, their officers, agents and employees as a result of the obligations assumed by the MUNCIPALITY under this Agreement.

6. If the MUNICIPALITY shall fail to perform any of the terms, conditions, and provisions of this Agreement, the MUNICIPALITY authorizes PENNDOT to withhold so much of the MUNICIPALITY's Liquid Fuels Tax Fund Allocation as may be needed to complete any necessary work and to reimburse PENNDOT in full for all costs due thereof, and does hereby and herewith authorize PENNDOT to withhold such amount and to apply such funds, or portion thereof, to remedy the default.

7. In the event that PENNDOT determines that certain repair, maintenance, or other required action is necessary with respect to the sidewalk, PENNDOT shall notify the MUNICIPALITY in writing. The MUNICIPALITY shall begin necessary work within five (5) days of receipt of PENNDOT's notice. In the event that the MUNICIPALITY fails to commerce necessary work within said five- (5-) day period

or fails to prosecute said work diligently to completion, PENNDOT may perform said repair, maintenance, or other necessary action at the MUNICIPALTY's sole cost and expense. Failure by the MUNICIPALITY to pay PENNDOT within forty-five (45) days of receipt of an invoice for work performed by PENNDOT shall constitute a default for purposes of Paragraph 6 of this Agreement.

8. RESOLUTIONS AND ORDINANCES

The MUNICIPALITY shall enact and/or adopt such ordinances and/or resolutions as may be necessary to effect the purposes of this Agreement.

9. NONDISCRIMINATION/SEXUAL HARRASSMENT CLAUSE

The MUNICIPALITY shall comply with the current version of the Commonwealth of Pennsylvania's Nondiscrimination/Sexual Harassment Clause, which is incorporated into this Agreement by reference as though physically attached.

10. CONTRACTOR INTEGRITY PROVISIONS

The MUNICIPALITY shall comply with the current version of the Commonwealth of Pennsylvania's Contractor Integrity Provisions, which are incorporated into this Agreement by reference as though physically attached.

11. AMERICANS WITH DISABILITIES ACT PROVISIONS

The MUNICIPALITY shall comply with the current version of the Commonwealth of Pennsylvania's Provisions Concerning the Americans with Disabilities Act, which are incorporated into this Agreement by reference as though physically attached.

12. RIGHT-TO-KNOW LAW

The Pennsylvania Right-to-Know Law, 65 P.S. §§ 67.101—3104, applies to this Agreement. Therefore, this Agreement is subject to, and the MUNICIPALITY shall comply with, the clause entitled Contract Provisions – Right to Know Law 8-K-1532, attached as Exhibit "A" and made a part of this Agreement. As used in this exhibit, the term "Contractor" refers to the MUNICIPALITY.

13. NOTICE

Notice under this Agreement shall be (a) by personal delivery; (b) by First Class Certified United States Mail, Return Receipt Requested, postage prepaid, or (c) by overnight delivery service having positive tracking, such as Federal Express or United Parcel Service. Notice shall be deemed given when received. The parties shall deliver notice to each other at the following addresses:

To DEPARTMENT:

______________________________________________________________

To MUNICIPALITY:

______________________________________________________________

or to such other address as either party may designate to the other in writing from time to time.

– ATTACHMENT "E" –

IN WITNESS WHEREOF, the parties have executed this Agreement the date first above written.

ATTEST MUNICIPALITY

________________________________ BY________________________________

Title: DATE Title: DATE

***If a Corporation, the President or Vice-president must sign and the Secretary, Treasurer, Assistant Secretary or Assistant Treasurer must attest; if a sole proprietorship, only the owner must sign; if a partnership, only one partner need sign; if a limited partnership, only the general partner must sign. If a Municipality, Authority or other entity, please attach a resolution.***

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**DO NOT WRITE BELOW THIS LINE--FOR COMMONWEALTH USE ONLY**

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION

BY________________________________________
Deputy Secretary or Designee DATE

APPROVED AS TO LEGALITY
AND FORM

BY________________________________
for Chief Counsel Date

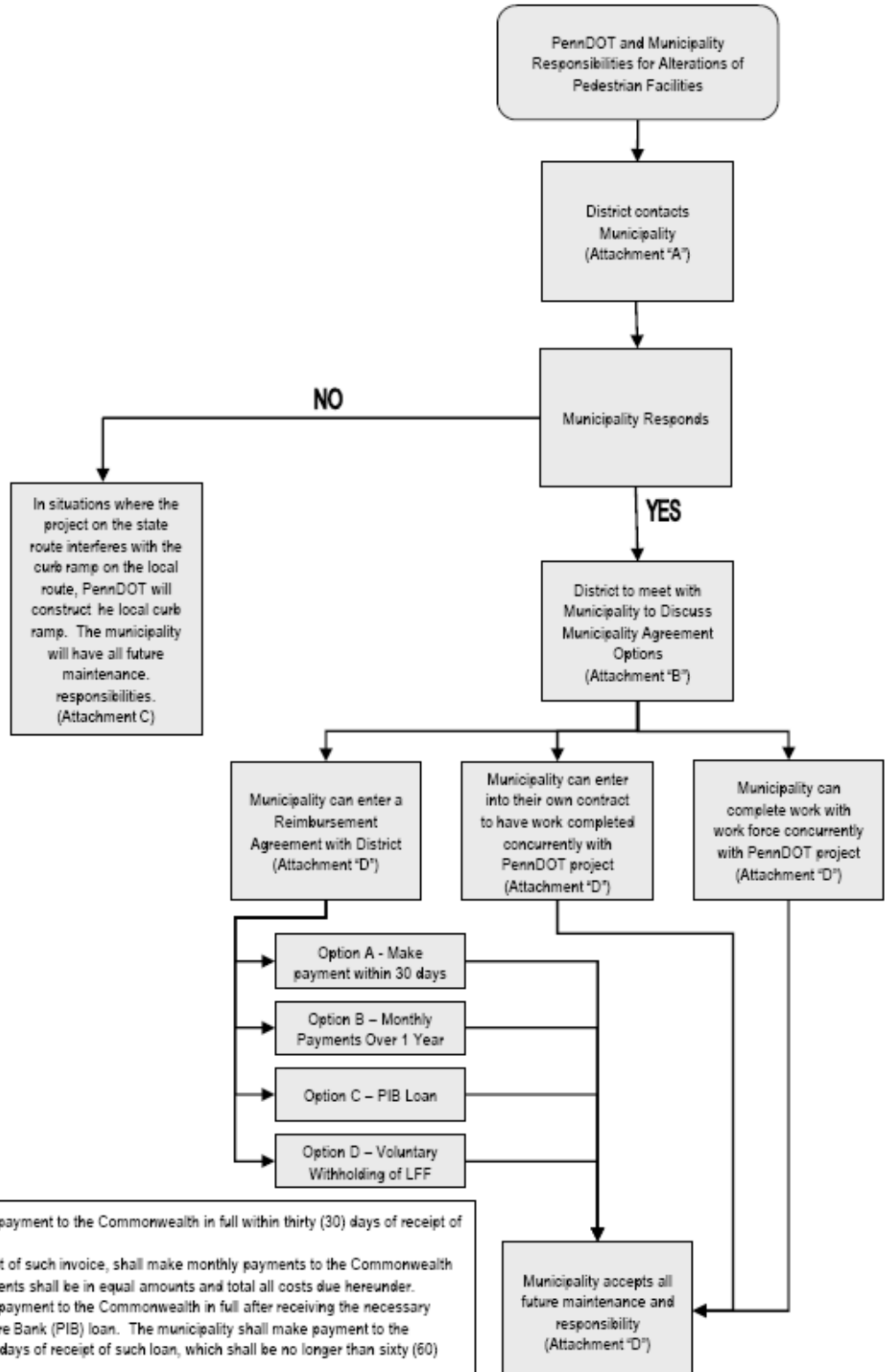
FUNDS COMMITMENT DOC. NO.____________
CERTIFIED FUNDS AVAILABLE UNDER
SAP NO. ________________________________
SAP COST CENTER________________________
GL ACCOUNT______________________________
AMOUNT_________________________________

BY________________________________
Deputy General Counsel Date

BY________________________________________
for Comptroller Operations Date

BY__________________________________
Deputy Attorney General Date

# PennDOT/Municipality Funding Scenario




<u>Option A</u>: The municipality shall make payment to the Commonwealth in full within thirty (30) days of receipt of such invoice.
<u>Option B</u>: The municipality, after receipt of such invoice, shall make monthly payments to the Commonwealth for a period of one (1) year. The payments shall be in equal amounts and total all costs due hereunder.
<u>Option C</u>: The municipality shall make payment to the Commonwealth in full after receiving the necessary funds from a Pennsylvania Infrastructure Bank (PIB) loan. The municipality shall make payment to the Commonwealth in full within thirty (30) days of receipt of such loan, which shall be no longer than sixty (60) days after completion of the Project.
<u>Option D</u>: The municipality authorizes the Commonwealth to withhold and apply a portion of the municipality's Liquid Fuels Tax Fund allocation as necessary to reimburse the Commonwealth in full for all costs due hereunder.

December 5, 2011

# CHAPTER 6, APPENDIX D

## RIGHT-OF-WAY LETTERS

Property Owner
Property Address
Authorization to Enter Introduction

Dear Property Owner:

In the coming months, the Pennsylvania Department of Transportation (PennDOT) plans to improve S.R. through roadway and sidewalk alterations or resurfacing at the intersection of Street. PennDOT will be requesting an Authorization to Enter your property in order to repair and/or replace the current Pedestrian Facility in order to comply with the current standards set forth by the Americans with Disabilities Act (ADA).

The Americans with Disabilities Act (ADA) of 1990 is a Federal civil rights statute that prohibits discrimination against people with disabilities. ADA regulations prohibit discrimination in the provision of services, programs, and activities by state and local governments. Designing and constructing pedestrian facilities in the public right-of-way that are not usable by people with disabilities may constitute discrimination. Section 504 of the Rehabilitation Act of 1973 (504) includes similar prohibitions in the conduct of federally-funded programs.

In the coming weeks, a representative of PennDOT will be visiting homes in your municipality to further explain the Authorization to Enter form. PennDOT will not repair and/or replace the current Pedestrian Facility on your property or acquire property from you for that purpose if the Authorization to Enter is not executed.

Should you require any additional information, please contact at .

Sincerely,

District Executive
Engineering District -0

Property Owner
Property Address
Authorization to Enter Denied or Failure to Respond

Dear Property Owner:

This letter is a follow-up to your decision not to grant Authorization to Enter to the Pennsylvania Department of Transportation (PennDOT). This is in reference to repairing or replacing the publicly used Pedestrian Access Facility (sidewalks and curb ramps) that pertain to project and are located within your property located at .

PennDOT will not be repairing and/or replacing the current Pedestrian Facility on your property. Be advised that if there are any claims or proceedings in relation to the publicly used Pedestrian Access Facility located within your property, you could potentially be sued or added to a lawsuit.

Should you require any additional information, please contact at .

Sincerely,

District Executive
Engineering District -0

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# CHAPTER 6, APPENDIX E

## PEDESTRIAN STUDY DETERMINATION

## Pedestrian Study Determination

**General Information**

Date: ____________________

District: ____________________

Submitted By: ____________________

**Location Information**

County: ____________________

Municipality: ____________________

SR and Section: ____________________

Segment/Offset: ____________________

Street Name: ____________________

Township Road: ____________________

**Project Description:**

Provide a brief project description and scope :

**The need for pedestrian accommodations has been identified through the following procedures.**

**1. Factors identified from the Bike/Ped. Checklist** Yes ☐ No ☐

**2. Local Comprehensive Planning** Yes ☐ No ☐

**3. Included in project scope at programming** Yes ☐ No ☐

**4. Critical safety need (Safety Review Committee concurrence)** Yes ☐ No ☐

**Description:**________________________________________

________________________________________

**5. Municipal request** Yes ☐ No ☐

**6. Field Observation** Yes ☐ No ☐

**(i.e., connect pedestrian generators; observed pedestrian movements)**

**Description:**________________________________________

________________________________________

**7. Are pedestrian accommodations needed?** Yes ☐ No ☐

**If "Yes" then list the facilities that need upgraded and construct them according to DM-2 Ch. 6 and RC-67M. (Use Executive Summary)**

**If "No", explain in Executive Summary.**

**Note: If a pedestrian need has been determined and the construction of pedestrian facilities do not fall within the project scope or the alteration, then ADA features must be included on a Transition Plan and this project should not preclude or impede the inclusion of pedestrian facilities with future projects or development.**

**Executive Summary (Engineering Judgement/Recommendation) :**

ADA Coordinator Concur
Signature ____________________

Design Engineer Concur
Signature ____________________

Project Manager Concur
Signature ____________________

ADE-Design Approval
Signature ____________________

**FORM 6.1**

# CHAPTER 6, APPENDIX F

## PARKING REMOVAL LETTERS

**DATE**

Municipality Contact Person
Municipality Name
Street Address
City, State Zip Code

**Subject: Notice of Future PennDOT Construction Project: Americans with Disabilities Act Compliance and Removal of On Street Parking**
County:
Municipality Name
SR , Section
Project Length:
Project Name:
MPMS Number:

Dear Municipality Contact Person:

The Pennsylvania Department of Transportation is planning a roadway alteration project within your [city/township/borough] which will affect the use of the public right-of-way.

The Americans with Disabilities Act (ADA) of 1990 is a civil rights statute that, among other things, defines the requirements for access to public programs and facilities by persons with disabilities. The implementing regulations for Title II of the ADA make clear that designing and constructing pedestrian facilities in the public right-of-way that are not accessible by persons with disabilities may constitute impermissible discrimination. Section 504 of the Rehabilitation Act of 1973 (504) includes similar prohibitions in the conduct of federally-funded programs.

All projects affecting the use of the public right-of-way must therefore incorporate needed pedestrian access measures within the scope of the project. Specifically, all pedestrian facilities within the scope of the project must comply with the current ADA standards and any locations missing a required pedestrian facility are subject to corrective action during construction of the project.

Along SR [____] there is/are (##) "T" intersection(s) with on street parking directly across from the corners. The on street parking at these "T" intersections prevents the installation of a pedestrian crossing of the SR that would be safe for all users. PennDOT recommends that the appropriate number of on street parking spaces be removed at these intersections to allow a safe and accessible crossing to be established. [Municipality Name] should evaluate the necessary steps required to restrict parking in these locations. Please see attached sketches indicating the "T" intersections, affected parking spaces and proposed crossing details.

We desire to meet with you within the next two weeks to discuss ADA accessibility issues, appropriate cost sharing, utility or right-of-way concerns, and future maintenance responsibilities for this project. The individual listed below will contact you to set-up a meeting date.

Please direct all correspondence to the following contact:

PennDOT Engineering District 0-0
Contact Person
Street Address
City, State  Zip Code
Telephone:  (000) 000-0000
E-mail:  xxxxx@pa.gov

Sincerely,

Project Manager's Name
Title

DATE

Municipality Contact Person **VIA CERTIFIED MAIL**
Municipality Name
Street Address
City, State Zip Code

**RE: Failure to remove on street parking to provide pedestrian accommodations**

Dear Municipality Contact Person:

As indicated in the letter dated [Date] and the follow up meeting held on [Date], the Pennsylvania Department of Transportation plans to improve SR [ ] through roadway alterations that include [describe alteration work and location], which is under the jurisdiction of [Municipality Name]. To meet current accessibility standards required by the Americans with Disabilities Act (ADA), altered pedestrian facilities must meet the latest design standards. It has been determined that [Municipality Name] has not taken action to remove on street parking located at the "T" intersection(s) (see attached summary) along SR [____] necessary for the establishment of a fully accessible crossing.

Due to the sight distance issues caused by [Municipality Name]'s lack of action regarding parking, PennDOT will not be able to install accessible pedestrian facilities at this/these intersection(s). [Municipality Name] must take appropriate action to prohibit pedestrian crossing at the intersection(s) referenced above. Complaints relating to the lack of accessibility under the ADA will be referred to [Municipality Name.]

Thank you for your attention to this matter. If you have any questions, please contact Contact Person at (000) 000-0000.

Sincerely,

Project Manager's Name
Title

# CHAPTER 7

## DRIVEWAYS

### 7.0 INTRODUCTION

It is in the public interest to regulate the location, design, construction, maintenance and drainage of access driveways, local roads and other property within State highway right-of-way for the purpose of security, economy of maintenance, preservation of proper roadway drainage, and safe and reasonable access for both vehicles and pedestrians crossing driveways. Driveways allow vehicles to ingress and egress streets at approved locations. In many locations, driveways will be required to cross pedestrian sidewalks within the roadway right-of-way. Driveways serve the same basic purpose for vehicles as curb ramps serve for pedestrians. Driveway crossings must be designed so that both drivers and pedestrians are able to use them effectively.

The requirements and regulations for driveways must meet the requirements of the latest edition of the Pennsylvania Code, Title 67 - Transportation, Chapter 441 entitled "Access to and Occupancy of Highways by Driveways and Local Roads" (67 PA Code § 441). No driveway must be constructed or altered within State highway right-of-way without first obtaining a highway occupancy permit from the Department.

The provisions of 67 PA Code § 441 contain the general conditions that apply to highway occupancy permit application procedures, fees, and permit issuance, general driveway design requirements and the general rules for penalties or revocation of permits based on violations pursuant to 67 PA Code § 441.

The Americans with Disabilities Act (ADA) of 1990 also requires that all pedestrians including persons with disabilities be able to safely use sidewalks that cross driveways.

This Chapter will provide various driveway design criteria presented in 67 PA Code § 441 and general driveway design guidelines presented in ADA accessibility provisions and best practice design guides for driveways presented in Chapter 5 of FHWA publication, *Designing Sidewalks and Trails for Access, Part II: Best Practices Design Guide*, September 2001.

### 7.1 DEFINITIONS

The following definitions must be used in conjunction with the criteria described in this Chapter.

**1.** Access. A driveway, street, or other means of vehicle passage between the highway and abutting property, including acceleration and deceleration lanes and such drainage structures as may be necessary for the proper construction and maintenance of the roadway system.

**2.** Curbline. A line formed by the face of a curb or in its absence the outer edge of the shoulder, along which curbing is or may be located.

**3.** Driveway. Every entrance or exit used by vehicular traffic to or from properties abutting a highway. The term includes proposed streets, lanes, alleys, courts, and other vehicular travel ways.

**4.** Driveway Crossing. The area where a driveway crosses a pedestrian walkway such as a sidewalk. This area generally extends in width from the curbline to the back edge of the sidewalk.

**5.** Driveway Entrance. The beginning of the driveway where vehicles ingress or egress the roadway.

**6.** Driveway Ramp. The sloped portion of a driveway usually beginning at the curbline.

**7.** Driveway Width. The narrowest width of a driveway measured perpendicular to the centerline of the driveway.

**8.** Egress. The exit of traffic from abutting properties to a highway.

**9.** Frontage Width. The distance along the right-of-way line in front of an abutting property.

**10.** Highway. A highway or bridge on the system of State highways and bridges, including the entire width between right-of-way lines, over which the Department has assumed or has been legislatively given jurisdiction.

**11.** Ingress. The entrance of traffic to abutting properties from a highway.

**12.** Joint-Use Driveway. A driveway shared by and constructed to provide access to two or three properties.

**13.** Limited Access Highway. A highway to which property owners or occupants of abutting lands or other persons have no legal right of access except at points and in the manner determined by the Department.

**14.** Local Road. Every public highway other than a State highway. The term includes existing or proposed streets, lanes, alleys, courts, or vehicular travel ways.

**15.** Pavement Edge. The edge of the main traveled portion of any highway exclusive of shoulder.

**16.** Permanent Curbing. Plain or reinforced cement concrete curb which meets Publication 72M, *Roadway Construction Standards*.

**17.** Permit. A highway occupancy permit issued by an Engineering District office pursuant to 67 PA Code § 441.

**18.** Property Line Clearance. The distance measured along the pavement edge or curb between the property frontage boundary line and the near edge of the driveway.

**19.** Returned Curb. A portion of a curb line that is formed by a turn or bend in the curb, usually perpendicular to the roadway curb line, and allows for adjusting heights of abutting surfaces from one elevation to another.

**20.** Right-of-Way. The area which has been acquired by the Department for highway transportation purposes.

**21.** Roadway. That portion of a highway improved, designed, or ordinarily used for vehicular travel, exclusive of the sidewalk or shoulder.

**22.** Roadway Construction Standards. Publication 72M, *Roadway Construction Standards,* containing the Department's design standards for roadway construction.

**23.** Setback. The lateral distance between the right-of-way line and a building, liquid fuel pump island, display stand, or other object, that will result in a space for vehicles to stop or park between the objects and the right-of-way line.

**24.** Shoulder. A section of a roadway system adjacent to the traveled way that may be shared by motorized vehicles, horse drawn vehicles, bicycles, and pedestrians. The shoulder facilitates drainage, supports the roadway and provides a buffer between vehicles and pedestrians.

**25.** Shoulder Line. The intersection of the shoulder slope with the side slope, drainage swale, or ditch slope.

**26.** Side-Flare. A paved, sloped portion of a driveway or curb ramp edge leading from one elevation to another and provides a surface that can generally be crossed by a vehicle or pedestrian.

**27.** Sidewalk. A portion of a roadway between curb lines or the lateral line of a roadway and the adjacent property line or easement of private property that is paved or improved and intended for use by pedestrians.

**28.** Travel Way. The portion of the roadway for the movement of vehicles exclusive of shoulders and auxiliary lanes.

**29.** Traffic Control Device. Any sign, signal, pavement marking, or device used to regulate, warn, or guide vehicular traffic and pedestrians that is placed on, over, or adjacent to a street, highway, pedestrian facility, or shared-use path by authority of a public agency having jurisdiction.

**30.** Turning Radius. The radius of an arc which approximates the turning path of the exterior corner of a vehicle.

## 7.2 GENERAL DRIVEWAY REQUIREMENTS

**A. Design Features.** Design features of driveways include the following items:

- Driveway width
- Turning radii and other points of curvature
- Driveway gradient, cross slope, and driveway profile
- Angle of driveway intersection with the roadway
- Driveway surface material and traffic island materials
- Depressed access curb type, side-flares, and return curb
- Sidewalk width, location, cross slope, and proposed surface material
- Appropriate property and highway right-of-way lines
- Location of all required traffic control devices
- Roadway curbs, gutters, shoulders, drainage features, and roadway surface material
- Appropriate adjacent building locations
- Adjacent above ground and subsurface utilities and other site features such as service lines, poles, hydrants, sign posts, street parking, grass or tree lawns, street trees, etc.

**B. General Driveway Design Criteria.**

**1.** Driveways must be located and designed in such a manner as not to interfere or be inconsistent with the design, function, drainage, or maintenance of the adjoining roadway. Driveway work must be done at such a time and in such manner to be consistent with the safety of the public and must conform to all requirements and standards of the Department. See 67 PA Code § 441 for driveway classifications based on traffic volumes and land use examples.

**2.** The ability of a driveway to safely and efficiently function as an integral component of a highway system requires that its design and construction be based on the amount and type of traffic that it is expected to serve and the type and character of roadway that it accesses. The driveway must be designed using values appropriate for the posted speed of the roadway being accessed. See 67 PA Code § 441.

**3.** Access driveways must be permitted at locations in which:

**a.** Sight distance is adequate to safely allow each permitted movement to be made into or out of the access driveway.

**b.** The free movement of normal highway traffic is not impaired.

**c.** The driveway will not create a hazard.

**d.** The driveway will not create an area of undue traffic congestion on the highway.

**4.** Specific driveway location restrictions must include the following:

**a.** Access driveways may not be located at interchanges, ramps, or locations that would interfere with the placement and proper functioning of highway signs, signals, detectors, lighting, or other traffic control devices.

**b.** The location of a driveway near a signalized intersection may include a requirement that the permittee provide, in cooperation with the local government, new or relocated detectors, signal heads, controller, etc. for the control of traffic movements from the driveway.

**c.** Access to a property which abuts two or more intersecting streets or highways may be restricted to only one driveway entrance that can more safely accommodate its traffic.

**d.** The Department may require the permittee to locate an access driveway directly across from a highway, local road, or access driveway on the opposite side of the roadway if it is judged that offset driveways will not permit left turns to be made safely or that access across the roadway from one access to the other will create a safety hazard.

**e.** An access intended to serve more than three properties or to act as a connecting link between two or more roadways must be, for the purpose of this Chapter, considered a local road and not a driveway regardless of its ownership. The access design must be in accordance with the Department's current standards governing the design of local roads. All other requirements of this Chapter must be complied with before the local road will be allowed access onto a State highway.

**f.** The number and location of entrances that may be granted will be based on usage, interior and exterior traffic patterns, and the current design policy of the Department.

**(1)** Normally, only one driveway will be permitted for a residential property and not more than two driveways will be permitted for a nonresidential property.

**(2)** If the property frontage exceeds 180 m (600 ft), the permit may authorize an additional driveway.

**(3)** Regardless of frontage, a development may be restricted to a single entrance / exit driveway, served by an internal collector road separated from the traveled way.

**5.** Driveway approaches must conform to the following criteria:

**a.** The location and angle of an access driveway approach in relation to the highway intersection must be such that a vehicle entering or leaving the driveway may do so in an orderly and safe manner and with a minimum of interference to highway traffic.

**b.** Where the access driveway approach and highway pavement meet, flaring of the approach may be necessary to allow safe and easy turning of any vehicular traffic.

**c.** Where the highway is curbed, a depressed curb driveway approach must be installed adjacent to the highway, shoulder, or gutter grade to maintain proper drainage along the curb. See Publication 72M, *Roadway Construction Standards*, Drawings RC-64M and RC-67M for cement concrete depressed driveway curbs and driveway apron details.

**d.** The angle of access driveway approach must include the following:

**(1)** Access driveway approaches used for two-way operation must be positioned at right angles (90°) to the highway or as near to perpendicular as site conditions allow.

**(2)** When two access driveways are constructed on the same property frontage and used for one-way operation, each of these driveways may be placed at an angle less than a right angle, but not less than 45° to the highway, except that along divided highways where no openings are allowed in the median, the minimum angle of an exit driveway may be 30°.

**6.** Driveways Adjacent to Intersections. Driveways serving properties located adjacent to a highway intersection must be subject to the following:

**a.** There must be a minimum 3 m (10 ft) tangent distance between the intersecting highway radius and the radius of the first permitted driveway.

**b.** The distance from the edge of pavement of the intersecting highway to the radius of the first permitted driveway must be a minimum of 6 m (20 ft) on curbed highways and 9 m (30 ft) on uncurbed highways.

**c.** Paragraphs a and b of this subsection may be waived only if the intersecting highway radius extends along the property frontage to the extent that compliance is physically impossible.

**7.** Property Line Clearance. Except for joint-use driveways, no portion of any access must be located outside of the property frontage boundary line.

**8.** Multiple Driveways. Multiple driveways serving the same property must be separated by a minimum distance of 4.6 m (15 ft) measured along the right-of-way line and 6 m (20 ft) measured along the shoulder, swale or ditch line, or curb. When the distance between multiple driveways is 15 m (50 ft) or less measured along the shoulder, swale or ditch line, the area between must be clearly defined by permanent curbing. This curb must be placed in line with existing curb or 610 mm (2 ft) back of the shoulder, swale or ditch line on uncurbed highways. It must be extended around the driveway radii to the right-of-way line.

**9.** Curb. Requirements for curbs must conform with the following:

**a.** Provide curbing wherever it is required to control access or drainage. All curbing must be permanent curbing.

**b.** Where property abutting the right-of-way line could be used as parking area, provide curbing, permanent guide rail, or fencing to be along the right-of-way line to prohibit vehicle encroachment upon the sidewalk or shoulder area.

**c.** When curb exists adjacent to the proposed driveway, the line and grade of the existing curb must be matched.

**10.** Grade for Access Driveway. The grade for access driveway must be constructed in the following manner:

**a.** All driveways must be constructed so as not to impair drainage within the right-of-way, alter the stability of the improved area, or change the drainage of adjacent areas.

**b.** Drainage pipe installed under driveways must be at least 380 mm (15 in) in diameter.

**c.** The side slopes for driveway embankments within the right-of-way must not be steeper than 1V:10H (10.00%).

**d.** Driveway grade requirements within the right-of-way must conform to Figure 7.1.

**(1)** The difference between the cross slope of the roadway and the upward grade of the driveway entrance approach must not exceed 8.00%.

**(2)** When a grass or tree lawn area exists between the roadway curb and the sidewalk and this area is wide enough to maintain a maximum 8.00% change in grade between the roadway surface and the driveway grade, construct a Type 1 or 2 Driveway Apron as shown in Figures 7.2 and 7.4. The sidewalk portion crossing the driveway must maintain a maximum 1V:50H (2.00%) cross slope.

**(3)** When a wide sidewalk parallels and abuts the curb, construct a Type 1A or Type 2A Driveway Apron, as shown in Figures 7.3 and 7.5. The sidewalk portion crossing the driveway must maintain a maximum 1V:50H (2.00%) cross slope.

**(4)** When sidewalk is directly behind and parallels the curb, a Type 3 or Type 3A Driveway Apron as shown in Figures 7.6 and 7.7 can be used. This driveway and sidewalk configuration depresses the sidewalk crossing. Certain site conditions may require constructing an additional cheek wall curbing to install this type of crossing.

**(5)** When a narrow sidewalk is directly behind and parallels the curb, a Type 4 Driveway Apron as shown in Figure 7.8 can be used. This driveway and sidewalk configuration positions the sidewalk crossing further away from the curb in order to maintain the desired sidewalk accessibility. The sidewalk portion crossing the driveway must maintain a maximum 1V:50H (2.00%) cross slope.

**(6)** All depressed curb side-flare height adjustments must be as indicated.

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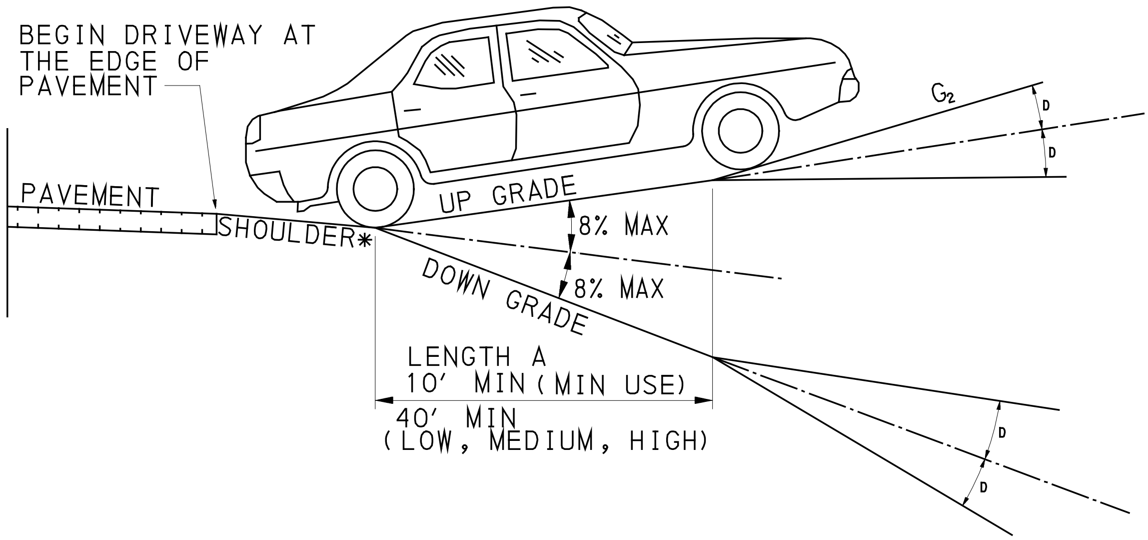



*** THE SHOULDER SLOPE USUALLY VARIES FROM 4% TO 6%. HOWEVER, THE SHOULDER SLOPE SHOULD BE MAINTAINED WHEN CONSTRUCTING THE DRIVEWAY.**

**FOR GRADE CHANGES GREATER THAN THOSE INDICATED ABOVE, VERTICAL CURVES AT LEAST 3 m (10 ft) LONG MUST BE CONSTRUCTED AND LENGTH "A" MUST BE INCREASED.**

**$G_2$ GRADES MUST BE LIMITED TO 15% FOR MINIMUM USE DRIVEWAYS AND 5% TO 8% FOR LOW, MEDIUM, OR HIGH VOLUME DRIVEWAYS WITHIN THE RIGHT-OF-WAY.**

| | MAXIMUM GRADE CHANGE (D) | |
|---|---|---|
| | DESIRABLE | MAXIMUM |
| HIGH VOLUME DRIVEWAY | 0% | +/-3% |
| MEDIUM VOLUME DRIVEWAY | +/-3% | +/-6% |
| LOW VOLUME DRIVEWAY | +/-6% | CONTROLLED BY VEHICLE CLEARANCE |

**FIGURE 7.1**
**Driveway Apron Grades**

## 7.3 ADA DRIVEWAY AND PEDESTRIAN GUIDELINES

**1.** Figures 7.2 through 7.8 illustrate minimum design requirements and acceptable design considerations described for driveway crossings of sidewalks. Although site conditions may not permit strict adherence to the dimensions indicated, every effort must be made to design and construct the safest and most efficient driveways leading onto State highways while ensuring that these facilities remain accessible to the public crossing them.

**2.** Driveway crossings without a continuous sidewalk cross slope 1V:50H (2.00%) forces pedestrians to travel across the driveway side-flare that can compromise balance and wheelchair stability. Driveways constructed with a return curb at the driveway crossing are also inaccessible to wheelchair users. Existing driveways not meeting these criteria should be replaced to meet new accessibility guidelines. Driveway crossings with steep side-flare connections to adjacent sidewalk (steeper than 10.00%) are not allowed under current design criteria.

**3.** Driveway crossings should be wide enough to accommodate both the driveway ramp and a level pedestrian sidewalk landing zone. See Figure 7.2 through Figure 7.5 (Types 1, 1A, 2, and 2A Driveway Aprons). These apron types can be constructed on wide parallel sidewalk corridors where either the entire sidewalk zone that abuts the curbline is paved or a non-walk (planting strip) surface is created. As indicated on RC-67M, the minimum sidewalk width is 1525 mm (5 ft). The minimum sidewalk width may be reduced to 1220 mm (4 ft) where 1525 mm × 1525 mm (5 ft × 5 ft) passing areas are provided every 61 m (200 ft).

**4.** Type 1 and 2 Driveway Aprons (Figures 7.2 and 7.4). Used when a planting strip abutting the curbline separates the sidewalk and curb. If the driveway ramp is not part of the pedestrian sidewalk, a returned curb is better for roadway drainage and has the added affect of slowing traffic due to the tighter turning radius needed to negotiate the driveway entrance approach.

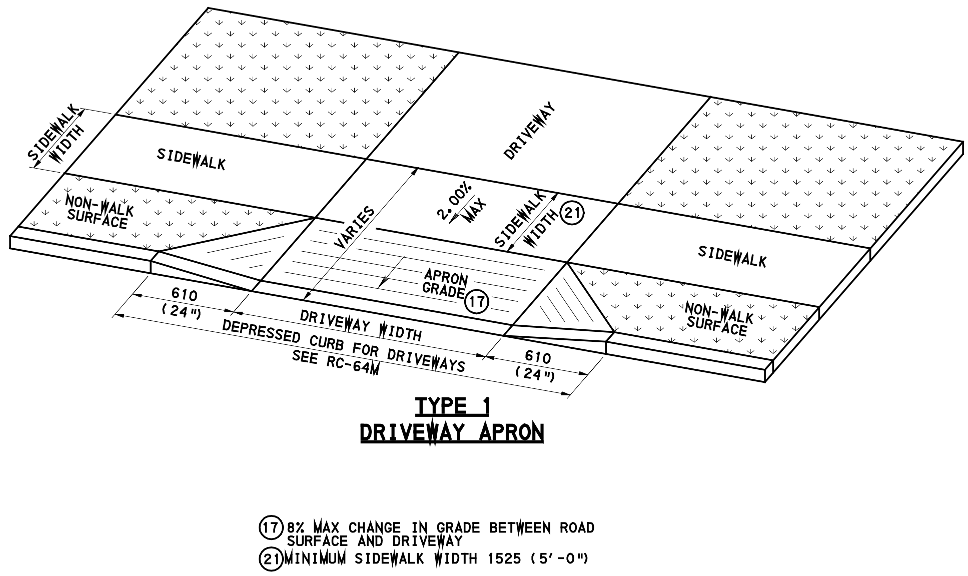
**5.** Type 1A and 2A Driveway Aprons (Figures 7.3 and 7.5). Used for driveway crossings where a wide sidewalk parallels and abuts the street curb line. These driveway aprons combine sloped side-flares or a curbed return, with a sidewalk landing.

**6.** Type 3 and 3A Driveway Aprons (Figures 7.6 and 7.7). Sidewalk corridors abutting the street curb line can also be depressed at the driveway entrance apron in many situations to provide a crossing with a maximum landing slope of 2.00% to help prevent poor drainage and ponding along the curb. The driveway ramp begins at the rear edge of the sidewalk landing. The sidewalk is sloped (maximum slope of 1V:12H (8.33%) along each side of the driveway to meet the higher adjacent sidewalk elevations. This type of driveway apron is not as desirable as a level jogged crossing since pedestrians are forced to travel down one ramp and then up another ramp. These crossings can also confuse visually impaired pedestrians since they may believe that they are about to cross a street intersection at a curb ramp. A narrow driveway apron is also desirable to slow down traffic using this type of driveway entrance.

**7.** Type 4 Driveway Apron (Figure 7.8). Securing additional easement or right-of-way from the adjacent property is recommended for creating a level jogged pedestrian sidewalk crossing for narrow sidewalks.

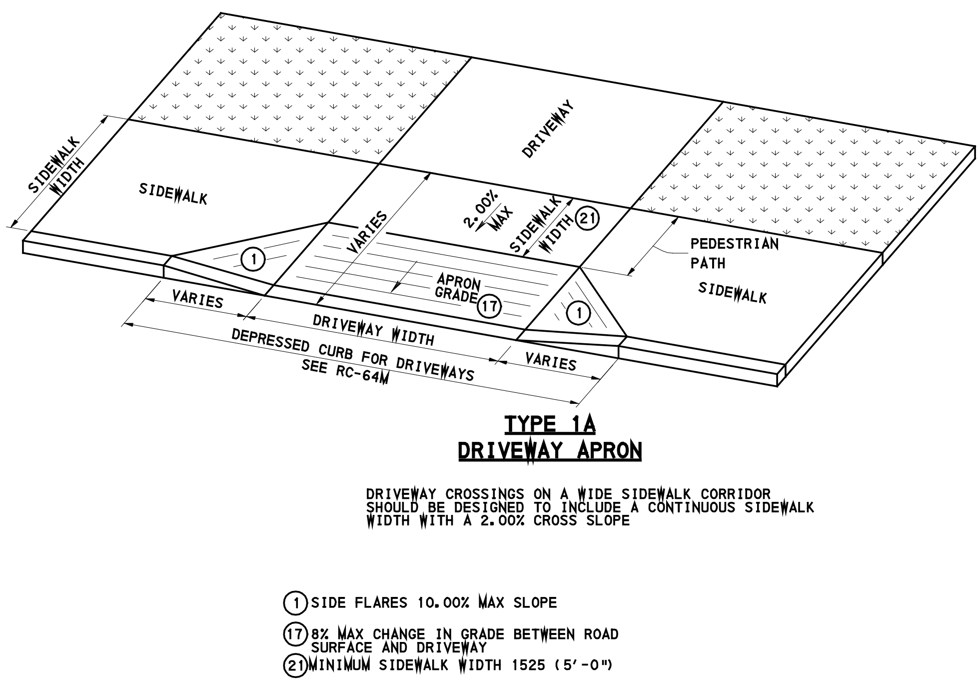
**8.** Gradually sloped driveway crossings constructed with flat side-flares under 1V:20H (5.00%) are beneficial for people with mobility impairments but can also become a problem for visually impaired pedestrians unless there is a detectable difference in the slope at the edge of the street. Without a steeper slope to trigger the awareness of a ramp condition, a visually impaired person could inadvertently veer into the street.

**9.** Built-up driveway entrances that project across the curb and into the street can hinder or obstruct roadway drainage at the curb and are not recommended.



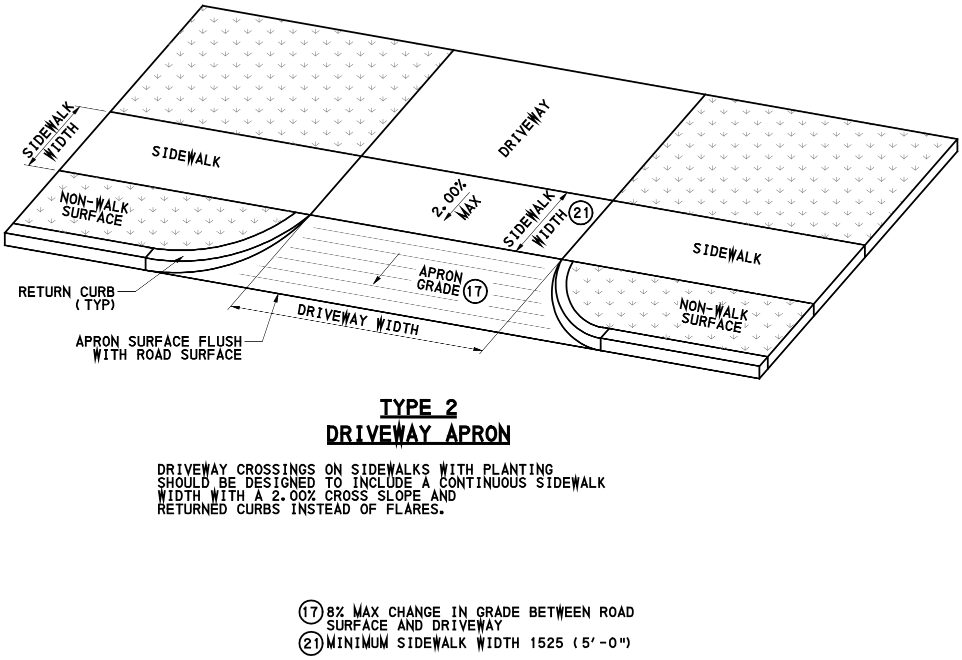

**DRIVEWAY CROSSINGS FOR SIDEWALKS ABUTTING PLANTING STRIPS CAN BE DESIGNED WITH A LEVEL LANDING USING SLOPED SIDE-FLARES THAT EASE VEHICLE TURNS.**

**FIGURE 7.2**
**Type 1 Driveway Apron**



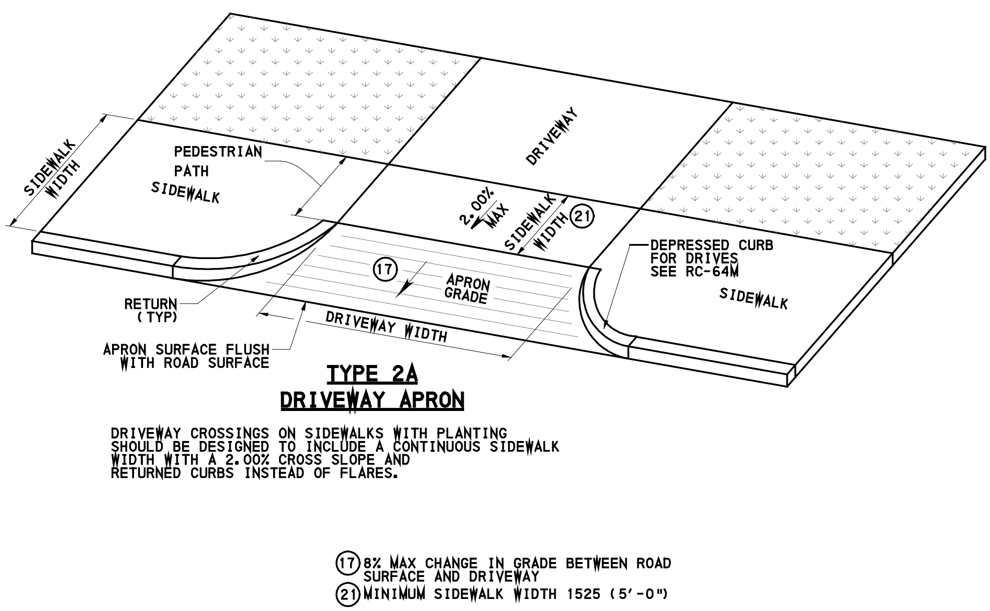

**WIDE SIDEWALK ZONES ALLOW MORE DESIGN CONFIGURATIONS. THIS CONFIGURATION IS MORE PEDESTRIAN FRIENDLY WITH A CONTINUOUS SIDEWALK AND A SIDE-FLARE WITH A MAXIMUM SLOPE OF 1V:10H (10.00%).**

**FIGURE 7.3**
**Type 1A Driveway Apron**



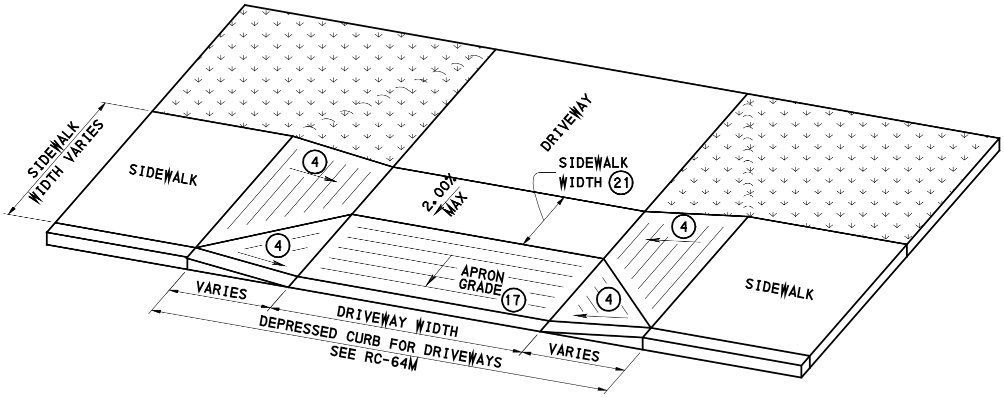

**DRIVEWAY CROSSINGS FOR SIDEWALKS ABUTTING PLANTING STRIPS CAN ALSO BE DESIGNED WITH RETURNED CURBS. THIS CONFIGURATION FORCES MOTORISTS TO ENTER THE DRIVEWAY CROSSING AT MORE OF A RIGHT ANGLE AND AT A LOWER SPEED.**

**FIGURE 7.4**
**Type 2 Driveway Apron**




**DRIVEWAY CROSSINGS FOR WIDE SIDEWALK ZONES CAN BE DESIGNED WITH RETURNED CURBS. THIS CONFIGURATION FORCES MOTORISTS TO ENTER THE DRIVEWAY CROSSING AT MORE OF A RIGHT ANGLE AND AT A LOWER SPEED BUT IS LESS PEDESTRIAN FRIENDLY SINCE A CURB IS INTRODUCED INTO THE WIDE PEDESTRIAN PATHWAY.**

**FIGURE 7.5**
**Type 2A Driveway Apron**

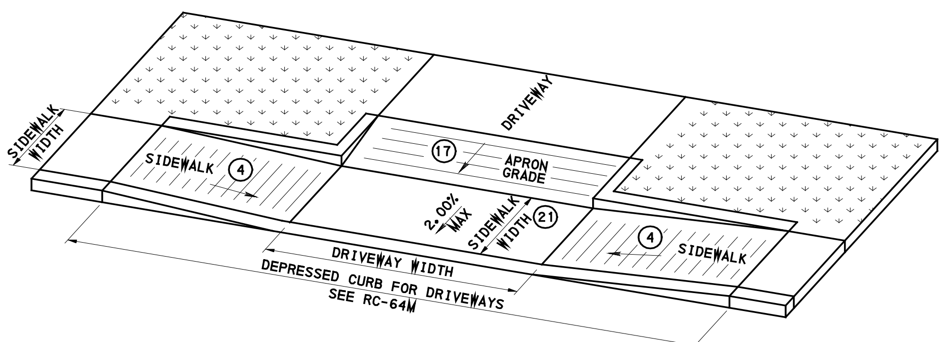



**TYPE 3**
**DRIVEWAY APRON**

(4) 8.33% MAX SLOPE
(17) 8% MAX CHANGE IN GRADE BETWEEN ROAD SURFACE AND DRIVEWAY
(21) MINIMUM SIDEWALK WIDTH 1525 (5'-0")

**DEPRESSED, LEVEL SIDEWALK CROSSINGS ENHANCE PEDESTRIAN ACCESS AT DRIVEWAY CROSSINGS WHERE SPACE IS LIMITED. THIS IS LESS PREFERRED DUE TO THE CHANGE IN SLOPE FOR THE PEDESTRIAN.**

## FIGURE 7.6
## Type 3 Driveway Apron



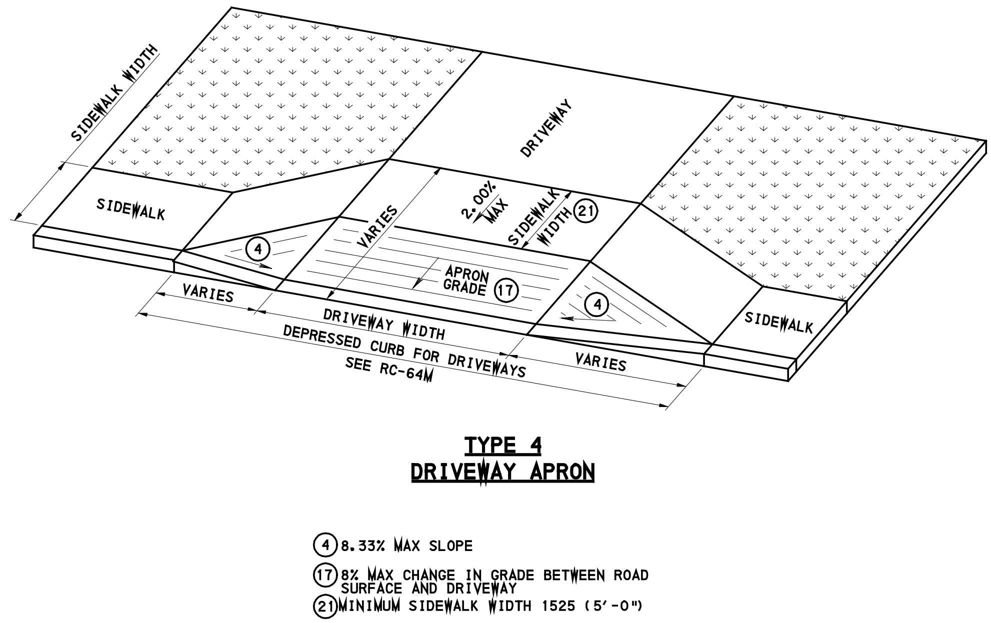

**TYPE 3A**
**DRIVEWAY APRON**

PARALLEL DRIVEWAY CROSSINGS ENHANCE PEDESTRIAN ACCESS AT A DRIVEWAY CROSSING WHEN THERE IS NO ROOM TO TRANSITION THE GRADES AND PROVIDE A CONTINUOUS SIDEWALK WIDTH WITH A 2.00% CROSS SLOPE. PARALLEL DRIVEWAY CROSSINGS ARE NOT AS DESIRABLE AS OTHER ACCESSIBLE DRIVEWAY CROSSINGS BECAUSE USERS ARE FORCED TO NEGOTIATE TWO RAMPS INSTEAD OF A LEVEL SURFACE.

(4) 8.33% MAX SLOPE
(17) 8% MAX CHANGE IN GRADE BETWEEN ROAD SURFACE AND DRIVEWAY
(21) MINIMUM SIDEWALK WIDTH 1525 (5'-0")

**NOTE: CERTAIN SITE CONDITIONS MAY REQUIRE CONSTRUCTING ADDITONAL CHEEK WALL CURBING TO INSTALL THIS TYPE OF CROSSING. THIS IS LESS PREFERRED DUE TO THE CHANGE IN SLOPE FOR THE PEDESTRIAN.**

## FIGURE 7.7
## Type 3A Driveway Apron




**NOTE: SHIFT SIDEWALK AWAY FROM CURB TO GAIN APPROPRIATE APRON GRADE.**

**FIGURE 7.8**
**Type 4 Driveway Apron**

# CHAPTER 8

## LANDSCAPE PLANTING DESIGN
## (ROADSIDE DEVELOPMENT)

### 8.0 INTRODUCTION

All roadside landscape planting design shall conform to the general principles of the latest edition of the AASHTO publication, *A Guide for Transportation Landscape and Environmental Design*. Roadside planting and roadway design should be correlated to achieve an overall unified plan. Roadside landscape planting design is a specialized field and should be assigned to personnel skilled in the use of plant material and experienced in the practice of Landscape Architecture. Landscape planting design should be completed under the direction of a Pennsylvania Registered Landscape Architect. Prepare the landscape planting design in conformance with the criteria presented in this Chapter.

### 8.1 PLANTING DESIGN

There are few mandatory rules for landscape planting design. The 1994 Presidential Executive Order on Environmentally Beneficial Landscaping provides guidance for implementing cost-effective, environmentally sound landscaping practices. Good design depends upon the knowledge and creativeness of the designer; however, a few basic guidelines do apply:

**1.** The designer should first gather knowledge of any special problems that may effect the location or survival of the plant material (soil data, utilities, water table, contour grading plan, etc.).

**2.** Highway planting should achieve a mass effect to be in scale for the viewer traveling at the design speed of the highway. Planting design should also achieve a well-balanced combination of both planted area and open spaces.

**3.** Planting should be both functional and aesthetic to serve some definite purpose such as traffic delineation, screening, erosion control, etc.

**4.** Where possible, especially in rural areas, planting designs should reflect the naturalistic conditions with informal flowing arrangements of material ecologically adapted to the site and purpose of the design. Avoid symmetrical, straight-line arrangements.

**5.** Contrasts of sizes, foliage, bark color, flower or fruit should be considered to add interest.

**6.** Form and shape should be utilized for harmony as well as for contrast. Round headed or spreading plants form more desirable masses, while columnar or conical shapes add greater visual emphasis. Plants as they mature change size and can quickly overgrow a particular planting site. Avoid planting trees too close together that would limit the potential width or height development of either plant.

**7.** Shrub use should be limited because of high maintenance costs, their relatively short life and large quantities of plants necessary to achieve large masses. Small flowering trees generally require less maintenance, have a longer life potential and can create larger and taller plant masses.

**8.** Plant selection should be based on the plant's adaptability to various environmental, climate and soil conditions as indicated below:

- Cold hardiness
- Salt spray tolerance
- Soil moisture requirements
- Drought tolerance
- Insect susceptibility
- Disease resistance
- Native plant classification
- Ease of transplant
- Sunlight or shade tolerance
- Off-site invasive characteristics
- Availability

**9.** Plant selection should emphasize the use of native plants to the highest extent possible. Efforts should be taken, when appropriate, to use regionally native plants for landscaping. However, the design should also strive to utilize the best plant selection possible for the prospective site and design concept. For example, White Pine (Pinus strobus) is a very nice native evergreen tree for use in many situations, but it is sensitive to salt spray damage. Therefore, white pine use in plantings along highways should be extremely limited to protected areas well away from potential salt spray damage zones. Japanese Black Pine (Pinus thunbergi) is a non-native evergreen tree but it is well suited to be used in areas subjected to salt spray.

**10.** Avoid selecting plants that have the potential to spread (invade) to areas adjacent to the highway right-of-way and adversely harm other existing plant communities.

**11.** Creating naturalized plant areas using decorative native shrubs, perennial bulbs, daylilies and wildflowers can be effective in providing colorful special focal areas along the highway.

**12.** Avoid placing trees and shrubs over underground utility lines and drainage pipes. Avoid planting trees under overhead utility lines unless the mature tree size is recognized as a tree type recommended for this purpose. Avoid placing trees and shrubs in the center of proposed drainage swales and in front of drainage pipe discharges.

**13.** The use of non-standard herbaceous seed mixtures containing native warm-season grasses and perennial wildflowers is encouraged for disturbed soil areas beyond the normal highway constructed slope limits. These herbaceous mixtures are well suited for revegetating areas for wildlife habitat mitigation and upslope areas for wetland replacement mitigation. All non-standard seed mixtures shall be approved by the Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section, on a project-by-project basis. See Chapter 13, Section 13.2 for additional guidance on these seed mixtures.

**14.** New construction projects shall also include a provision to plant native wildflowers. The wildflower planting shall be of a value of at least 1/4 of 1% of the total landscape planting cost, exclusive of planting items considered to be erosion and sedimentation control plantings.

**15.** All standard items for plants, planting and transplanting shall conform to the Construction Items Catalog which can be found in ECMS's Master Items screen in the Construction Projects menu, under Resources. Exceptions shall be approved by Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section, on a project by project basis.

**16.** The designer shall be familiar with the applicable sections of Publication 408, *Specifications*, and the Standard Drawings.

## 8.2 SET-BACK DISTANCE

**A.** Major trees that can attain a trunk diameter greater than 100 mm (4 in) should not be located within the median area or on the outside of curves adjacent to high speed highways where the cross section permits vehicular recovery, usually 9.0 m (30 ft) from the edge of traveled way. Major trees may be planted outside the existing minimum unobstructed distance specified in Chapter 12, Table 12.3. Other considerations such as the potential maintenance problems of roadway shading, leaf or other tree debris litter and the tree damage potential from winter maintenance chemicals shall be considered when planting trees closer than 9.0 m (30 ft) to the edge of traveled way.

**B.** Major trees that can attain a trunk diameter greater than 100 mm (4 in) should not be located between a diverging ramp and the mainline roadway, as follows:

**1.** For diverging ramps with a radius of less than 200 m (650 ft), the area between the mainline and the ramp shall be clear of trees to the intersection point of two lines measuring 30 m (100 ft) on the perpendicular from the mainline and ramp traveled way edges as indicated in Figure 8.1.

**2.** For diverging ramps with a radius greater than 200 m (650 ft), the area between the mainline and the ramp shall be clear of trees from a point 120 m (400 ft) from the nose, measured along the ramp traveled way and a line perpendicular to the mainline as indicated in Figure 8.1.

**C.** Trees and shrubs should not be located between converging ramps and mainline roadways, as follows:

**1.** For converging ramps with standard acceleration lane tapers, the area between the mainline and the ramp shall be clear of all vegetation over 600 mm (24 in) in height, from a point measured 275 m (900 ft) from the end of the traffic separator and an intersecting line at a right angle to the left edge of traveled way of the converging ramp (see Figure 8.2).

**2.** For converging ramps where a structure or a deceleration ramp is closer than the 275 m (900 ft) and right angle clear area stated in C.1 above, use an intersecting line at a right angle to the left edge of traveled way of the converging ramp to the furthest point available at the structure or the other deceleration ramp for the clear area limits (see Figures 8.3 and 8.4).

## 8.3 MOW LINE LIMIT

Mow line limits are encouraged to be established in areas of mass planting to help natural vegetation regeneration, protect the new plant installations, and reduce mowing requirements. These limits can be indicated on the Landscape Planting (Roadside Development) Plans. See Publication 14M, Design Manual, Part 3, *Plans Presentation*, Chapter 7, Section 7.3 for the recommended plan designation.

## 8.4 MULCHING

All tree pits and individual shrub pits are mulched with appropriate surface mulch as indicated on Publication 72M, *Roadway Construction Standards*, Drawing RC-91M. Mulch with or without weed barrier mat or weed control mat is measured on a square meter (square foot) basis for any designated shrub bed areas.

## 8.5 STAKING AND GUYING

Trees are staked and guyed and this operation is incidental to the planting cost as indicated on Publication 72M, *Roadway Construction Standards*, Drawing RC-91M.

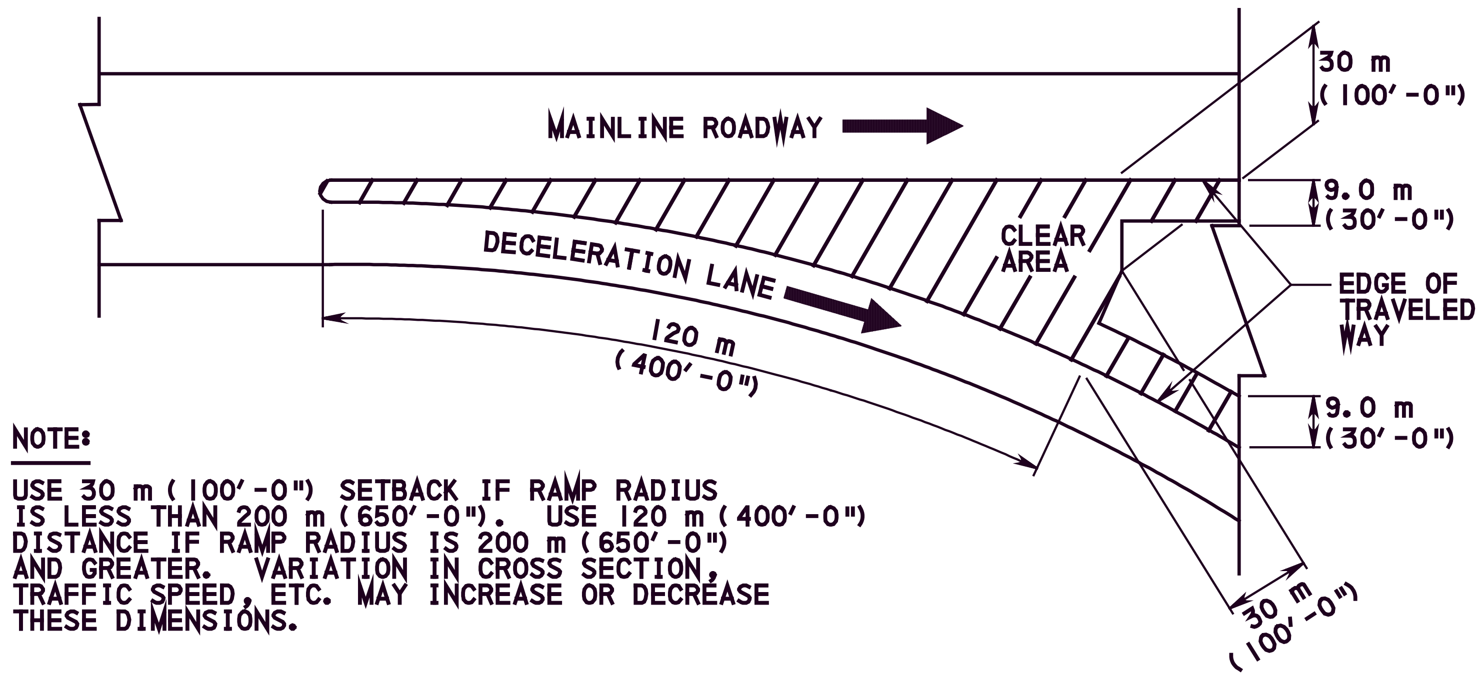



FIGURE 8.1
SAFETY SET-BACK GUIDE
FOR INTERCHANGE TREE PLANTING

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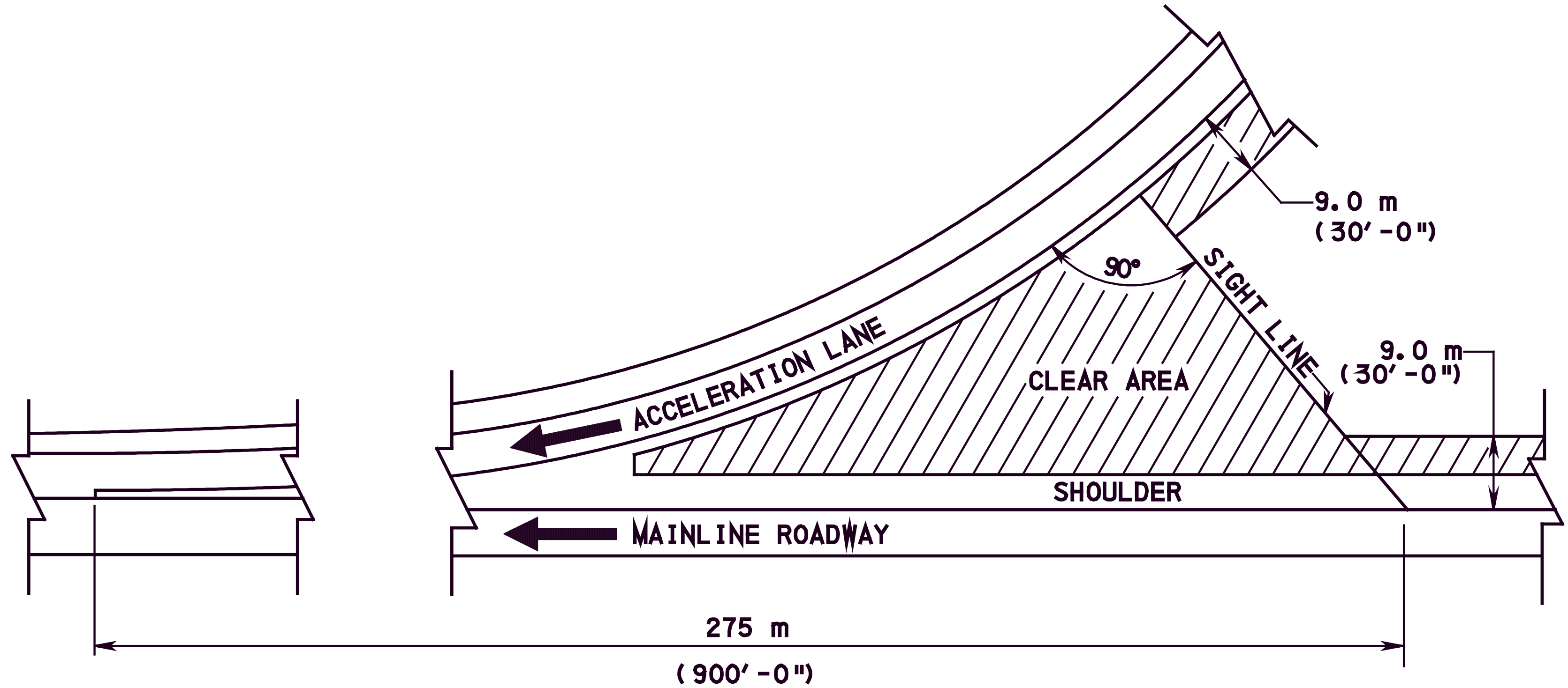


FIGURE 8.2
CLEAR SIGHT DISTANCE GUIDE
FOR INTERCHANGE TREE PLANTING

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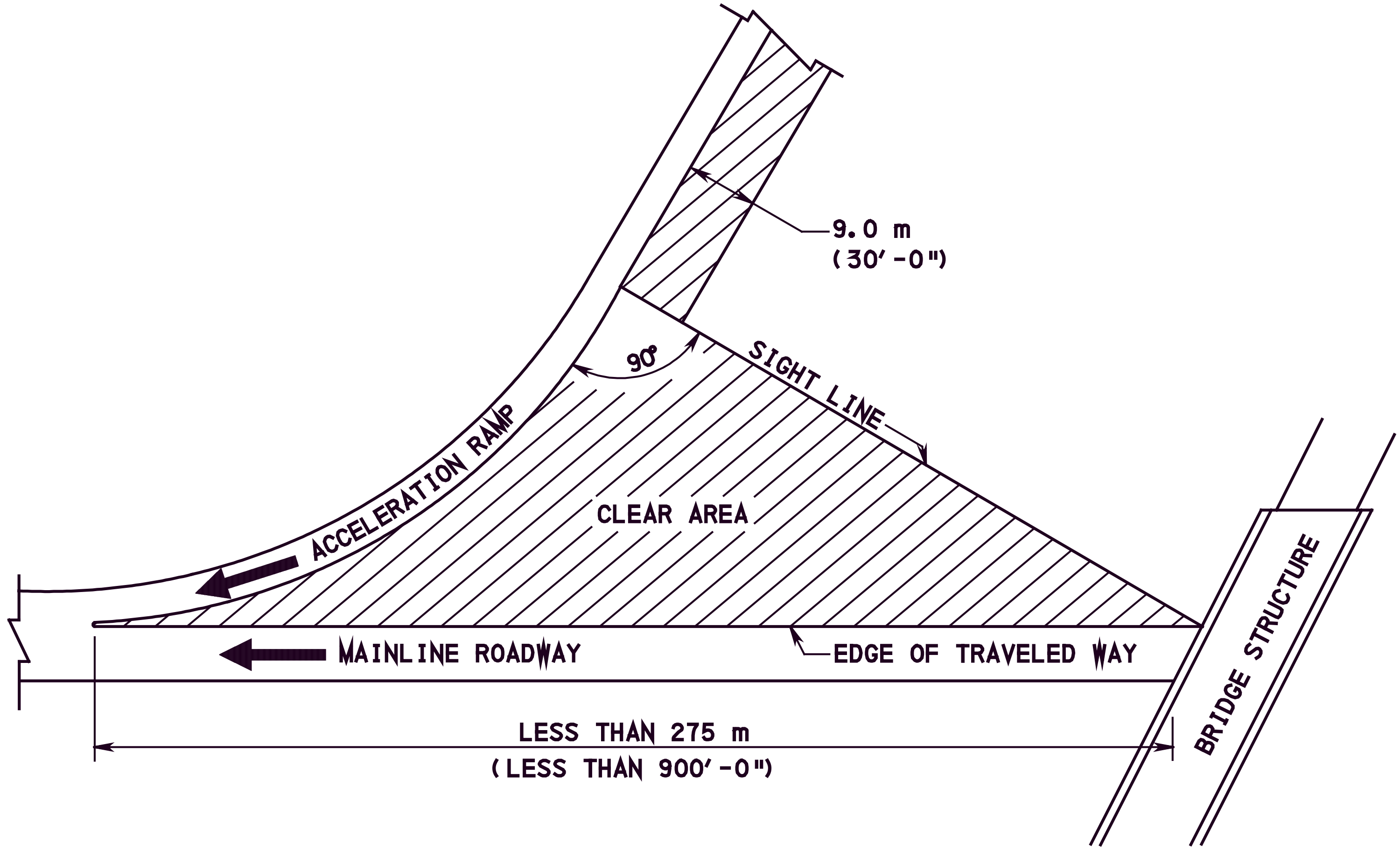


FIGURE 8.3
CLEAR SIGHT DISTANCE GUIDE
FOR INTERCHANGE TREE PLANTING

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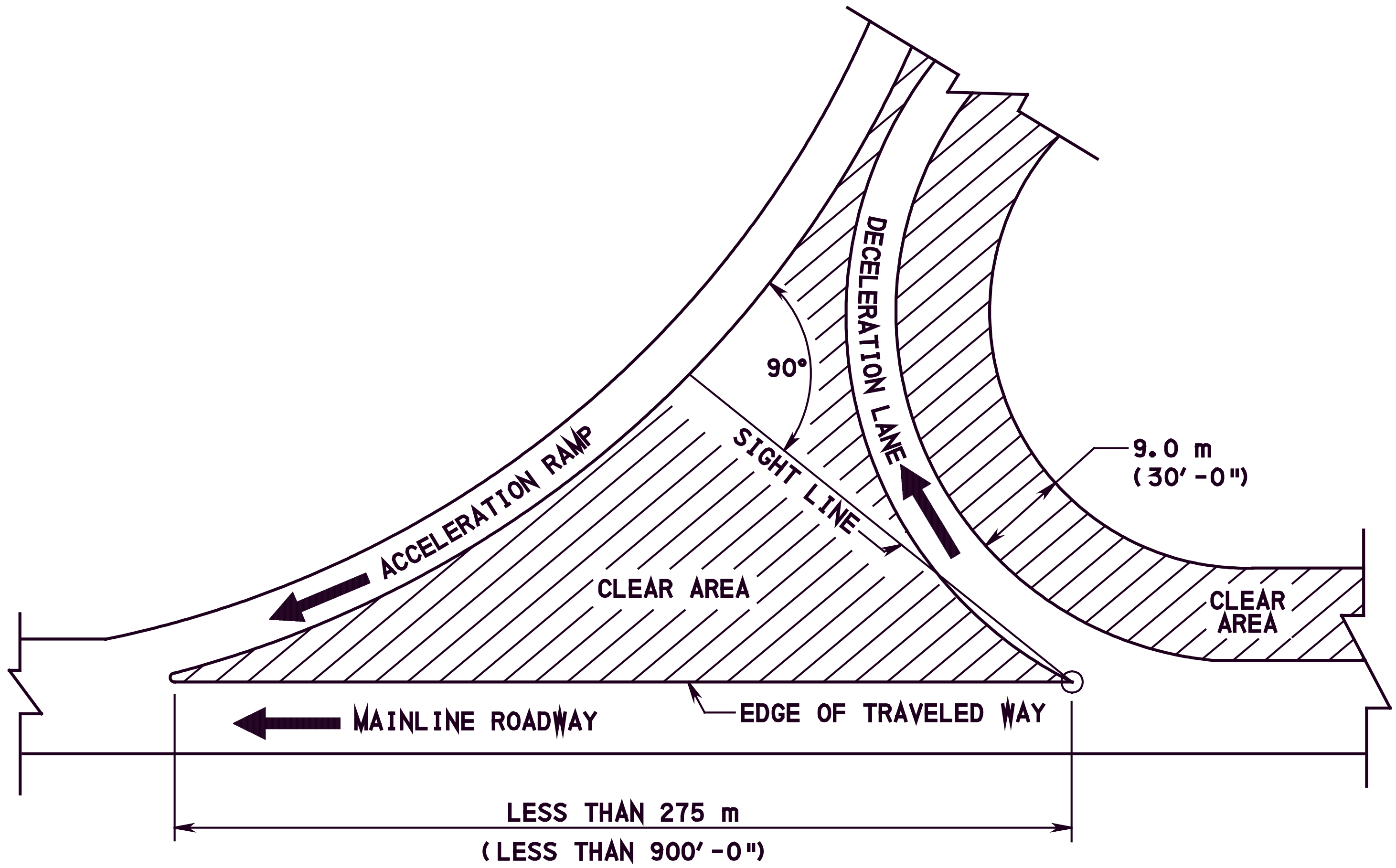


FIGURE 8.4
CLEAR SIGHT DISTANCE GUIDE
FOR INTERCHANGE TREE PLANTING

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## 8.6 SELECTIVE TREE REMOVAL AND TRIMMING

Selective tree removal and trimming work is accomplished in accordance with Publication 408, *Specifications*, Section 810. Calculate selective tree removal and trimming work as follows:

**1.** In median or interior areas of interchanges where stands of trees are less than 30 m (100 ft) in width, perform work as required on entire stand.

**2.** Where the median or interchange areas are greater than 30 m (100 ft) in width, perform work as required a minimum 15 m (50 ft) from the grading limits.

**3.** For outer areas, perform work as required a minimum of 8 m (25 ft) or to the right-of-way line, whichever is less.

Tabulate all desired selective tree removal and trimming operations on the appropriate Landscape Planting (Roadside Development) Plan Tabulation Sheets.

# CHAPTER 9

## SAFETY REST AREAS AND WELCOME CENTERS

### 9.0 INTRODUCTION

The development of Safety Rest Areas and Welcome Centers is a necessary component of highway development. Site development of these areas may also include the provision for a truck weigh-in-motion scale system in order to provide a dual use opportunity at the Safety Rest Area.

Site development must provide visually pleasing, safe and easily accessible facilities which are also fully accessible to persons with disabilities.

### 9.1 DEFINITIONS

**1.** Access Aisle. An accessible pedestrian space between parking stalls that provides appropriate clearances to use the space.

**2.** Accessible Route (AR). A continuous unobstructed path connecting all accessible elements and spaces of a building or facility.
(Americans with Disabilities Act (ADA) Accessibility Guidelines for Buildings and Facilities (ADAAG))
http://www.access-board.gov/adaag/html/adaag.htm

**3.** Parking Stall. Surface area generally paved and delineated by pavement markings to denote intended vehicle parking space allotments.

**4.** Pedestrian Access Route (PAR). A continuous and unobstructed walkway within a pedestrian circulation path that provides accessibility. Pedestrian accessible routes may include parking access aisles, curb ramps, crosswalks at vehicular ways, walks, ramps, and lifts.
Draft Public Rights of Way Accessibility Guidelines (PROWAG)
http://www.access-board.gov/prowac/draft.htm

**5.** Safety Rest Area. A roadside facility safely removed from the roadway with parking, and other facilities deemed necessary for the rest, relaxation, comfort, convenience and information of the motorist. Interstate Safety Rest Areas will also have an all-weather, enclosed building.

**6.** Sidewalk. A portion of a roadway between curb lines or the lateral line of a roadway and the adjacent property line or easement of private property that is paved or improved and intended for use by pedestrians.

**7.** Welcome Center. A Safety Rest Area specifically designed to provide information and other services of interest to the traveling public. Welcome Centers are generally located at major highway entry points to the state.

### 9.2 DESIGN CRITERIA

The design of Safety Rest Areas and Welcome Centers must be in accordance with current Department design standards and the American Association of State Highway and Transportation Officials (AASHTO) to insure adequacy of acceleration and deceleration ramps, turning radii, vehicle parking areas, signing, surface water drainage provisions and highway lighting.

Wastewater disposal systems and drinking water supply systems must be in accordance with all appropriate regulations of the PA Department of Environmental Protection (PA DEP).

Chapter 6, Pedestrian Facilities and the Americans with Disabilities Act must be used for all pedestrian accessibility provisions.

## 9.3 PARKING CAPACITY DETERMINATION

The capacity of the parking areas needed for each site are determined by calculating traffic volume data for the projected design year with directional distribution and design hour volume constants for peak hour usage as outlined below:

### A. Traffic Data - Peak Hour.

ADT = Average Daily Traffic (Normal 20-year projection or other design year as directed)

K = Ratio of Design Hour Volume to ADT (Interstate - Rural 12% or Urban 10%)

D = Directional Distribution (generally about 0.60)

Therefore: Peak Hour Directional Traffic (PHD) = ADT × K × D

### B. Parking Requirements.

N = Percentage of vehicles stopping at Safety Rest Areas during peak hours (location factor). The percentage varies from about 5% to about 13% depending upon the location as follows:

**1.** Near commercial or recreational facilities = 5%.

**2.** Rural Area = 9%.

**3.** Isolated area with no nearby commercial or recreational facilities = 13%.

Percentages may be interpolated to reflect locations of nearby existing or proposed facilities.

M = Total parking spaces = PHD × N × length of stay in Safety Rest Area (generally 20 to 30 min or 0.33 to 0.50)

Car Parking Spaces = M × the percentage of cars (generally about 0.80; a lower factor may be used if anticipated truck traffic is high)

Truck Parking Spaces = M - Car Parking Spaces

It is desirable to use the maximum number of calculated parking spaces if the topography of the site and the available property size are compatible for full sized development.

<u>Example</u>: Determine Range of Parking Needed

Assume: ADT = 31 714 (20-year design projection)

N = Rural Area of 9%
Length of stay of 20 min = 0.33
Length of stay of 30 min = 0.50

Therefore: PHD = 31 714 × 0.12 × 0.60 = 2283
M = 2283 × 0.09 × 0.33 = 67.8 CALL 68
2283 × 0.09 × 0.50 = 102.7 CALL 103

Car Parking Spaces = 68 × 0.80 = 54.4 CALL 54
Truck Parking Spaces = 68 - 54 = 14

or

Car Parking Spaces = 103 × 0.80 = 82.4 CALL 82
Truck Parking Spaces = 103 - 82 = 21

Therefore: Desirable range of parking requirements = Car Parking - 54 to 82
Truck Parking - 14 to 21
Total Parking - 68 to 103

## 9.4 PARKING CRITERIA

### A. General.

**1.** Vehicular traffic flows should be in a continuous, one-way direction. Avoid two-way traffic and the use of dead-end parking lot arrangements.

**2.** Whenever possible, the car parking area should be designed as a separate area from the parking area used for trucks, buses, car-trailers and recreational vehicles.

**3.** The geometric design of the parking areas should avoid small acute angle curbed areas and excessive small protrusions or islands into the parking area which can make snow removal operations difficult.

**4.** The design of the parking areas must be functional, simple, and attractive and provide safe vehicular movements which will not test the driver's ability.

**5.** The gradient of the parking areas should be relatively level but still sloped or crowned to permit surface drainage flows directed toward inlet structures.

**6.** Clearing or removal of snow during winter should be carefully analyzed. Increased turning radii for snow removal equipment should be considered. Determining where snow can be piled during the design stage can increase the efficiency of the parking area during the winter season.

**7.** Parking stalls must be indicated with pavement markings to delineate the designated parking pattern and other pavement markings such as directional arrows, crosswalk indicators, etc. should be considered.

**8.** If parking stalls are too narrow, the drivers will often ignore stripe demarcation lines and overlap into adjacent stalls. Drivers often do not park precisely in the center of the designated stall and do not always pull-in to the full depth allowance of the stall. Therefore, where space permits, it is always best to avoid minimum stall dimensions.

Maximum allowable grade for the accessible parking stalls is 1V:50H (2.00%). Parking spaces that are not level may deny use to persons with disabilities since vehicle doors are more difficult to operate on slopes where wheelchairs tend to roll away.

### B. Parking Configurations.

**1.** Car Parking.

**a.** The car parking stalls should be designed for head-in parking either at a 60° or 45° angle to the traffic lane.

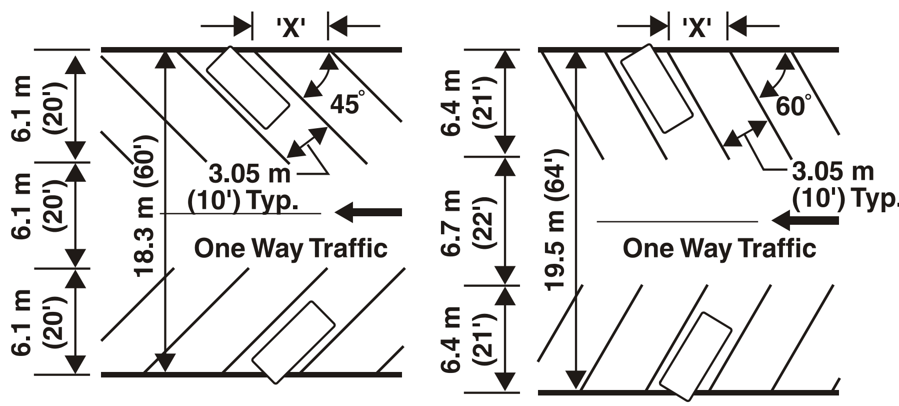
**b.** Stalls at a 60° angle are more commonly used and are generally considered the most satisfactory in relation to pull-in and back-out vehicle movements. Traffic aisle and parking lot widths are reasonable.

**c.** Stalls at a 45° angle are preferred in some cases since they require a smaller change of direction to enter the stall and allow a reduced lot width. However, fewer cars can be parked in a given space since the stall width dimension per vehicle measured along the curb is greater.

**d.** Refer to Figure 9.1 for recommended parking dimension information.

**e.** Provide the appropriate number of accessible car parking stalls as shown in Table 9.1 at a convenient location or locations near the Safety Rest Area/Welcome Center building. Provide an accessible route from the parking area to the building.

**f.** Two accessible car parking stalls can share a common access aisle. In general, a person with disabilities should not be forced to travel behind parked vehicles along their circulation path.




| METRIC | | | | | |
|---|---|---|---|---|---|
| **PARKING ANGLE (DEGREES)** | **AISLE WIDTH (m)** | **STALL DEPTH (m)** | **STALL WIDTH (m)** | **TOTAL WIDTH (m)** | **CURB LENGTH 'x' (m)** |
| 45 | 6.1 | 6.1 | 3.05 | 18.3 | 4.31 |
| 60 | 6.7 | 6.4 | 3.05 | 19.5 | 3.52 |

| ENGLISH | | | | | |
|---|---|---|---|---|---|
| **PARKING ANGLE (DEGREES)** | **AISLE WIDTH (ft)** | **STALL DEPTH (ft)** | **STALL WIDTH (ft)** | **TOTAL WIDTH (ft)** | **CURB LENGTH 'x' (ft)** |
| 45 | 20 | 20 | 10 | 60 | 14.14 |
| 60 | 22 | 21 | 10 | 64 | 11.55 |

**FIGURE 9.1**
**DIMENSIONS FOR CAR PARKING SPACES**

## TABLE 9.1
## REQUIRED MINIMUM NUMBER OF ACCESSIBLE CAR SPACES AT SAFETY REST AREAS

| NUMBER OF SPACES IN SAFETY REST AREA PARKING LOTS | REQUIRED MINIMUM NUMBER OF ACCESSIBLE SPACES |
|---|---|
| 1 TO 25 | 1 |
| 26 TO 50 | 2 |
| 51 TO 75 | 3 |
| 76 TO 100 | 4 |
| 101 TO 150 | 5 |
| 151 TO 200 | 6 |

**g.** At least one accessible parking space must be served by an access aisle at least 2440 mm (96 in) wide and be signed by an appropriate "VAN ACCESSIBLE" sign. Utilization of the universal parking space design criteria can eliminate the requirement for the "VAN ACCESSIBLE" sign. See Section 9.4.B.2.

**h.** Access aisles should be delineated with white cross-hatch pavement markings to further indicate that these areas should not be obstructed by parked vehicles.

Use 100 mm (4 in) wide stripes spaced 1220 mm (48 in) center to center to delineate the access aisle. Border the entire area with a 100 mm (4 in) wide stripe. Generally position the stripe at a 45° angle to the vehicle stall curb line. Extend stripes the full length and width of the aisle. See Figures 9.2 and 9.3 for details of the accessible parking stall layout.

**2.** Universal Parking Design Criteria. All accessible car spaces are 3350 mm (132 in) wide with a 1525 mm (60 in) access aisle so that the stall measures 4875 mm (192 in) wide. See Figure 9.4.

The 4875 mm (192 in) stall permits vehicles to park to one side or the other within the 3350 mm (132 in) dimension to allow persons to exit and enter the vehicle on either the driver or passenger side although the marked access aisle may not be usable.

No additional signage for vans is needed since all spaces can accommodate a van with a side-mounted lift or ramp. The 4875 mm (192 in) stall eliminates competition between cars and vans for space since all stalls can accommodate either vehicle.

**3.** Truck Parking (Buses, RV's, Car-Trailers).

**a.** Truck parking stalls should be designed for pull-through operation at either a 30°, 45° or 60° angle to the traffic lane.

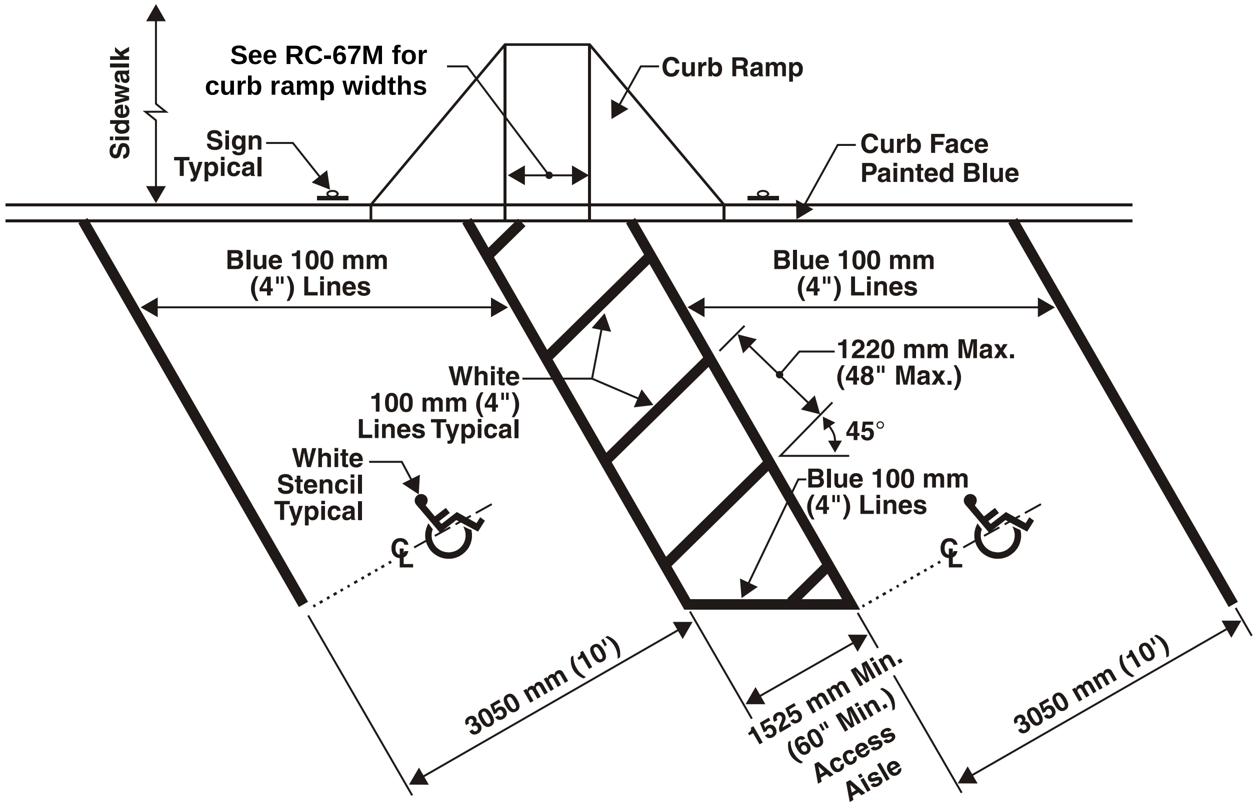
**b.** Stalls at a 30° angle are generally more satisfactory in relation to pull-through vehicle movements. However, they also require a longer overall length of parking area.

**c.** In certain situations, parallel park stalls designed for RV or car-trailer type vehicles which would allow a right-side curb discharge for occupants of the vehicle should be considered in order to increase the capacity of the parking area and safety of the vehicle occupants.

**d.** Parking stall dimensions should be designed to accommodate the WB-20 (WB-67) truck Interstate semi-trailer units.

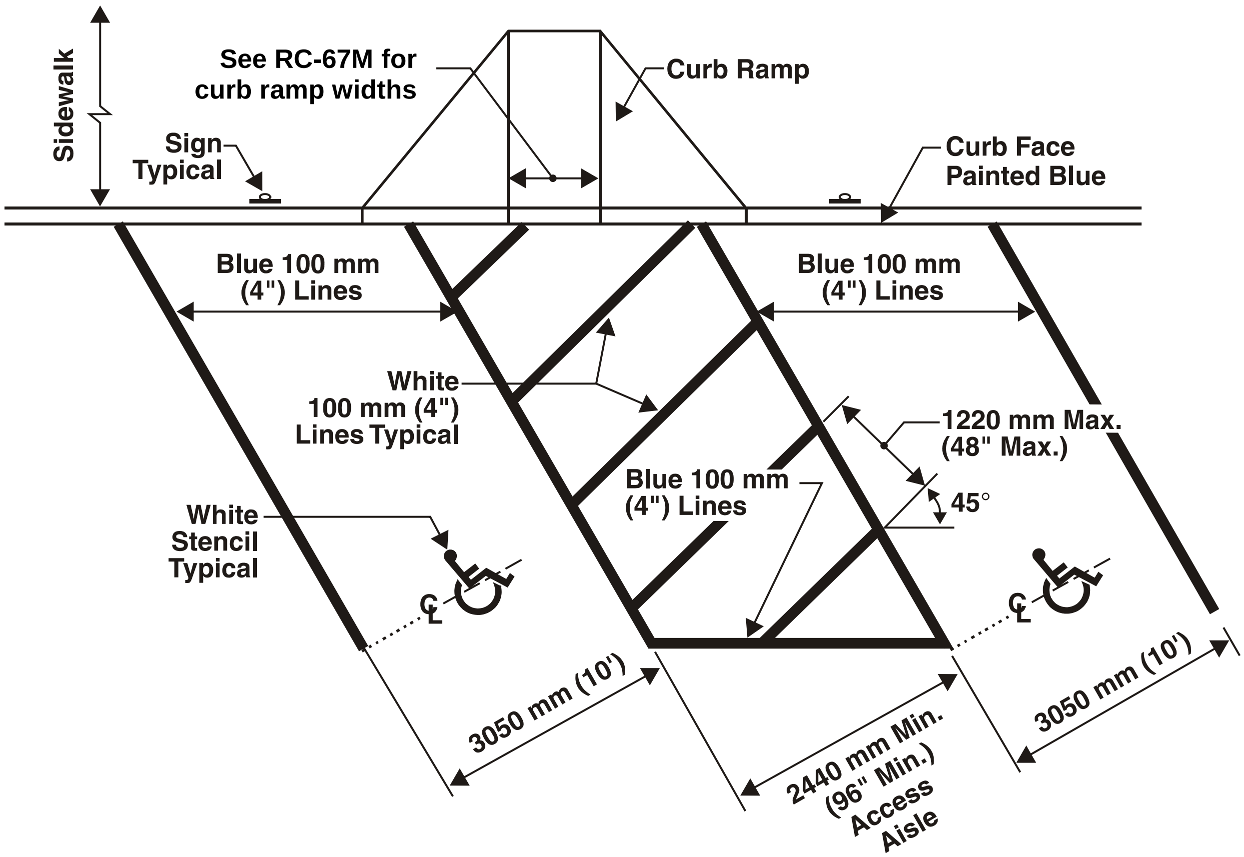
**e.** An accessible route must be provided from the truck parking lot to the building.

**f.** Refer to Figure 9.5 for recommended parking dimension information.




**Note:** Accessible parking signs shall be mounted 2.4 m (8 ft) above grade and setback sufficient to avoid car bumper overhang and pedestrian traffic.

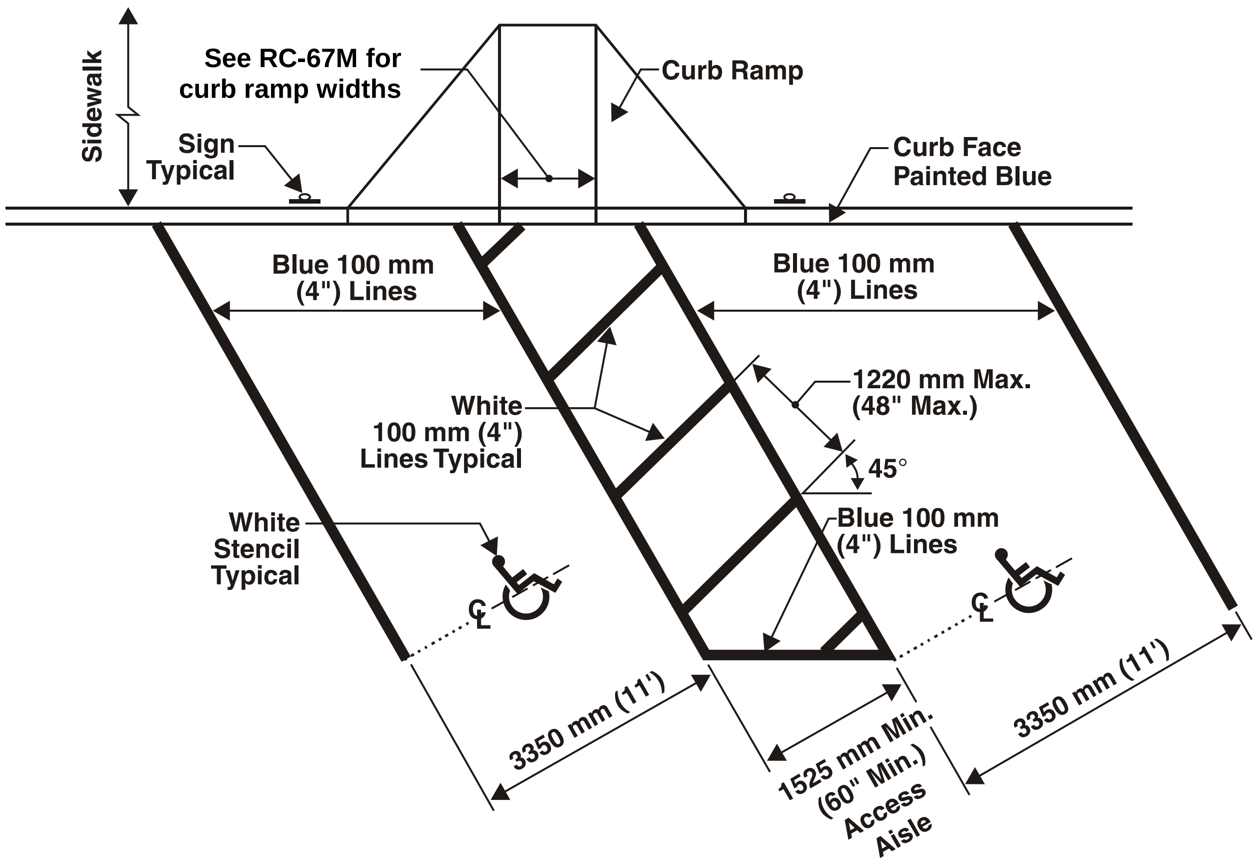
## FIGURE 9.2
## Standard Accessible Parking Stalls




Note: **Accessible parking signs shall be mounted 2.4 m (8 ft) above grade and setback sufficient to avoid car bumper overhang and pedestrian traffic.**

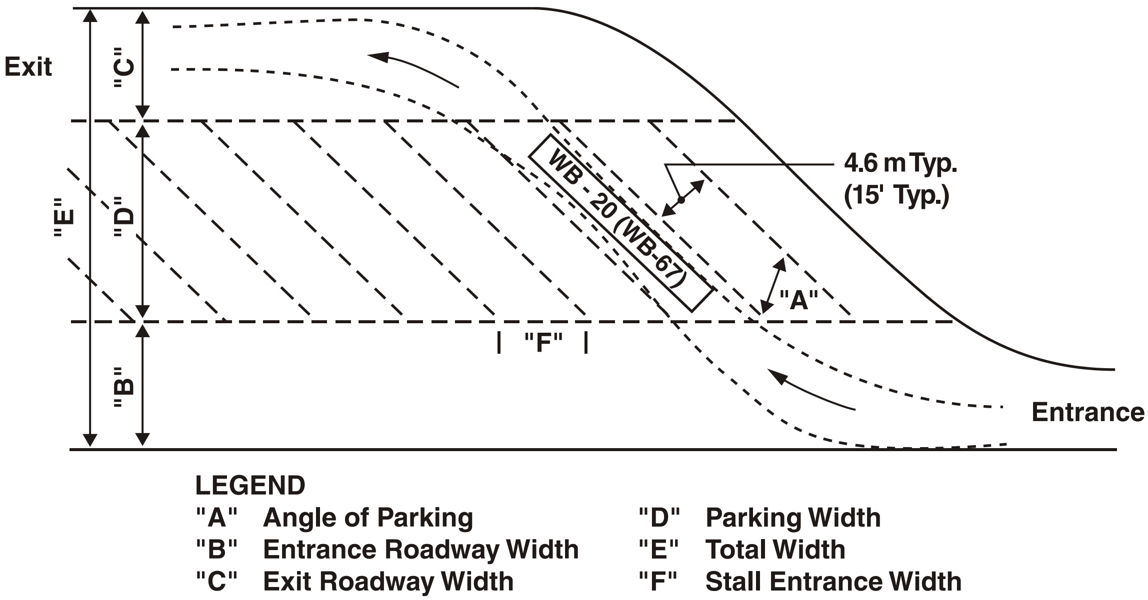
**FIGURE 9.3**

## Van Accessible Parking Stalls




**Note:** **Accessible parking signs shall be mounted 2.4 m (8 ft) above grade and setback sufficient to avoid car bumper overhang and pedestrian traffic.**

**FIGURE 9.4**
**Universal Accessible Parking Stalls**




| METRIC (WB-20) | | | | | |
|---|---|---|---|---|---|
| ANGLE OF PARKING (DEGREES) "A" | ENTRANCE ROADWAY WIDTH (m) "B" | EXIT ROADWAY WIDTH (m) "C" | PARKING WIDTH (m) "D" | TOTAL WIDTH PARKING AREA (m) "E" | STALL ENTRANCE WIDTH (m) "F" |
| 30* | 6.7 | 6.7 | 14.0 | 27.4 | 9.20 |
| 45 | 9.1 | 9.1 | 18.3 | 36.5 | 6.51 |
| 60 | 12.2 | 10.7 | 21.3 | 44.2 | 5.31 |

| ENGLISH (WB-67) | | | | | |
|---|---|---|---|---|---|
| ANGLE OF PARKING (DEGREES) "A" | ENTRANCE ROADWAY WIDTH (ft) "B" | EXIT ROADWAY WIDTH (ft) "C" | PARKING WIDTH (ft) "D" | TOTAL WIDTH PARKING AREA (ft) "E" | STALL ENTRANCE WIDTH (ft) "F" |
| 30* | 22 | 22 | 46 | 90 | 30 |
| 45 | 30 | 30 | 60 | 120 | 21.2 |
| 60 | 40 | 35 | 70 | 145 | 17.3 |

*Note: The "D" parking width dimension will allow a truck vehicle length of 23.7 m (78 ft) if parked in center of stall.

**FIGURE 9.5**
**DIMENSIONS FOR TRUCK PARKING SPACES**
**(DESIGN VEHICLE WB-20 (WB-67))**

## 9.5 WASTEWATER FLOW CALCULATION

Determine the average daily flow of wastewater from the Safety Rest Area facility by using the following calculations and procedures:

Assume: ADT = Average Daily Traffic (20-year projection or other design year as directed).

D = Directional Distribution (assume 0.60).

N = Percentage of vehicles stopping at Safety Rest Area (assume 9% or 0.09).

V = The number of vehicles stopping per day at the Safety Rest Area.

= ADT × D × N.

U = Vehicle Occupancy (3.0 to 3.5 persons per vehicle, assume average of 3.25).

S = Percentage of persons stopping at Safety Rest Area using the toilet facilities (assume 75% or 0.75).

P = The number of restroom facility users per day.

= V × U × S.

Design Parameters:

**1.** 60% male users.

**2.** 40% female users.

**3.** 67% of males use the urinals (40% of total usage).

**4.** 60% watercloset (toilet) usage.

**5.** Assume 2.3 L (0.6 gal) of grey water per user. (This figure includes all other water usage in the building excluding toilet and urinal usage).

**6.** Low-flow water saving fixture usage.
Urinal - 3.8 L (1.0 gal) per flush.
Toilet - 6.0 L (1.6 gal) per flush.

**7.** Diurnal Flow Distributions:
8:00 AM - 12:00 Noon = 30% of total daily flow
12:00 Noon - 4:00 PM = 30% of total daily flow
4:00 PM - 8:00 AM = 40% of total daily flow

**8.** Peak Hourly Flow (PHQ) Percentage of the average daily flow (Q) ranges between 13.5% and 16%. (Assume average of 15% or 0.15)
Q (Average Daily Wastewater Flow) = P × CF (Composite Flow Per User)

Determine the composite wastewater flow (liters (gallons)) per user (CF) based on the proposed fixture water usage as indicated in the following example:

| **METRIC** | **ENGLISH** |
|---|---|
| 0.6 toilet usage × 6.0 L/flush = 3.6 L | 0.6 toilet usage × 1.6 gal/flush = 1.0 gal |
| 0.4 urinal usage × 3.8 L/flush = 1.5 L | 0.4 urinal usage × 1.0 gal/flush = 0.4 gal |
| Grey water usage = 2.3 L | Grey water usage = 0.6 gal |
| CF = 7.4 L/user | CF = 2.0 gal/user |

| Calculation Example: Design Year ADT = 21 688 | |
|---|---|
| **METRIC** | **ENGLISH** |
| V = ADT × D × N<br>V = 21 688 × 0.6 × 0.09<br>V = 1171 (vehicles per day stopping at Safety Rest Area)<br><br>P = V × U × S<br>P = 1171 × 3.25 × 0.75<br>P = 2854 (users per day)<br><br>Q = P × CF<br>Q = 2854 users/day × 7.4 L/user<br>Q = 21 119.6 L/day<br>CALL 21 000 L/day (Average Daily Flow)<br><br>PHQ = Q × 0.15<br>PHQ = 21 000 × 0.15<br>PHQ = 3150 L | V = ADT × D × N<br>V = 21,688 × 0.6 × 0.09<br>V = 1171 (vehicles per day stopping at Safety Rest Area)<br><br>P = V × U × S<br>P = 1171 × 3.25 × 0.75<br>P = 2854 (users per day)<br><br>Q = P × CF<br>Q = 2854 users/day × 2.0 gal/user<br>Q = 5708 gal/day<br>CALL 5700 gal/day (Average Daily Flow)<br><br>PHQ = Q × 0.15<br>PHQ = 5700 × 0.15<br>PHQ = 855 gal |

Diurnal Flow Distribution:

| | **METRIC** | **ENGLISH** |
|---|---|---|
| 8:00 AM - 12:00 Noon | 0.3 × 21 000 = 6300 L | 0.3 × 5700 = 1710 gal |
| 12:00 Noon - 4:00 PM | 0.3 × 21 000 = 6300 L | 0.3 × 5700 = 1710 gal |
| 4:00 PM - 8:00 AM | 0.4 × 21 000 = 8400 L | 0.4 × 5700 = 2280 gal |

## 9.6 WATER SUPPLY DEMAND CALCULATION

The method for determining the peak instantaneous demand must be based on weighting fixtures in accordance with their water supply load producing effects on the water distribution system as follows:

**1.** Determine the total number of toilets, urinals and sinks in the Safety Rest Area building.

**2.** Assign a demand weight to each fixture in terms of Fixture Units (FU) (Refer to Table 9.2) and compute the cumulative Fixture Unit value.

**3.** Convert the total Fixture Unit value to equivalent liters per second (gallons per minute) peak instantaneous demand. (Refer to Table 9.3)

Calculation Example:

Refer to Section 9.7.A, Safety Rest Area Building Criteria and Tables 9.2 and 9.3.

Determination of Fixture Units:

| | |
|---|---|
| 17 water closets (toilets) × 10 FU | = 170 |
| 6 urinals × 5 FU | = 30 |
| 17 lavatories (sinks) × 2 FU | = <u>34</u> |
| Total Fixture Units | = 234 |

234 Fixture Units equates to 6.2 L/s (98 gal/min) peak instantaneous demand. (Table 9.3)

## TABLE 9.2
## DEMAND WEIGHT OF FIXTURES IN FIXTURE UNITS

| FIXTURE | OCCUPANCY | TYPE OF SUPPLY CONTROL | LOAD (FIXTURE UNITS) |
|---|---|---|---|
| Water Closet | Public | Flush Valve | 10 |
| Water Closet | Private | Flush Valve | 6 |
| Urinal | Public | Flush Valve | 5 |
| Lavatory | Public | Faucet | 2 |
| Lavatory | Private | Faucet | 1 |
| Kitchen Sink | Private | Faucet | 2 |
| Service or Mop Basin Sink | Office, etc. | Faucet | 4 |

## TABLE 9.3
## CONVERSION OF FIXTURE UNITS TO EQUIVALENT L/s (gal/min)

| DEMAND (LOAD) FIXTURE UNITS | DEMAND (LOAD), L/s SYSTEM WITH FLUSH VALVES (METRIC) | DEMAND (LOAD), gal/min, SYSTEM WITH FLUSH VALVES (ENGLISH) |
|---|---|---|
| 6 | – | – |
| 8 | – | – |
| 10 | 1.7 | 27 |
| 12 | 1.8 | 29 |
| 14 | 1.9 | 30 |
| 16 | 2.0 | 32 |
| 18 | 2.1 | 33 |
| 20 | 2.2 | 35 |
| 25 | 2.4 | 38 |
| 30 | 2.6 | 41 |
| 35 | 2.8 | 44 |
| 40 | 3.0 | 47 |
| 45 | 3.1 | 49 |
| 50 | 3.3 | 52 |
| 60 | 3.5 | 55 |
| 70 | 3.7 | 59 |
| 80 | 3.9 | 62 |
| 90 | 4.1 | 65 |
| 100 | 4.3 | 68 |
| 120 | 4.6 | 73 |
| 140 | 4.9 | 78 |
| 160 | 5.2 | 83 |
| 180 | 5.5 | 87 |
| 200 | 5.8 | 92 |
| 225 | 6.1 | 97 |
| 250 | 6.4 | 101 |
| 275 | 6.7 | 106 |
| 300 | 6.9 | 110 |
| 400 | 7.9 | 126 |
| 500 | 9.0 | 142 |

## 9.7 SAFETY REST AREA AND WELCOME CENTER BUILDINGS

**A. Safety Rest Area Building.** The current standard Safety Rest Area building design includes 23 rest room fixtures comprised as follows:

Men's Rest Room - 6 water closets (toilets)
6 urinals
8 lavatories (sinks)

Women's Rest Room- 10 water closets
8 lavatories

Family Assisted Rest Room - 1 water closet
1 lavatory

**B. Welcome Center Building.** A standard Welcome Center building design does not exist. Each building design and its component number of rest room fixtures will be determined for each site location.

## 9.8 WEIGH-IN-MOTION SCALE SYSTEM

The truck weigh-in-motion (WIM) scale system comprised of stationary weighpads installed in the roadway must be designed to operate in conjunction with the design layout of the truck parking access roadway and parking area when directed.

The access roadway is an essential part of the WIM system and therefore should be as flat and uniform as possible for approximately 60 m (200 ft) ahead of and 15 m (50 ft) beyond the weighpad location. The roadway gradient should not exceed 3% and the transverse slope of the pavement should not exceed 1%.

The WIM scales should be located within a tangent section of the access roadway and outside of the superelevation of the roadway, if possible.

The design layout relationship of the truck parking area to the access roadway should promote a reasonable view of the side of each truck as it passes over the sorting scale from the first truck parking space where the mobile weigh command center van will park.

The WIM scale location must be set no closer than 90 m (300 ft) from the location of the system control enclosure. The control enclosure pedestal support must be located from 1.5 m to 4.5 m (5 ft to 15 ft) behind the curb line of the first truck parking stall.

## 9.9 PLANTING DESIGN GUIDELINES FOR WELCOME CENTERS AND SAFETY REST AREAS

The following guidelines should be used when considering landscape planting design for Welcome Centers and Safety Rest Areas.

- Consider trees that will provide good shading opportunities at table pad areas. Place trees on the appropriate side of the pad to give shade throughout the afternoon if possible.

- Avoid 'dirty' trees that have the potential to drop excessive branches, fruit, and large leaves in use and pavement areas such as: Sugar and Norway Maple, American Redbud, White and Green Ash, some crabapples, etc.

- Use colorful spring flowered and fall foliage species.

- Avoid disease prone varieties of Crabapple and other flowering trees. Avoid pest problem trees such as Littleleaf Linden (Japanese Beetle). Avoid thorny type trees and shrubs.

- Use native species to the best extent possible but do not be strictly limited to native species. Use the best plant necessary for the planting situation.

- Avoid planting too close to buildings and other structures such as light poles and signs. Allow for normal plant growth development and light to reach all sides of the plant. Remember, plants are constantly changing in size as they mature and can quickly overgrow a particular planting site. Trees planted too close together will grow into or over any nearby plants.

- Avoid planting vegetation over underground utility service runs and drainage pipes. Avoid planting in the center of drainage swales.

- Avoid planting shrubs too close to the edge of sidewalks where the shrub's potential spread will grow out over the sidewalk and require pruning to keep it from interfering with pedestrian movement.

- Trees located along sidewalks should not be placed where their lower limbs will interfere with pedestrian movement. Larger growing trees such as Sycamore and Maple with large growing surface roots should not be placed where the roots can damage sidewalks.

- Avoid placing plants that can be damaged by salt in areas where winter maintenance activities will harm the plants either by spray or by plowed snow. Snow pushed or dumped on top of the plants will physically damage them.

- Avoid using planting arrangements that could promote unsafe conditions by creating areas where people can easily hide.

- Avoid excessive use of ground cover type plants such as ivy, myrtle, pachysandra, etc. since they are hard to maintain (weed) and require large numbers of plants to "fill" in an area. Ivy will eventually climb over other landscape features.

- Use varying planting sizes of trees and shrubs. Use deciduous trees up to 90 mm (3.5 in) caliper. However, cost considerations may limit the size to smaller caliper trees. More trees can be provided at 50 mm (2 in) cal. than for 90 mm (3.5 in) caliper. Limit planting size of evergreen trees to 1.8 m (6 ft) or less in height. Limit planting size of shrubs to 1.2 m (4 ft) or less in height. Larger plants do not survive transplant shock, as well as smaller plants, since a large amount of the feeder roots are lost in digging the plant.

- Small earth mounds can be used to help limit views to certain areas and to provide special planting sites. Limit the steepness of the mound slope to a 1V:4H ratio. Large rocks and boulders can also be placed among shrub plantings to create visual diversity. Landscape timbers or interlocking blocks can be useful to create shrub bed edges or planting walls.

- Planting for naturalized areas with daylilies and spring bulbs can be effective in creating colorful planting sites that do not have to be mowed.

- If trees are to be braced, use a 1 or 2 stake method (see Publication 72M, *Roadway Construction Standards*, Drawing RC-91M) that will not interfere with mowing operations.

- Layout trees and shrubs in free flowing or "natural" arrangements in order to avoid straight-line plantings.

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# CHAPTER 10

## DRAINAGE DESIGN AND RELATED PROCEDURES

### 10.0 INTRODUCTION

Drainage design is an essential element of highway design. It encompasses hydrology, hydraulics, permitting, and ultimately, providing facilities to collect and intercept surface runoff, remove or diverting it from the roadway, and channel it to suitable locations where it can be safely discharged downstream of the roadway.

Drainage is a key factor in the development of all types of improvements on all classifications of highways, and in all phases of project development. It must be considered in the development of preliminary location studies for new, low volume, local roads in rural areas, as well as the preparation of final design plans, specifications and estimates for the reconstruction of busy, urban freeways.

Hydrology, hydraulics and soil mechanics are the sciences generally applicable to the design of highway drainage. The application of these sciences to drainage design is relatively new and consequently research work carried on throughout the country has altered and will continue to alter some of the original practices. Therefore, this Chapter may be revised from time to time in order to keep pace with the modern development of hydraulic science. It should be noted that this Chapter only serves as a general guide to design techniques and procedures; there is no intention to replace sound engineering judgment.

Controlled aerial photography should be obtained, prior to construction, on the portion of projects involving significant floodplain encroachment or on those projects where there is a potential for significant additional flooding. This data would be of significant value during design and in evaluating flooding complaints.

The roadway drainage and waterway structures as referred to above include culverts, bridges, channel changes and longitudinal encroachments on waterways or floodplains.

This Chapter provides the engineer with general guidance and direction to the Department's drainage design procedures by addressing a broad range of issues related to drainage design. Careful analysis of existing site conditions, sound engineering judgment, and judicious application of the principles and procedures described or referenced in this Chapter will result in highway drainage designs that are functional and cost effective.

The following is a brief summary of the contents of this Chapter:

Section 10.1 addresses procedures for compliance with waterway and floodplain management requirements or regulations. The procedure described herein allows the Department to obtain waterway approvals from various regulatory agencies while fulfilling the applicable requirements and regulations.

Section 10.2 describes the hydrologic and hydraulic methods required to estimate peak discharges for roadway drainage structures. These include procedures for accumulating preliminary data and estimating peak flow discharges using storm intensity-frequency-duration curves. Also included are discussions of storm durations and times of concentration.

Section 10.3 describes the hydraulic capacities of various types of drainage facilities, including ditches, swales, curbed sections, depressed medians, inlets, pipe culverts, inlets, and junctions, storm sewer systems and pavement base drains. This Section introduces a computation table for preliminary storm sewer design. Also included is a brief discussion of stormwater management facilities and how to obtain hydraulic computation approval, including an example of a Drainage Design Report.

Section 10.4 presents the Department's design criteria for various types of storm drainage pipes. The criteria were used to develop fill height tables presented in the Standard Drawings and in Chapter 10, Appendix B. The tables discussed herein specify maximum and minimum allowable fill heights for reinforced concrete, metal and thermoplastic pipes.

Section 10.5 discusses the Department's recommended procedure for obtaining a waterway approval. It describes the role of the Engineering District in preparing the permit applications and technical submissions required by various regulatory agencies, including the Pennsylvania Department of Environmental Protection (PA DEP), the Pennsylvania Fish and Boat Commission (PFBC), the US Coast Guard, the US Army Corps of Engineers (USACE), and the Federal Highway Administration (FHWA).

Section 10.6 discusses the Department's criteria for selection of the appropriate hydrologic and hydraulic methodologies for a range of drainage design situations. Hydrologic and hydraulic (H&H) requirements are two key issues that must be addressed in the early phases of a project's drainage design. The Department's standard "toolbox" of H&H methodologies includes established analysis techniques that are well-suited to the majority of waterway structures typically encountered in Pennsylvania.

Section 10.7 provides detailed guidance in the preparation of Hydrologic and Hydraulic (H&H) reports, and may be used as a practical checklist of data that should be considered for inclusion in an H&H report. The criteria provided in this Section should be adapted to the nature of the stream and floodplain, the importance of the structure and other pertinent factors.

Section 10.8 describes the Department's procedure for obtaining permits from the US Coast Guard. Included herein is a map indicating the boundaries and mailing addresses of the US Coast Guard Districts with jurisdiction over the navigable waters of the United States in Pennsylvania. This Section also describes the information to be included in a Bridge Permit Application.

Section 10.9 describes the Department's procedure for obtaining permits from the US Army Corps of Engineers (USACE). This Section serves as a general guide to the various USACE regulations, including the Section 404 Permit, the Section 10 Permit, and the Pennsylvania State Programmatic General Permit (PASPGP). Also included herein is a map indicating the boundaries and mailing addresses of the USACE Districts with jurisdiction over the waters of the United States in Pennsylvania.

Section 10.10 provides the Department's recommended procedure for the design of channel construction involving fishable streams. Included in this Section is a discussion of the role of the Pennsylvania Fish and Boat Commission (PFBC), and factors to consider when designing channel relocations and crossings of various types of fishable streams.

Section 10.11 provides general guidance in the design of systems to accommodate fish passage in low flow highway culverts. Included herein is a discussion of the need to provide zones of slow water where fish can rest while traversing culverts, and detailed guidelines for the design of baffle systems and other features to accommodate fish passage.

Section 10.12 describes the Department's procedures for filling, removing, sealing, and/or altering abandoned water supply sources within the right-of-way. These sources typically include drilled wells, driven wells, dug wells, and springs.

Chapter 10, Appendix A presents a FHWA memorandum dated June 25, 1982 and is entitled, *Procedures for Coordinating Highway Encroachments on Floodplains with the Federal Emergency Management Agency (FEMA).*

Chapter 10, Appendix B contains the Fill-Height Criteria and Tables for Concrete, Metal and Thermoplastic Pipes discussed in Section 10.4.

Chapter 10, Appendix C presents the joint guidance issued by PennDOT and PA DEP regarding Hydraulic Modeling Requirements for PennDOT H&H Reports.

Chapter 10, Appendix D provides checklists that must be used to review Hydrologic and Hydraulic Reports, hydrology, HEC-RAS, HY-8, and scour analysis, where applicable.

Chapter 10, Appendix E provides a list of references cited throughout the Chapter, particularly Section 10.6.

Chapter 10, Appendix F presents a FEMA memorandum dated April 30, 2001 and is entitled, *Policy for Use of HEC-RAS in the NFIP*.

Chapter 10, Appendix G presents joint agency guidance between the Department and PA DEP for permitting requirements for hydraulic modeling of temporary construction activities, particularly for temporary structures needed to facilitate the construction of permanent bridges and culverts.

Chapter 10, Appendix H furnishes permit coordination procedures agreed to by the Department and PA DEP for erosion and sediment pollution control plan approvals and NPDES permits.

Chapter 10, Appendix I provides clarification from PA DEP of consistency letter requirements for stormwater management analysis and floodplain management analysis.

## 10.1 PROCEDURE FOR COMPLYING WITH WATERWAY AND FLOODPLAIN MANAGEMENT REQUIREMENTS OR REGULATIONS

**A. General.** This Section describes the Department's procedure for complying with applicable waterway and floodplain management regulations. The discussion below refers several times to Title 23 (Highways) of the Code of Federal Regulations (CFR). This document may be viewed on the website for the Government Printing Office.

**1. Department's Proposed Activity or Action.** The term "proposed activity or action" applies to any highway (roadway and structure) construction, reconstruction, rehabilitation, repair or improvement undertaken by the Department. This term also applies to all roadway drainage and waterway structures referred to in this Chapter.

**2. Potential Encroachment on 100-Year Floodplain.** All bridges, culverts and channel changes are assumed to encroach on 100-year floodplains. Encroachments should be avoided wherever possible. For encroachments, the following sources of information can be utilized to determine if the encroachment does exist:

**a.** Federal Emergency Management Agency (FEMA) flood maps (Floodway Maps, Flood Insurance Rate Maps or Flood Hazard Boundary Maps).

**b.** US Geological Survey Maps of Flood-Prone Areas.

**c.** Hydraulic computations.

**d.** Flood history.

**e.** Engineering judgment.

The highest order of information available and practical shall be used. FEMA and Geological Survey maps have been made available to the Engineering Districts.

**3. Preliminary Risk Assessment.** Once it is concluded that the proposed activity encroaches on a 100-year floodplain, a risk assessment may be made to determine if there is a potential for property loss or risk to human life during the service life of the highway. Qualified personnel knowledgeable of drainage principles should perform the preliminary risk assessment. This assessment can be performed in the field, with or without minimal hydraulic computations. Its findings (with or without risk) should be recorded in the Engineering District's project files. For practical purposes, only those activities which are likely to cause noticeable adverse effects on human life, property or environment are to be considered as having a "risk". The risk assessment should also determine if the flooding would impact emergency personnel or facilities. The findings of the risk assessment should also be noted in the environmental documents.

**4. Compliance with FEMA Regulatory Floodway Requirement.** FEMA floodway maps should be utilized to determine if the proposed activity encroaches on the "Regulatory Floodway". Any encroachment on a regulatory floodway shall be avoided, where practicable. If this encroachment cannot be practicably avoided and results in an increase in the 100-year flood elevation, an appropriate corrective measure (occasional flowage easement, hydraulically equal compensated area or hydraulically equal dispersed floodway) should be provided or a revision of the floodway data and/or maps should be made. On an individual project basis, approval or concurrence may be required from FEMA, PA DEP, the Pennsylvania Department of Community and Economic Development (PennDCED), and the applicable municipalities for providing the corrective measure and revising the floodway information.

Where appropriate and applicable, the procedures as established between FEMA and the Federal Highway Administration (FHWA) shall be utilized for coordinating or adopting FEMA regulatory requirements on highway encroachments. One such procedure is the conditional letter of map revision (CLOMR). These procedures are indicated in a FHWA memorandum dated June 25, 1982 titled, *Procedures for Coordinating Highway Encroachments on Floodplains with the Federal Emergency Management Agency (FEMA)*, a copy of which is found in Chapter 10, Appendix A. Additional guidance is found in the 1990 publication, *Procedures for Compliance with Floodway Regulations*, which is specific between Pennsylvania and FEMA; a copy is found on the Department's website. Additional regulations on this topic are found in 23 CFR Part 650, Subpart A, "Location and Hydraulic Design of Encroachments on Flood Plains".

**5. Identify Significant or Non-Significant Encroachments.** The definition, as specified below and indicated in 23 CFR Part 650, Subpart A, Sec 650.105, should be used as the basis to determine if the proposed activity is classified as a "significant encroachment".

A "Significant Encroachment" is a highway encroachment and any direct support of likely base floodplain development that would involve one or more of the following construction or flood-related impacts:

**a.** A significant potential for interruption or termination of a transportation facility which is needed for emergency vehicles or provides a community's only evacuation route,

**b.** A significant risk, or

**c.** A significant adverse impact on natural and beneficial floodplain values.

Any encroachment which does not fall within the definition of "significant encroachment" shall be considered as a "non-significant encroachment". Copies of 23 CFR Part 650 Subpart A titled, "Location and Hydraulic Design of Encroachments on Flood Plains", have been made available to the Engineering Districts and are also accessible through the website for the Government Printing Office.

For any highway action which requires an environmental approval (Categorical Exclusion, Environmental Assessment or Environmental Impact Statement) and which involves encroachment(s) within the limits of the base floodplain (100-year floodplain), each encroachment site shall be field viewed by qualified personnel who are knowledgeable of hydraulic principles and analysis, to determine if the affected encroachment constitutes a "significant encroachment" or "non-significant encroachment". In some cases, certain hydrologic and hydraulic computations and analysis may be needed to assist in making the determination. In determining whether a traverse crossing (bridge or culvert) constitutes a significant or insignificant encroachment, the crossing shall be properly sized in accordance with the Department's hydrologic and hydraulic procedure.

Documentation for the determination of a "significant encroachment" or "non-significant encroachment" should be included in the project files and in the environmental documents submitted for approval. For any highway action that has a potential involvement as "significant encroachment", the plan should be forwarded to FHWA for a determination of the applicability of a Categorical Exclusion.

**6. Concern of Regulatory Agencies.** The following is a list of the major Federal, State and other agencies directly or indirectly exercising jurisdiction over the Department's highway activities involving encroachments on waterways or floodplains:

**a.** Federal Highway Administration (FHWA)
**b.** Corps of Engineers, Department of the Army (USACE)
**c.** US Coast Guard
**d.** Federal Emergency Management Agency (FEMA)
**e.** US Fish and Wildlife Service (USF&W)
**f.** Environmental Protection Agency (EPA)
**g.** Natural Resources Conservation Service (NRCS)

- **h.** Pennsylvania Department of Environmental Protection (PA DEP)
- **i.** Pennsylvania Fish and Boat Commission (PFBC)
- **j.** Pennsylvania Historical and Museum Commission (PHMC)
- **k.** Delaware River Basin Commission
- **l.** Susquehanna River Basin Commission
- **m.** Ohio River Basin Commission
- **n.** Local Flood Control Authority (administering USACE's water resources projects)
- **o.** Pennsylvania Game Commission

It is recommended that a pre-application meeting be scheduled with all interested agencies to verify all of the required permits to be obtained.

The above listing may not be all-inclusive. In special cases, certain agencies may also get involved in the decision-making process of some regulatory permits.

It should be noted that not all of the agencies listed above exercise jurisdiction over all types of the Department's activities. It is quite common on many highway actions that only some of the listed agencies are involved in the regulatory process. Minor interagency involvements are anticipated for small roadway drainage structures. The regulatory requirements of each key individual agency are discussed in detail in the subsequent sections of this Chapter.

The Department generally obtains regulatory permits and approvals for proposed actions during final design. At this late stage of project development, it is often necessary to first hold a preliminary consultation with the affected regulatory agencies. This meeting provides an opportunity to discuss activities that may adversely affect the environment, or that the regulatory agencies might consider contrary to public interests. The preliminary consultation can help avoid unnecessary delays in project development and/or the expense of preparing plans that may be rejected. An example of an activity for which a preliminary consultation is strongly recommended is a major channel relocation in a fishable stream.

**7. Consult with the FHWA Division Office.** The FHWA Division Office should be contacted in regard to any Federally funded highway action for which there may be a potential problem in obtaining a regulatory permit. In some cases FHWA's expertise can be utilized to solve the problem. The US Department of Transportation (DOT) has established separate memoranda of understanding with the USACE and the Coast Guard to expedite the processing of necessary regulatory permits. The DOT has also developed coordination procedures with FEMA on highway encroachments, as mentioned in item 4 above, to achieve cost-effective designs. In the event a consultation with FHWA is deemed necessary, the request should be initiated by the Engineering District and shall be made through the Bureau of Project Delivery.

The following memoranda of understanding were established between FHWA and the USACE and between FHWA and the Coast Guard to expedite interagency coordination:

**a.** "Memorandum of Agreement between the Department of Transportation and the Department of the Army", signed January 18, 1983 and December 18, 1982.

**b.** "US Coast Guard/Federal Highway Administration, Memorandum of Understanding on Coordinating the Preparation and Processing of Environmental Documents", signed April 27, 1981 and May 6, 1981 and revised Attachment A dated October 11, 1983.

**8. Consult with Regulatory Agencies - by the FHWA and the Department.** After a request for consultation with the applicable regulatory agencies is made, FHWA may independently contact, delegate the Department to contact, or join with the Department in contacting these agencies for the purpose of soliciting comments on the proposed highway action. Although both the Department and the regulatory agencies share a common goal of preserving the environment, the former is usually more cost-sensitive than the latter. Mitigation measures must be assessed during planning/preliminary engineering in the design process, and recorded in the environmental documentation process.

**9. Public Involvement.** The public involvement procedures contained in 23 CFR Part 650 Subpart A generally shall be followed to provide an opportunity for early public review and comment on alternatives that contain encroachments. The extent of public involvements shall be commensurate with the scope of the project.

**10. Location Hydraulic Studies.** Location Hydraulic Studies are described in 23 CFR Part 650 Subpart A. These studies usually are performed during the earliest phase of project development for the purpose of evaluating floodplain impacts of various highway alternative alignments. The studies should be summarized in the environmental documents. Location Hydraulic Studies involve field reconnaissance and analysis of data by preliminary design engineers for the purpose of identifying and classifying encroachments. It is highly desirable that the appropriate State and FHWA environmental and engineering personnel be directly involved with the Location Hydraulic Studies, including field trip(s) to probable encroachment sites.

Actual hydraulic computations normally are required and shall include preliminary work considered necessary to delineate floodplain boundaries (in the absence of flood maps) and to evaluate flooding impacts of various alternatives. Each encroachment for each location alternative under consideration should be given substantial treatment in the development of the draft environmental document.

Location Hydraulic Studies generally are required for highway actions that require the preparation of an Environmental Assessment (EA) or Environmental Impact Statement (EIS). For a categorical exclusion (CE), these studies generally are less detailed and are used primarily to determine that there is minimal impact to the floodplain and that no significant floodplain encroachment is expected to occur. The scope, application and requirements for EIS, EA and CE are indicated in the Department's applicable directives. The identification of a significant or non-significant encroachment, as referred to in item 5 above, should be done when and if Location Hydraulic Studies are performed.

**11. Preliminary Risk Analysis.** Risk Analysis is defined in 23 CFR Part 650 Subpart A as "an economic comparison of design alternatives using expected total costs (construction costs plus risk costs) to determine the alternative with the least total expected cost to the public."

The preliminary risk analysis for a floodplain encroachment should be performed only if this analysis is expected to be a dominant factor in determining the highway alignment. The use of preliminary data is normally sufficient for making this analysis in Location Hydraulic Studies.

**12. Compliance with 23 CFR Part 650.111, Paragraphs (a) Through (f).** Where applicable and practicable, the format and requirements specified in 23 CFR Part 650.111, Paragraphs (a) through (f) as indicated below, shall be incorporated in location hydraulic studies:

> **(a)** National Flood Insurance Program (NFIP) maps, or information developed by the highway agency if NFIP maps are not available, shall be used to determine whether a highway location alternative includes an encroachment.
>
> **(b)** Location studies shall include evaluation and discussion of the practicability of alternatives to any longitudinal encroachments.
>
> **(c)** Location studies shall include discussion of the following items, commensurate with the significance of the risk or environmental impact, for all alternatives containing encroachments and for those actions that would support base floodplain development:
>
> > **(1)** The risks associated with implementation of the action,
> >
> > **(2)** The impacts on natural and beneficial floodplain values,
> >
> > **(3)** The support of probable incompatible floodplain development (i.e., development that is not consistent with a community's floodplain development plan),
> >
> > **(4)** The measures to minimize floodplain impacts associated with the action and
> >
> > **(5)** The measures to restore and preserve the natural and beneficial floodplain values impacted by the action.

**(d)** Location studies shall include evaluation and discussion of the practicability of alternatives to any significant encroachments or any support of incompatible floodplain development.

**(e)** The studies required by paragraphs (c) and (d) above shall be summarized in environmental review documents prepared pursuant to 23 CFR 771.

**(f)** Local, State and Federal water resources and floodplain management agencies shall be consulted to determine if the proposed highway action is consistent with existing watershed and floodplain management programs and to obtain current information on development and proposed actions in the affected watersheds.

**13. Significant Encroachment.** If the Location Hydraulic Studies conclude that a proposed highway action constitutes a significant encroachment as defined in 23 CFR 650 Subpart A, certain procedures as referred to in item 14 below shall be followed to support the choice of this action. A proposed Federally aided action which includes a significant encroachment cannot be approved unless the FHWA finds that the proposed significant encroachment is the only practicable alternative.

**14. Only Practicable Alternative Finding.** The only practicable alternative finding for the significant encroachment shall be included in the final environmental document and the proposed action shall be supported by the information required and specified in 23 CFR 650.113, Paragraph (a) below:

**(a)** A proposed action that includes a significant encroachment shall not be approved unless FHWA finds that the proposed significant encroachment is the only practicable alternative. This finding shall be included in the final environmental document (Final Environmental Impact Statement or Finding Of No Significant Impact) and shall be supported by the following information:

**(1)** The reasons why the proposed action must be located in the floodplain,

**(2)** The alternatives considered and why they were not practicable and

**(3)** A statement indicating whether the action conforms to applicable state or local floodplain protection standards.

**15. Design Hydraulic Studies.** The term "Design Hydraulic Studies", as used in this Manual, refers to the detailed hydrologic and hydraulic studies generally performed during the final design stage. These studies normally require field survey data and they are performed to show that the design of the proposed project is consistent with all relevant design criteria from applicable regulations, standards, and policies such as:

**(a)** PennDOT design policy (including Design Manuals and Strike-Off-Letters).

**(b)** Regulatory design requirements including 23 CFR 650.

**(c)** State and federal regulatory permitting requirements, including PA Title 25 Chapters 105 and 106.

**(d)** The National Flood Insurance Program (NFIP) and state regulations regarding floodplain management.

**(e)** 1978 Act 167 stormwater management plans.

The design hydraulic study should list and discuss all applicable design criteria and it should demonstrate that each of these criteria has been met or it should explain how they have been addressed.

In general, design hydraulic studies are required for waterway obstructions and encroachments associated with new highway (roadway and structure) construction and highway reconstruction, rehabilitation or improvement where the hydraulic performance may be affected. Design hydraulic studies may not be required for projects that do not affect the waterway or waterway opening such as minor bridge repair, minor shoulder widening, or replacement-in-kind of an existing superstructure.

**16. Hydraulic Computations.** Hydraulic computations shall be prepared if the drainage area of the proposed water obstruction is greater than 1.5 $km^2$ (0.5 $mi^2$) (see Section 10.3.H).

**17. Roadway Drainage Structure Approved by Engineering Districts.** Hydraulic computations for roadway drainage structures are approved at the District Office with one copy of the submission and approval sent to the Bureau of Project Delivery for information, according to the procedures specified in Section 10.2. The Bureau of Project Delivery may perform a Quality Assurance review of the submission and forward any comments on major policy deviations to the District Office.

**18. Water Obstructions and Encroachments.** Waterway obstructions and encroachments are subject to permitting requirements according to 25 PA Code §105; however, a waterway obstruction with a drainage area of 100 acres or less with no wetlands in the floodway (as defined by 25 PA Code §105.1) may be eligible for the waiver from permit requirements in Section 105.12(a)(2) of the regulation (refer to Section 12 of the regulation for additional information regarding waivers). Note that the waiver in Section 105.12(a)(2) does NOT include waterway encroachments. Projects with obstructions that are eligible for waivers from state permitting requirements may still be subject to the waterway permitting regulations of other agencies such as the U.S. Army Corps of Engineers (USACE) under Section 404 of the Clean Water Act (33 USC §§1344). Instances could include obstructions that may affect threatened and endangered species, or that may affect cultural resources, or that are located inside Federal project areas that are administered by the USACE.

Waterway encroachments with drainage areas greater than 100 acres and equal or less than 1 $mi^2$ may be eligible for a general permit when the conditions specified in the general permit are met. When permits are required, the Engineering District should process either a Joint Permit Application (JPA) or a General Permit (GP) application using the $JPA_2$ Expert System.

**19. General Permits.** General Permits from PA DEP are to be obtained when there are plans to construct, operate, maintain, or enlarge any water obstruction or encroachment that will affect a waterway, its 100-year floodway, or any lake, pond, reservoir, or wetland. The type of General Permit needed is related to the proposed activity. A partial list of the types of General Permits is listed below; refer to Section 10.5.A for a complete list. PA DEP's website also provides a complete list of the types of General Permits, along with specific permit limitations.

An application for a General Permit shall be developed and submitted to PA DEP using the $JPA_2$ Expert System. If the PA DEP region does not accept the electronic submission of the permit, the JPA is to be prepared in the normal manner using the $JPA_2$ Expert System. After completion, the application should be printed using the print capabilities of the $JPA_2$ Expert System. Attachments to the application that need to be printed in large format may be printed directly from the $JPA_2$ Expert System or they may be printed or plotted using conventional procedures.

If the drainage area is 2.6 $km^2$ (1 $mi^2$) or less, a general permit (General Permit BDWM-GP-7) may be applicable where the specified conditions are met.

A brief Hydrologic and Hydraulic Report or roadway hydraulic computations, as applicable for "General Permit BDWM-GP-7", shall be prepared for wetland disturbance areas of less than 0.04 ha (0.1 acre). However, for wetland disturbance areas of 0.04 ha (0.1 acre) or more, a joint permit application shall generally be submitted and processed.

"General Permit BDWM-GP-7, Minor Road Crossings" shall be prepared and submitted to the applicable PA DEP Regional Office. Stream enclosures (culverts in excess of 30 m (100 ft) in length) are not eligible for this general permit.

"General Permit BDWM-GP-3, Bank Rehabilitation, Bank Protection and Gravel Bar Removal" shall be prepared and submitted to the applicable PA DEP Regional Office. The use of this General Permit is limited to activities which constitute a single, complete project in and along a continuous reach of stream channel not exceeding 152 m (500 ft).

"General Permit BDWM-GP-8, Temporary Road Crossings" shall be prepared and submitted to the applicable PA DEP Regional Office. The use of this General Permit is for the construction, operation and maintenance of temporary road crossings across regulated waters of the Commonwealth, including wetlands, where no practicable alternatives exist.

"General Permit BWM-GP-11, Maintenance, Testing, Repair, Rehabilitation, or Replacement of Water Obstructions and Encroachments" shall be prepared and submitted to the appropriate PA DEP Regional Office only if the county conservation district is not delegated to review Chapter 105. The use of this General Permit is for minor deviations in the structure's configuration or filled area including those due to changes in materials, construction techniques, current construction codes or safety standards which are necessary to repair, modify, or replace the water obstruction or encroachment.

"Permit (E02-9999) Standards for Bridge Cleaning" shall be prepared and submitted by PennDOT personnel to the appropriate PA DEP Regional Office. Use of this permit is for general maintenance of a bridge that was built a long time ago and there are no waterway permits of record. Information that will be required includes: a narrative, plan sheet, photos, work schedule, location map, PNDI receipt, and sequence of construction.

**20. Hydrologic and Hydraulic Report.** The nucleus of design hydraulic studies is the Hydrologic and Hydraulic (H&H) Report, which is prepared in accordance with the general guidelines of Section 10.7. Design hydraulic studies shall be performed and processed if they are required to obtain a permit for a waterway obstruction or encroachment (General Permit BDWM-GP-7) when the drainage area exceeds 100 acres. If the drainage area of the proposed project is 1.5 $km^2$ (0.5 $mi^2$) or more, the Department requires a Hydrologic and Hydraulic Report to be prepared.

**21. Processing of Waterway Approval.** A waterway approval for each waterway structure including its necessary regulatory permits shall be processed according to the procedure specified in Section 10.6.

The Department is required by 25 PA Code §105 to obtain a permit from PA DEP for any waterway obstruction or encroachment not subject to a waiver from permitting by the regulation. An individual Section 404 permit may be required from the USACE for a proposed activity whenever the USACE decides to issue individual Section 404 permit, or when the proposed activity is not covered by the Pennsylvania State Programmatic Permit (PASPGP) or a nationwide permit. For any work encroaching on a navigable water of the United States, a Section 9 or Section 10 permit from the US Coast Guard and/or the USACE is required. A joint permit application should be submitted by the Engineering District to PA DEP. If required, PA DEP will transmit a copy of the application to the USACE. Further information on the permit requirements of various regulatory agencies is described in Sections 10.8 and 10.9.

**22. Waterway Approval.** Receipt of all necessary design approvals and Regulatory permits constitutes a waterway approval to the Engineering District. Additional information regarding the waterway approval is provided in Section 10.5.

**23. Fulfillment of Waterway and Floodplain Management Regulations.** Compliance with the applicable waterway and floodplain management regulations and procedures described above generally signifies the fulfillment of necessary requirements during the design stage. Most regulatory permits require certain actions be performed during construction and/or subsequent maintenance of the facility. The Engineering District shall review the permit and verify that all applicable conditions and restrictions stipulated in the regulatory permits will be practicably observed.

Although the above procedure is intended to cover the majority of the Department's proposed actions, this procedure and the referenced criteria can be altered on basis of engineering judgment in some instances to address the specific needs of individual projects.

## 10.2 ESTIMATING PEAK DISCHARGES FOR ROADWAY DRAINAGE FACILITIES

**A. General.** The first step in designing a drainage facility is to determine the design discharges for the facility. The hydrologic analysis required to estimate discharge can be a major component of the overall drainage design effort. The level of effort required depends on the available data and the complexity of the analytical techniques selected. Regardless of the analytical technique(s) used, hydrologic analysis always involves engineering judgment. Unlike many other aspects of engineering design, the quantification of runoff is a study of a stochastic process.

For many design problems, particularly involving small drainage areas, it is unnecessary to use difficult analytical methods that require extensive time and labor. Fortunately, there are a number of sound and practical methods available to analyze hydrology for the many design problems.

The hydrologic analysis, based on methods recommended herein, provides the basis for the design of roadway drainage structures and facilities such as:

- The best size and shape of pipe or culvert to satisfy field conditions,
- The size for open channels,
- The spacing of inlets,
- Stormwater detention ponds,
- Groundwater infiltration devices, or
- Channel protection.

The hydraulic capacity of some of these features is discussed in Section 10.3.

Proper drainage design is based on anticipating where surface runoff can accumulate and making provisions for the release of excess water at the proper rates to preclude:

- Unusual damage to private property,
- Undue interference with the operation of vehicles or
- An excessive maintenance burden.

The discussion that follows is divided into two sections:

- Accumulation of preliminary data (Section 10.2.B)
- Determination of peak discharge (Section 10.2.C)

The discussion for erosion control of drainage facilities is included in Chapter 13, Erosion and Sediment Pollution Control.

Some reference materials to be used with this section include:

- Highway Hydrology
  Hydraulic Design Series No. 2 (HDS-2)
  US Department of Transportation-Federal Highway Administration

- Introduction to Highway Hydraulics
  Hydraulic Design Series No. 4 (HDS-4), Section 2
  US Department of Transportation-Federal Highway Administration

- Publication 584, *PennDOT Drainage Manual*
  Pennsylvania Department of Transportation

- Urban Drainage Design Manual
  Hydraulic Engineering Circular No. 22 (HEC-22), Chapter 3
  US Department of Transportation-Federal Highway Administration

- Technical Release 55, Urban Hydrology for Small Watersheds
  Natural Resources Conservation Service
  US Department of Agriculture

**B. Accumulation of Preliminary Data.** Proper drainage analysis requires accumulation of specific information by office and field investigation, before attempting to apply analytical techniques.

It is necessary that plans be prepared indicating topography, preliminary alignment and profile information. In addition, note the following information on prints of project plans:

- All proposed curve and superelevation data.
- Station of cut areas.
- Station of fill areas.
- Station of low points.
- Station of high points.
- Depth of cut and fill (±).
- Areas of relatively flat tangent sections.
- Existing drainage facilities (includes ditch and stream slopes).
- Drainage area from proposed topography as indicated by cross section.
- Area of sharp grades.
- Drainage areas obtainable from USGS maps or other available sources.
- Preliminary location of proposed drainage facilities.
- Known high water marks.
- Horizontal and vertical geometry.

Then review the prints, as prepared above, in the field. Observations on the field trip may be recorded on the prints. Collect data to support decisions such as:

**1.** In Cut Areas:

- Establish the topographic runoff coefficient to be applied (e.g., Rational "C" or SCS curve number).
- Check drainage areas in field by using odometer readings, etc.
- Is benching necessary?
- Is lined gutter necessary at benches or parallel ditches?
- What is the possibility of erosion? At what location? How can it be corrected?

**2.** In Fill Areas:

- What is the possibility of erosion?
- Is lined gutter or ditch necessary?
- Can runoff be carried away at toe of slope?

**3.** Flat Tangent Sections:

- Observe where drainage is to be carried.
- Is the slope sufficient?
- Is it necessary to increase the parallel ditch slope?

**4.** Existing Drainage Facilities:

- Do they need to be replaced?
- Do they appear to have ample capacity?
- What is salvageable?
- Height of stream banks?

**5.** Sharp Grades:

- What is erosion possibility?
- Is lined ditch necessary?
- Are pipes necessary?
- Are shoulders and parallel ditches adequate or are sub-drains required?
- Are ditch checks or other erosion control devices apparently necessary?

**6.** Intersecting Roads:

- Review inlet locations.
- Note warping and crowning of roadways.

After completion of the field investigation, sufficient information will be available for final design of the drainage system. The final design includes the determination of the type of facilities, location, waterway area required and the erosion control device.

**C. Estimating Peak Discharge.** The Peak Discharge may be defined as the maximum expected rate of flow, created by the design storm, passing at a particular location (inlet, ditch, etc.).

For roadway drainage, the design storm is a selected intensity and duration of rainfall, expressed in millimeters per hour (inches per hour), which tends to occur once during a specified period of years.

The rational formula is the recommended hydrologic method for drainage areas up to 80 ha (200 acres) in size. For additional information, refer to Section 10.6.C.4.b.

The rational formula is as follows:

| **METRIC** | **ENGLISH** |
|---|---|
| $Q = \frac{CIA}{360}$ | $Q = CIA$ |

where:

Q = Peak discharge ($m^3$/s (cfs)).

C = Runoff factor (based on drainage area surface type)

I = Rate of rainfall for the time of concentration of the drainage area for a given storm frequency (Rainfall Intensity, mm/h (in/h)).

A = Drainage area (ha (acres)).

It is necessary to adjust the total quantity of water falling on an area (IA) because a certain percentage of water is dissipated by evaporation, transpiration, percolation, ponding and physical characteristics such as sinkholes. Therefore, the runoff factor "C" is introduced into the Rational Equation to account for the dissipated water. The runoff factor "C" is a percentage factor which represents the proportion of the total quantity of water falling on the area that remains as runoff. Suggested values for "C" for various types of drainage areas are presented in Table 10.2.1. The runoff factors presented in Table 10.2.1 provide generally accurate runoff results for most situations. If a higher level detail is desired, the methodology provided in Publication 584, *PennDOT Drainage Manual*, Sections 7.5.C through 7.5.G may be referenced.

Rainfall Intensity "I" curves are presented in Publication 584, *PennDOT Drainage Manual*, Chapter 7, Appendix A, Figures 7A.7 through 7A.16. The curves provide for variation in rainfall intensity according to:

**1.** Location. Select the curve of a particular region where the site in question is located (reference Publication 584, *PennDOT Drainage Manual*, Chapter 7, Appendix A for determination of the particular region).

**2.** Storm Frequency. A 10-year storm frequency shall be used for city streets and for all highways with longitudinal drains, side drains, and slope pipes.

For the storm frequency of culvert cross drains and any type of drainage facility in an underpass or depressed section of highway, refer to Section 10.6.E and Table 10.6.1. Additional criteria for the design frequency are indicated in Section 10.3.C.

**3.** When a pipe is part of a storm sewer system and crosses the roadway, it shall be designed as a storm sewer with the same design storm as the remainder of the drainage system.

**4.** Greater design frequencies may be justified on individual projects.

For design storms associated with pavement drainage, refer to Section 10.3.A for guidance.

**D.** **Storm Duration.** Time of concentration may be defined as the interval of time required for water from the most hydrologically distant portion of the drainage area to reach the point of interest.

**1.** A 5 minute storm duration may be used when the duration does not result in a maximum expected discharge that exceeds the capacity of a 750 mm (30 in) pipe.

**2.** If a 5 minute duration results in a pipe size exceeding 750 mm (30 in), use the time of concentration to determine the design storm duration.

## TABLE 10.2.1
## RUNOFF FACTORS FOR
## THE RATIONAL EQUATION

| TYPE OF DRAINAGE AREA OR SURFACE | RUNOFF FACTOR "C" | |
|---|---|---|
| | MINIMUM | MAXIMUM |
| Pavement, concrete or bituminous concrete | 0.75 | 0.95 |
| Pavement, bituminous macadam or surface-treated gravel | 0.65 | 0.80 |
| Pavement, gravel, macadam, etc. | 0.25 | 0.60 |
| Sandy soil, cultivated or light growth | 0.15 | 0.30 |
| Sandy soil, woods or heavy brush | 0.15 | 0.30 |
| Gravel, bare or light growth | 0.20 | 0.40 |
| Gravel, woods or heavy brush | 0.15 | 0.35 |
| Clay soil, bare or light growth | 0.35 | 0.75 |
| Clay soil, woods or heavy growth | 0.25 | 0.60 |
| City business sections | 0.60 | 0.80 |
| Dense residential sections | 0.50 | 0.70 |
| Suburban, normal residential areas | 0.35 | 0.60 |
| Rural areas, parks, golf courses | 0.15 | 0.30 |

**NOTES**

**1.** Higher values are applicable to denser soils and steep slopes.
**2.** Consideration should be given to future land use changes in the drainage area in selecting the "C" factor.
**3.** For drainage area containing several different types of ground cover, a weighted value of "C" factor shall be used.
**4.** In special situations where sinkholes, stripped abandoned mines, etc. exist, careful evaluation shall be given to the selection of a suitable runoff factor with consideration given to possible reclamation of the land in the future.

**E. Time of Concentration.** The time of concentration ($T_c$) may be influenced by:

**1.** The Type of Terrain over Which the Water Flows. See Table 10.2.2 for recommended average velocities for estimating travel time of overland flow. Other recognized methods such as the Kinematic Wave Equation (Overton and Meadow, 1976) and the NRCS TR-55 segmental method may also be used for determining the overland flow travel time.

**2.** Stream Velocities. Prior to reaching the point of interest, the water may flow overland and subsequently flow into a stream. The stream velocities shall be calculated using Manning's Equation.

The time of concentration may be determined by the criteria indicated above and considered as representing the duration of a storm. The extent of the drainage area may be determined from the following:

- Photogrammetric Plans
- Roadway Design Plans
- Field Observations
- USGS Maps

Use the highest order of information available and practical. Care shall be taken to include all areas delivering runoff to the point under consideration and to consider physical obstructions, such as existing arches with inadequate capacity inhibiting the delivery of runoff.

Publication 584, *PennDOT Drainage Manual*, Section 7.4 presents a number of methods that may be used to estimate the time of concentration. These methods are intended to calculate the flow velocity within individual segments of the flow path (e.g., shallow concentrated flow, open channel flow, gutter flow, etc.). Hydraulic Design Series No. 2, Second or latest edition, Section 2.6 also provides background data and methodologies on time of concentration.

**TABLE 10.2.2 (METRIC)**
**RECOMMENDED AVERAGE VELOCITIES**
**OF OVERLAND FLOW FOR DETERMINING**
**TIME OF CONCENTRATION**

| DESCRIPTION OF COURSE OF RUNOFF WATER | SLOPE (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0-3 | 4-7 | 8-10 | 11-15 | 16-20 | 21-25 | 26-30 |
| | VELOCITIES (m/s) | | | | | | |
| Woodland | 0.15 | 0.30 | 0.45 | 0.50 | 0.60 | 0.80 | 1.10 |
| Pasture | 0.25 | 0.45 | 0.65 | 0.80 | 0.90 | 1.25 | 1.35 |
| Cultivated (Row Crop) | 0.30 | 0.60 | 0.90 | 1.10 | 1.20 | 1.35 | 1.50 |
| Pavement | 1.50 | 3.65 | 4.70 | 5.50 | — | — | — |
| Natural Draw (Not Well Defined) | 0.25 | 0.75 | 1.20 | 1.85 | — | — | — |

**TABLE 10.2.2 (ENGLISH)**
**RECOMMENDED AVERAGE VELOCITIES**
**OF OVERLAND FLOW FOR DETERMINING**
**TIME OF CONCENTRATION**

| DESCRIPTION OF COURSE OF RUNOFF WATER | SLOPE (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0-3 | 4-7 | 8-10 | 11-15 | 16-20 | 21-25 | 26-30 |
| | VELOCITIES (ft/s) | | | | | | |
| Woodland | 0.5 | 1.0 | 1.5 | 1.7 | 2.0 | 2.7 | 3.5 |
| Pasture | 0.8 | 1.5 | 2.2 | 2.6 | 3.0 | 4.1 | 4.5 |
| Cultivated (Row Crop) | 1.0 | 2.0 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 |
| Pavement | 5.0 | 12.0 | 15.5 | 18.0 | — | — | — |
| Natural Draw (Not Well Defined) | 0.8 | 2.5 | 4.0 | 6.0 | — | — | — |

## 10.3 CAPACITY OF ROADWAY HYDRAULIC FACILITIES

Section 10.2 established the criteria for determining how much water is expected to arrive at a particular location. This section is primarily concerned with the removal of the water arriving at a particular location. The drainage facilities should have adequate capacity to assist in removing water from the surface of the highway and adjacent ground.

The drainage facilities that assist in collecting and removing water from the surface of the highway and adjacent ground may be classified as follows:

- Pavement Drainage, Roadside Drainage, and Subsurface Pipes (See Section 10.3.A and Publication 584, *PennDOT Drainage Manual*, Chapter 13).
- Storm Sewer Systems (See Section 10.3.B and Publication 584, *PennDOT Drainage Manual*, Chapter 13).
- Pipe Culverts (See Section 10.3.C and Publication 584, *PennDOT Drainage Manual*, Chapter 9).
- Pavement Base Drains (See Section 10.3.D and Publication 584, *PennDOT Drainage Manual*, Chapter 13).
- Stormwater Management Facilities (See Section 10.3.E and Publication 584, *PennDOT Drainage Manual*, Chapter 14).
- Superstructure Drainage (See Section 10.3.F and Publication 584, *PennDOT Drainage Manual*, Chapter 13).

The capacity of the drainage facilities is measured in terms of discharge and may be determined by the equation of continuity as follows:

$$Q = AV$$

where:

Q = Discharge of water ($m^3$/s (cfs)). A drainage facility at a particular location shall hydraulically and economically accommodate the peak discharge for the location.

A = Net effective area provided by the drainage facility ($m^2$ ($ft^2$)). The effective area is that cross sectional area of the facility which may be used to carry water. It may not be desirable that the entire cross sectional area of the drainage facility be utilized to carry water.

V = Velocity of the water (m/s (ft/s)). The velocity shall generally be determined by Manning's equation.

Manning's equation is as follows:

| **METRIC** | **ENGLISH** |
|---|---|
| $V = \frac{1}{n} R^{2/3} S^{1/2}$ | $V = \frac{1.486}{n} R^{2/3} S^{1/2}$ |

where:

V = Velocity of the water (m/s (ft/s)).

R = Hydraulic radius which is equal to the net effective area (A) divided by the wetted perimeter (WP):

$$R = \frac{A}{WP}$$

The wetted perimeter is the length in meters (feet) of the drainage facility cross section which is wetted by the water.

S = Slope of energy line (for approximation, use water surface slope in wetted stream and stream bed slope in dry stream).

n = The roughness coefficient. Acceptable roughness coefficients are presented in Publication 584, *PennDOT Drainage Manual*, Table 7.5 (for pipes and pavements) and Table 8.1 (for channels, floodplains and earth).

Capacity solutions to these facilities are well documented within FHWA's Urban Drainage Design Manual (Hydraulic Engineering Circular No. 22) and/or Introduction to Highway Hydraulics (Hydraulic Design Series No. 4). Approved computerized methods, which have been developed from material presented in these documents, are acceptable design tools; however, graphical solutions (e.g., TR-55) may be acceptable.

Design criteria for the specific drainage facilities identified above are presented as follows:

**A. Pavement Drainage, Roadside Drainage, and Subsurface Pipes.** Inundation of the traveled way dictates the level of traffic service provided by a waterway facility. The overtopping flood level for the traveled way identifies the upper limit of serviceability, and it provides one of the important definitions of the term "design flood".

When the peak design flow in a roadside swale or gutter is permitted to spread into a through travel lane, the maximum encroachment of water shall not exceed one-half of the through travel lane and may be further limited based on design speed and class of roadway. For limits of spread on bridges, see Publication 15M, Design Manual, Part 4, *Structures*, Volume 1, Part A, Chapter 3.

Design criteria for specific roadway drainage facilities are as follows:

**1.** Swales Adjacent to Shoulders in Cut Areas. When swales are provided in cut areas, the water shall not encroach upon the shoulder during a 10-year storm of 5 min duration. Frequent and/or sustained flooding of the subbase shall be avoided.

The maximum velocity, as determined by a normal depth calculation using Manning's equation, shall not exceed the allowable velocity for the swale material as specified in Publication 584, *PennDOT Drainage Manual*, Chapter 8.

Inlets or other hydraulic controls shall be provided as necessary in swales adjacent to shoulders in cut areas to meet:

**a.** Design requirements regarding roadway encroachments and
**b.** Design and regulatory requirements regarding water velocity.

The frequency of inundation and/or sustained flooding of the subbase shall be minimized.

Preferred ditch line treatments are found for typical roadway cross sections of interstate and other limited access freeways and of arterials in Chapter 1, Section 1.5. The Combination Storm Sewer and Underdrain should be designed in the manner described in Section 10.3.B.5.

Where subbase cannot be outletted, pavement base drain shall be installed as indicated on the "ALTERNATE SUBSURFACE DRAINAGE TREATMENT" in Chapter 1, Section 1.5.

**2.** Curbed Sections. The maximum encroachment of water on the roadway pavement shall not exceed half of a through traffic lane during a 10-year storm of 5 min duration. The maximum depth at the curb shall be 25 mm (1 in) below the top of the curb.

**3.** Depressed Medians. The maximum width of water flowing in a depressed median shall not exceed one-half of the total median width during a 10-year storm of 5 min duration.

**4.** Shoulders in Cut Areas Without Swales. This design for roadway sections should be avoided; however, if conditions require use of this type of section, then the spread shall not exceed two-thirds of the shoulder width during a 10-year storm of 5 min duration.

**5.** Ditches. Ditches are graded, open channels that are typically located along the bottom of an embankment slope or at the top of a cut slope. They are generally parallel to the highway and carry runoff coming from the pavement, shoulders and adjacent areas. They may also be used to protect the highway's boundaries from stormwater originating offsite.

The most common types of ditches are triangular, trapezoidal and rectangular. They are often lined to control velocities and soil erosion. The trapezoidal shape is preferred due to its higher hydraulic efficiency. Triangular shapes require less right-of-way and are readily maintained with a grader. Rectangular shapes are generally used in rock areas.

To facilitate the design of ditches, methods are presented in Publication 584, *PennDOT Drainage Manual*, HDS-4 and HEC-22.

Transverse ditches shall not intersect parallel ditches at right angles. To minimize scour and sedimentation, transverse ditches shall join parallel ditches at an angle of approximately 30º with the parallel ditch.

Erosion and sedimentation control measures for ditches and channels are discussed in Chapter 13, Erosion and Sediment Pollution Control.

In general, a 10-year storm shall be used for the design of ditches; however, the magnitude may be modified to balance with the planned life of the facility and damage potential of the structure or area to be protected, or to meet the design requirements of local municipalities.

For every ditch and channel, a fully dimensioned typical cross section shall be shown on the project drawings. As shown in the Publication 72M, *Roadway Construction Standards*, all excavation involved is either Class 1 or Class 2 Excavation, depending upon the bottom width of the ditch or channel.

Small drainage dikes downstream of inlets can be provided to impede bypass flow in an attempt to cause complete interception of the approach flow. The dikes usually need not be more than a few inches high and shall have traffic safe slopes. The height of dike required for complete interception on continuous grades or the depth of ponding in sag vertical curves can be computed using HEC-22, Chapter 4. Refer to the Publication 72M, *Roadway Construction Standards* for installation of drainage dikes in swales and medians.

**6.** Inlets and Junctions. Four classes of storm drain inlets generally have been investigated for channel flow interception capacity and are listed below:

**a.** Grate Inlets. Grate inlets (Types C, D-H, M, and S) perform satisfactorily over a wide range of gutter grades. Grate inlets generally lose capacity with an increase in grade, but to a lesser degree than curb opening inlets. The principal advantage of grate inlets is that they are installed along the roadway where the water is flowing. Their principal disadvantage is that floating trash or debris may clog them. For safety reasons, preference should be given to grate inlets. Additionally, where bicycle traffic occurs or is expected to occur, bicycle safe grates shall be provided. Curved vane grate inlets provide the best capture efficiency.

**b.** Curb-Opening Inlets. Curb-opening inlets are most effective on flatter slopes, in sags, and with flows which typically carry significant amounts of floating debris. The interception capacity of curb-opening inlets decreases as the gutter grade increases. Consequently, the use of curb-opening inlets may be considered in sags and on grades less than 3%.

**c.** Combination Inlets. Combination inlets (Type C) result in a high capacity inlet which offers the advantages of both grate and curb opening inlets. When the curb opening precedes the grate in a "sweeper" configuration, the curb-opening inlet acts as a trash interceptor during the initial phases of a storm. Used in a sag configuration, the sweeper inlet can have a curb opening on both sides of the grate.

**d.** Slotted Drain Inlets. Slotted drain inlets may be considered in areas where it is desirable to intercept sheet flow before it crosses onto a section of roadway. Their principal advantage is their ability to intercept flow over a wide section. However, slotted inlets are very susceptible to clogging from sediments and debris, and are not recommended for use in environments where significant sediment or debris loads may be present. Slotted inlets on a longitudinal grade do have the same hydraulic capacity as curb openings when debris is not a factor. Publication 408, *Specifications,* Section 617 describes the construction of slotted drains.

Three basic types of grate inlets, namely Types C, M and S, are included in Publication 72M, *Roadway Construction Standards*. Each type of inlet is suited for a particular situation. Type C Inlet is designated for installation in non-mountable curbs; Type M Inlet is designated for installation in median areas and mountable curbs; and Type S Inlet is designated for installation in shoulder swale areas.

A special double size grate inlet, designated as a Type D-H Inlet or Type D-H Level Inlet and indicated in Publication 72M, *Roadway Construction Standards*, can be used to accommodate high storm runoff and debris problems for shoulder areas associated with 3R projects or similar type projects. An alternate single upstream unit inlet may be used by a special provision in those locations where a cost-effective design may be achieved without requiring both the upstream and downstream grates.

Where bicycle traffic is anticipated, a bicycle safe grate shall be used for all inlet units.

On curbed sections immediately adjacent to structures, inlets shall be provided on each side of all structures having spans of 6.0 m (20 ft) or greater for grades less than 1%.

When there are no curbs immediately adjacent to a structure and the structure has a span of 6.1 m (20 ft) or greater, inlets shall be provided on the downgrade side of the structure and placed to permit slope pipes to be utilized without encroaching on the substructure. On longer structures, under similar conditions, in which the structure is at or close to the summit of a vertical curve, inlets shall be provided on both the upgrade and downgrade sides.

**7.** Inlet Capacities. Inlet capacities for each specific type of inlet under various conditions are specified in the tables and figures as described below:

**a.** Type C Inlet or Type M Inlet (Mountable Curb). The capacities of Type C Inlets or Type M Inlets (mountable curb) on a continuous grade are presented in Table 10.3.1 for a 100% efficiency and in Figure 10.3.1 through Figure 10.3.4 for various percents of efficiency. The efficiency of an inlet is defined as $(Q_2/Q_1) \times 100\%$, where $Q_1$ is the channel flow ($m^3/s$ (cfs)) and $Q_2$ is the rate of flow ($m^3/s$ (cfs)), intercepted by the inlet gratings. The capacities for these inlets under sump conditions are indicated on Table 10.3.2.

**b.** Type M Inlet (Median) or Type S Inlet. The capacities of Type M Inlets (Median) or Type S Inlets on a continuous grade are presented in Table 10.3.3. The capacities for these inlets under sump conditions are indicated in Figure 10.3.5 and Figure 10.3.6.

**c.** Type D-H Inlet. The hydraulic capacities of the D-H Inlet and its alternate single unit inlet are indicated in Figure 10.3.7.

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## TABLE 10.3.1
## CAPACITY OF TYPE C INLET OR
## TYPE M INLET (MOUNTABLE CURB)

| LONGITUDINAL SLOPE (%) | METRIC | | ENGLISH | |
|---|---|---|---|---|
| | SWALE* | INLET** CAPACITY ($m^3/s$) | SWALE* | INLET** CAPACITY (cfs) |
| 0.5 | 1V:12H | 0.042 | 1V:12H | 1.5 |
| 0.5 | 1V:16H | 0.042 | 1V:16H | 1.5 |
| 0.5 | 1V:24H | 0.008 | 1V:24H | 0.3 |
| 0.5 | 1V:48H | 0.006 | 1V:48H | 0.2 |
| 2.0 | 1V:12H | 0.079 | 1V:12H | 2.8 |
| 2.0 | 1V:16H | 0.059 | 1V:16H | 2.1 |
| 2.0 | 1V:24H | 0.051 | 1V:24H | 1.8 |
| 2.0 | 1V:48H | 0.017 | 1V:48H | 0.6 |
| 4.0 | 1V:12H | 0.096 | 1V:12H | 3.4 |
| 4.0 | 1V:16H | 0.074 | 1V:16H | 2.6 |
| 4.0 | 1V:24H | 0.034 | 1V:24H | 1.2 |
| 4.0 | 1V:48H | 0.011 | 1V:48H | 0.4 |
| 8.0 | 1V:12H | 0.068 | 1V:12H | 2.4 |
| 8.0 | 1V:16H | 0.057 | 1V:16H | 2.0 |
| 8.0 | 1V:24H | 0.034 | 1V:24H | 1.2 |
| 8.0 | 1V:48H | 0.014 | 1V:48H | 0.5 |

*Pavement Cross Slope
**100% Efficiency

## TABLE 10.3.2 (METRIC)
## CAPACITY OF TYPE C INLET OR
## TYPE M INLET (MOUNTABLE CURB)
## AT SUMP CONDITION

| PAVEMENT CROSS SLOPE | INLET CAPACITY ($m^3/s$)* | |
|---|---|---|
| | TYPE C | TYPE M (MOUNTABLE CURB) |
| 1V:48H | 0.057 | 0.057 |
| 1V:24H | 0.127 | 0.099 |
| 1V:16H | 0.218 | 0.142 |
| 1V:12H | 0.317 | 0.142 |

*Maximum allowable spread of water on pavement and limitation of curb height were considered in determining the inlet capacity.

## TABLE 10.3.2 (ENGLISH)
## CAPACITY OF TYPE C INLET OR TYPE M INLET (MOUNTABLE CURB) AT SUMP CONDITION

| PAVEMENT CROSS SLOPE | INLET CAPACITY (cfs)* | |
|---|---|---|
| | TYPE C | TYPE M (MOUNTABLE CURB) |
| 1V:48H | 2.0 | 2.0 |
| 1V:24H | 4.5 | 3.5 |
| 1V:16H | 7.7 | 5.0 |
| 1V:12H | 11.2 | 5.0 |

*Maximum allowable spread of water on pavement and limitation of curb height were considered in determining the inlet capacity.

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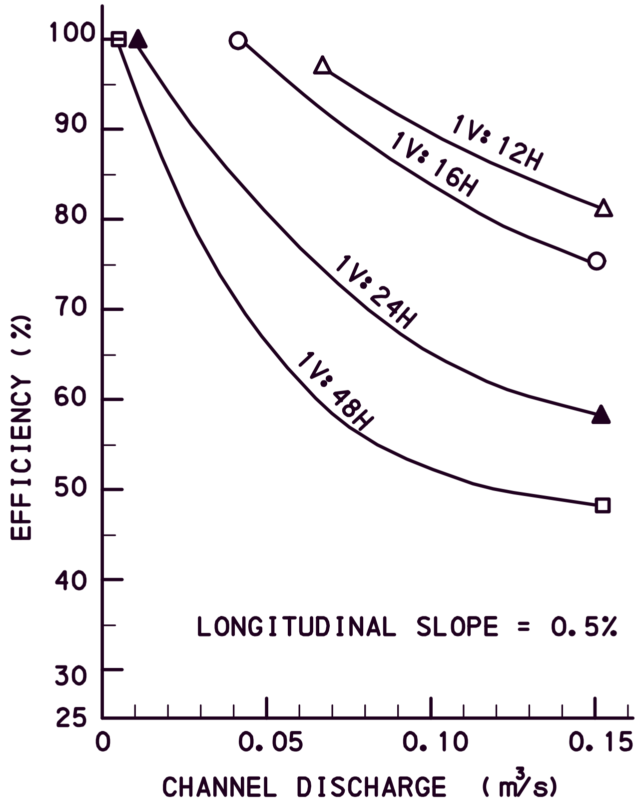



**FIGURE 10.3.1 (METRIC)**
**EFFICIENCY CURVES: CAPACITY OF TYPE C INLET OR TYPE M INLET (MOUNTABLE CURB)**

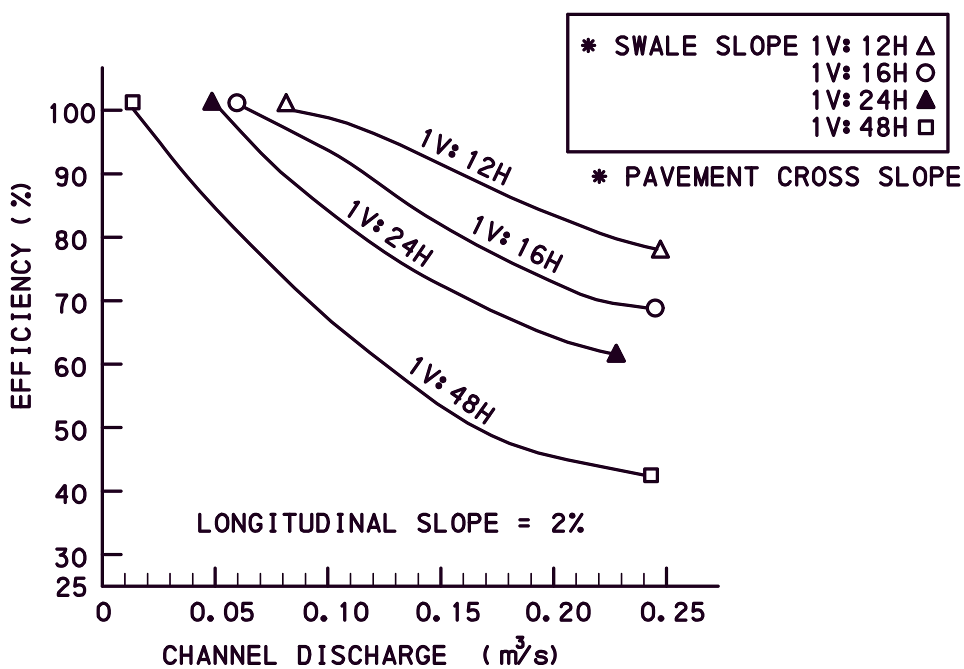



**FIGURE 10.3.2 (METRIC)**
**EFFICIENCY CURVES: CAPACITY OF TYPE C INLET OR TYPE M INLET (MOUNTABLE CURB)**

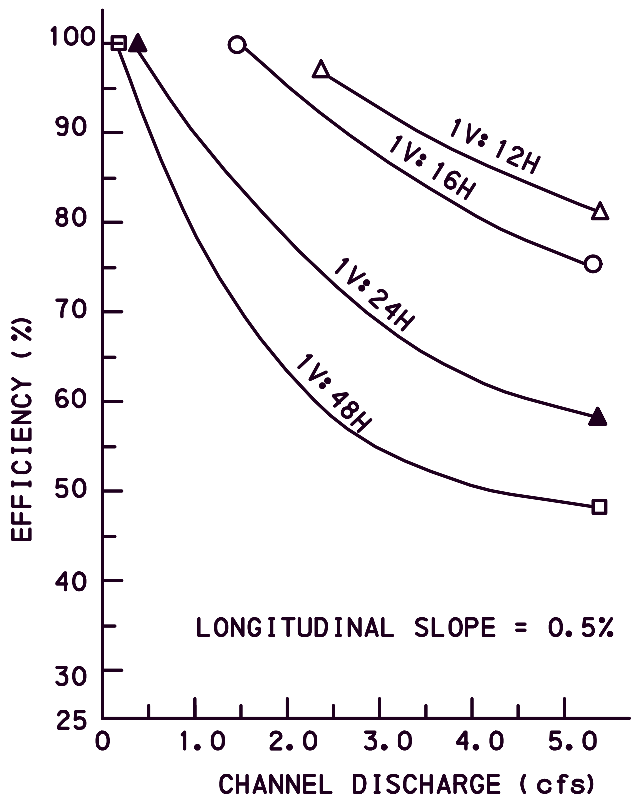



**FIGURE 10.3.1 (ENGLISH)**
**EFFICIENCY CURVES: CAPACITY OF TYPE C INLET OR TYPE M INLET (MOUNTABLE CURB)**

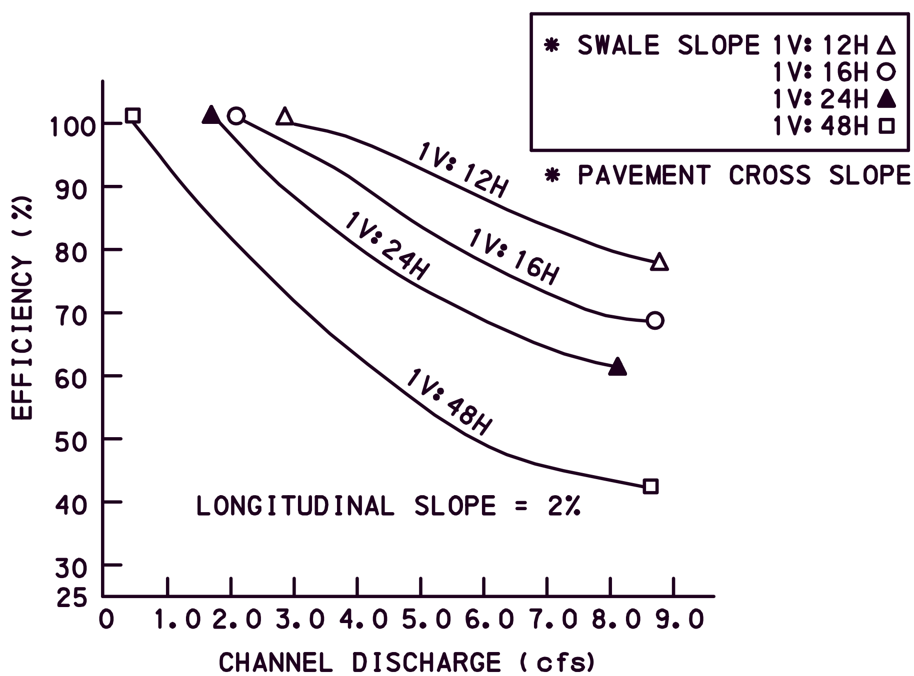



**FIGURE 10.3.2 (ENGLISH)**
**EFFICIENCY CURVES: CAPACITY OF TYPE C INLET OR TYPE M INLET (MOUNTABLE CURB)**

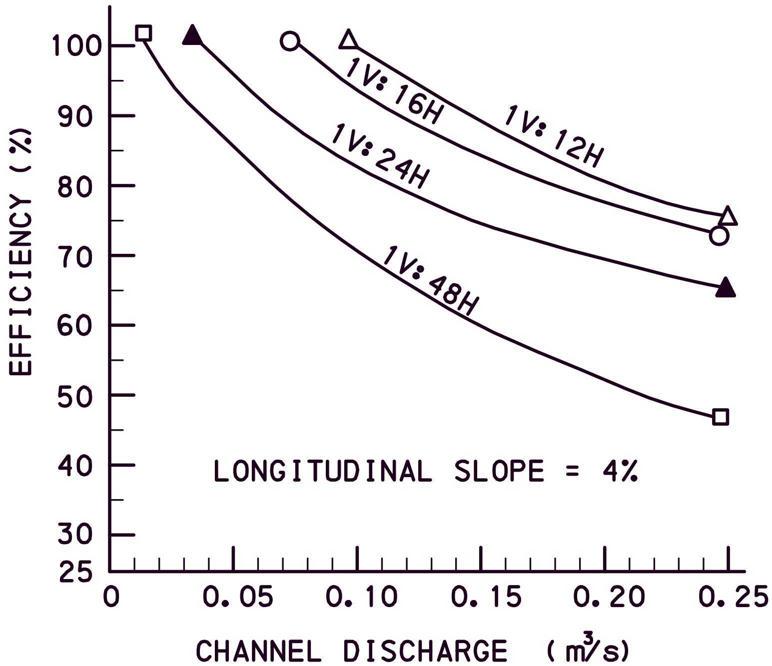



**FIGURE 10.3.3 (METRIC)**
**EFFICIENCY CURVES: CAPACITY OF TYPE C INLET OR TYPE M INLET (MOUNTABLE CURB)**

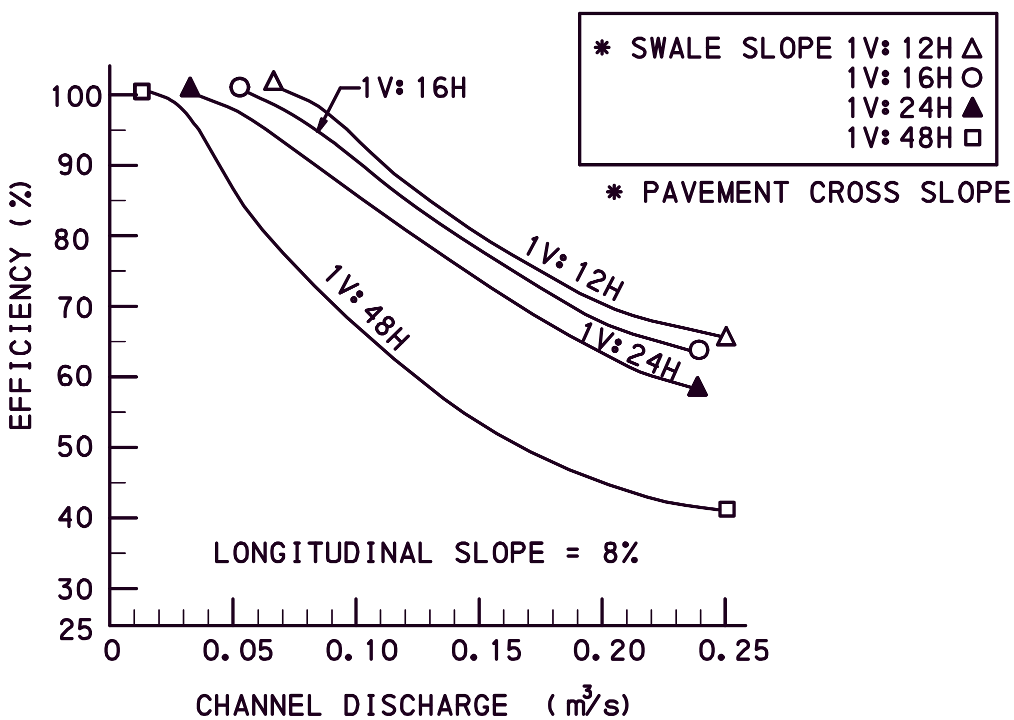



**FIGURE 10.3.4 (METRIC)**
**EFFICIENCY CURVES: CAPACITY OF TYPE C INLET OR TYPE M INLET (MOUNTABLE CURB)**

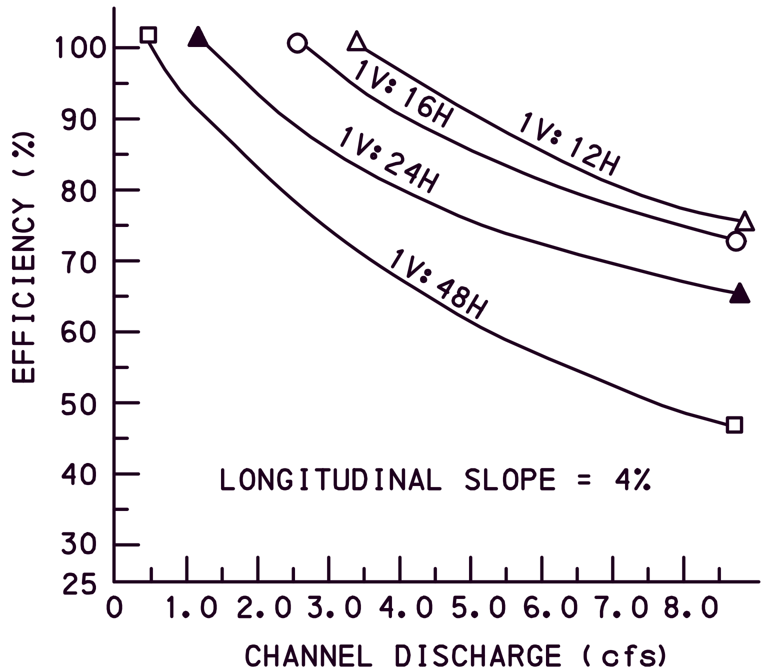



**FIGURE 10.3.3 (ENGLISH)**
**EFFICIENCY CURVES: CAPACITY OF TYPE C INLET OR TYPE M INLET (MOUNTABLE CURB)**

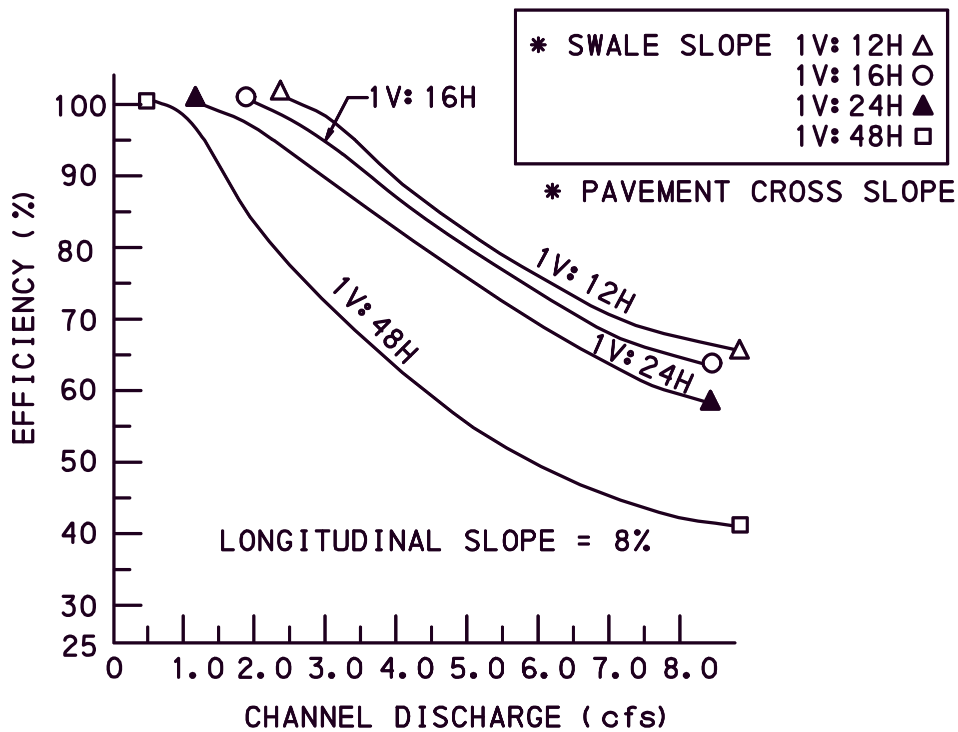



**FIGURE 10.3.4 (ENGLISH)**
**EFFICIENCY CURVES: CAPACITY OF TYPE C INLET OR TYPE M INLET (MOUNTABLE CURB)**

## TABLE 10.3.3 (METRIC)
## CAPACITY OF TYPE M INLET (MEDIAN)
## OR TYPE S INLET

| SLOPES | | | INLET CAPACITY WITHOUT DIKE ($m^3$/s) | INLET CAPACITY WITH DIKE ($m^3$/s)* | | |
|---|---|---|---|---|---|---|
| **LONGITUDINAL** | **SWALE** | **BACK** | | **0.30 m DEPTH** | **0.25 m DEPTH** | **0.15 m DEPTH** |
| 0.5% | 1V:12H | 1V:2H | 0.088 | 0.484 | 0.385 | 0.286 |
| | | 1V:4H | 0.102 | 0.473 | 0.379 | 0.286 |
| | | 1V:6H | 0.119 | 0.464 | 0.379 | 0.292 |
| | | 1V:8H | 0.125 | 0.459 | 0.377 | 0.292 |
| | | 1V:12H | 0.130 | 0.479 | 0.391 | 0.306 |
| | 1V:6H | 1V:2H | 0.167 | 0.470 | 0.394 | 0.320 |
| | | 1V:4H | 0.238 | 0.470 | 0.411 | 0.354 |
| | | 1V:6H | 0.255 | 0.470 | 0.416 | 0.362 |
| | | 1V:8H | 0.218 | 0.462 | 0.402 | 0.340 |
| | | 1V:12H | 0.119 | 0.464 | 0.379 | 0.292 |
| 2.0% | 1V:12H | 1V:2H | 0.099 | 0.354 | 0.292 | 0.227 |
| | | 1V:4H | 0.099 | 0.371 | 0.303 | 0.235 |
| | | 1V:6H | 0.099 | 0.433 | 0.354 | 0.275 |
| | | 1V:8H | 0.102 | 0.433 | 0.351 | 0.269 |
| | | 1V:12H | 0.105 | 0.498 | 0.399 | 0.303 |
| | 1V:6H | 1V:2H | 0.161 | 0.467 | 0.391 | 0.314 |
| | | 1V:4H | 0.218 | 0.462 | 0.402 | 0.340 |
| | | 1V:6H | 0.255 | 0.450 | 0.399 | 0.351 |
| | | 1V:8H | 0.207 | 0.464 | 0.399 | 0.344 |
| | | 1V:12H | 0.099 | 0.433 | 0.354 | 0.275 |
| 4.0% | 1V:12H | 1V:2H | 0.045 | 0.283 | 0.224 | 0.164 |
| | | 1V:4H | 0.057 | 0.306 | 0.244 | 0.181 |
| | | 1V:6H | 0.096 | 0.371 | 0.303 | 0.235 |
| | | 1V:8H | 0.091 | 0.365 | 0.295 | 0.227 |
| | | 1V:12H | 0.091 | 0.379 | 0.309 | 0.235 |
| | 1V:6H | 1V:2H | 0.178 | 0.337 | 0.297 | 0.258 |
| | | 1V:4H | 0.227 | 0.388 | 0.348 | 0.306 |
| | | 1V:6H | 0.246 | 0.416 | 0.374 | 0.331 |
| | | 1V:8H | 0.210 | 0.416 | 0.365 | 0.312 |
| | | 1V:12H | 0.096 | 0.371 | 0.303 | 0.235 |
| 8.0% | 1V:12H | 1V:2H | 0.042 | 0.261 | 0.207 | 0.153 |
| | | 1V:4H | 0.057 | 0.249 | 0.201 | 0.153 |
| | | 1V:6H | 0.079 | 0.263 | 0.218 | 0.173 |
| | | 1V:8H | 0.076 | 0.258 | 0.212 | 0.167 |
| | | 1V:12H | 0.068 | 0.269 | 0.218 | 0.167 |
| | 1V:6H | 1V:2H | 0.147 | 0.346 | 0.297 | 0.246 |
| | | 1V:4H | 0.176 | 0.391 | 0.337 | 0.283 |
| | | 1V:6H | 0.195 | 0.399 | 0.348 | 0.297 |
| | | 1V:8H | 0.176 | 0.382 | 0.331 | 0.280 |
| | | 1V:12H | 0.079 | 0.263 | 0.218 | 0.173 |

* Height of dike is dependent on the longitudinal slope, width available and depth of water desired over the inlet grate.

## TABLE 10.3.3 (ENGLISH)
## CAPACITY OF TYPE M INLET (MEDIAN) OR TYPE S INLET

| SLOPES | | | INLET CAPACITY WITHOUT DIKE (cfs) | INLET CAPACITY WITH DIKE ($ft^3/s$)* | | |
|---|---|---|---|---|---|---|
| **LONGITUDINAL** | **SWALE** | **BACK** | | **12 in DEPTH** | **9 in DEPTH** | **6 in DEPTH** |
| 0.5% | 1V:12H | 1V:2H | 3.1 | 17.1 | 13.6 | 10.1 |
| | | 1V:4H | 3.6 | 16.7 | 13.4 | 10.1 |
| | | 1V:6H | 4.2 | 16.4 | 13.4 | 10.3 |
| | | 1V:8H | 4.4 | 16.2 | 13.3 | 10.3 |
| | | 1V:12H | 4.6 | 16.9 | 13.8 | 10.8 |
| | 1V:6H | 1V:2H | 5.9 | 16.6 | 13.9 | 11.3 |
| | | 1V:4H | 8.4 | 16.6 | 14.5 | 12.5 |
| | | 1V:6H | 9.0 | 16.6 | 14.7 | 12.8 |
| | | 1V:8H | 7.7 | 16.3 | 14.2 | 12.0 |
| | | 1V:12H | 4.2 | 16.4 | 13.4 | 10.3 |
| 2.0% | 1V:12H | 1V:2H | 3.5 | 12.5 | 10.3 | 8.0 |
| | | 1V:4H | 3.5 | 13.1 | 10.7 | 8.3 |
| | | 1V:6H | 3.5 | 15.3 | 12.5 | 9.7 |
| | | 1V:8H | 3.6 | 15.3 | 12.4 | 9.5 |
| | | 1V:12H | 3.7 | 17.6 | 14.1 | 10.7 |
| | 1V:6H | 1V:2H | 5.7 | 16.5 | 13.8 | 11.1 |
| | | 1V:4H | 7.7 | 16.3 | 14.2 | 12.0 |
| | | 1V:6H | 9.0 | 15.9 | 14.1 | 12.4 |
| | | 1V:8H | 7.3 | 16.4 | 14.1 | 11.8 |
| | | 1V:12H | 3.5 | 15.3 | 12.5 | 9.7 |
| 4.0% | 1V:12H | 1V:2H | 1.6 | 10.0 | 7.9 | 5.8 |
| | | 1V:4H | 2.0 | 10.8 | 8.6 | 6.4 |
| | | 1V:6H | 3.4 | 13.1 | 10.7 | 8.3 |
| | | 1V:8H | 3.2 | 12.9 | 10.4 | 8.0 |
| | | 1V:12H | 3.2 | 13.4 | 10.9 | 8.3 |
| | 1V:6H | 1V:2H | 6.3 | 11.9 | 10.5 | 9.1 |
| | | 1V:4H | 8.0 | 13.7 | 12.3 | 10.8 |
| | | 1V:6H | 8.7 | 14.7 | 13.2 | 11.7 |
| | | 1V:8H | 7.4 | 14.7 | 12.9 | 11.0 |
| | | 1V:12H | 3.4 | 13.1 | 10.7 | 8.3 |
| 8.0% | 1V:12H | 1V:2H | 1.5 | 9.2 | 7.3 | 5.4 |
| | | 1V:4H | 2.0 | 8.8 | 7.1 | 5.4 |
| | | 1V:6H | 2.8 | 9.3 | 7.7 | 6.1 |
| | | 1V:8H | 2.7 | 9.1 | 7.5 | 5.9 |
| | | 1V:12H | 2.4 | 9.5 | 7.7 | 5.9 |
| | 1V:6H | 1V:2H | 5.2 | 12.2 | 10.5 | 8.7 |
| | | 1V:4H | 6.2 | 13.8 | 11.9 | 10.0 |
| | | 1V:6H | 6.9 | 14.1 | 12.3 | 10.5 |
| | | 1V:8H | 6.2 | 13.5 | 11.7 | 9.9 |
| | | 1V:12H | 2.8 | 9.3 | 7.7 | 6.1 |

* Height of dike is dependent on the longitudinal slope, width available and depth of water desired over the inlet grate.

CROSS SLOPES 1V:6H AND 1V:4H △
1V:6H AND 1V:8H ○
1V:12H AND 1V:4H (OR 1V:2H) ▲
1V:12H AND 1V:12H ●

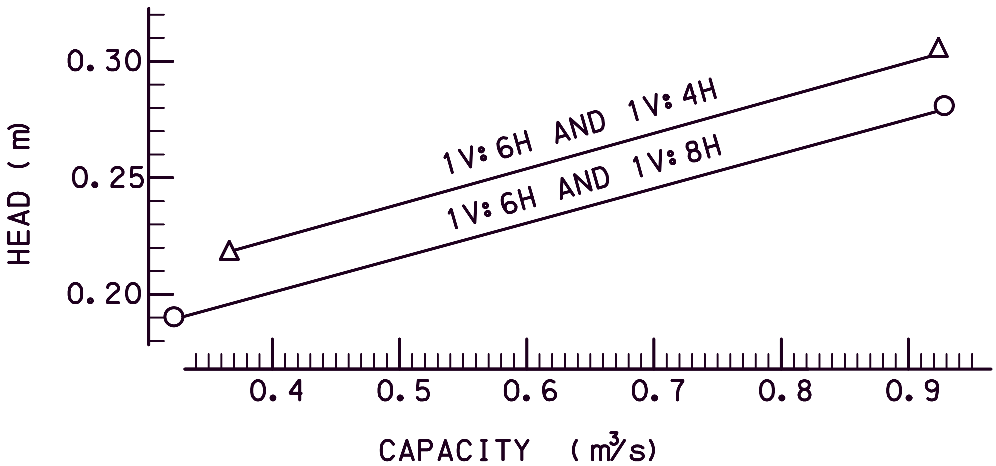



**FIGURE 10.3.5 (METRIC)**
**CAPACITY OF TYPE M INLET (MEDIAN)**
**OR TYPE S INLET AT SUMP CONDITION**

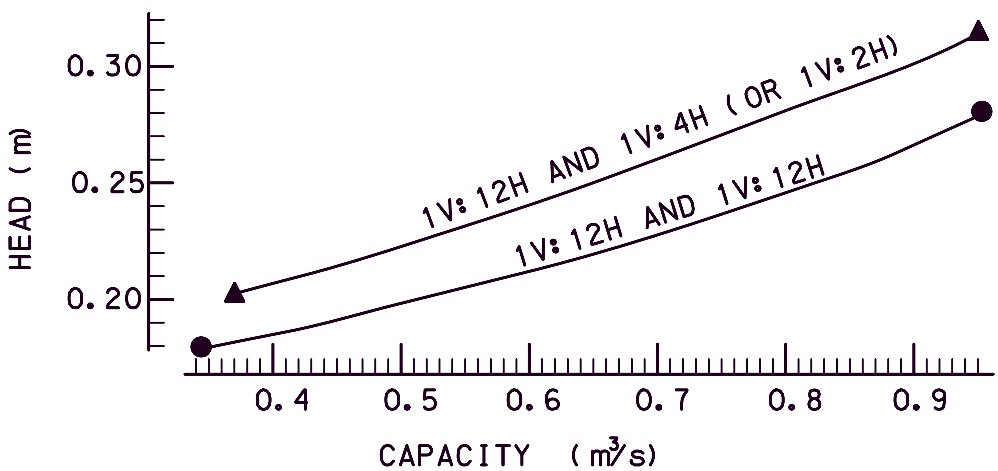
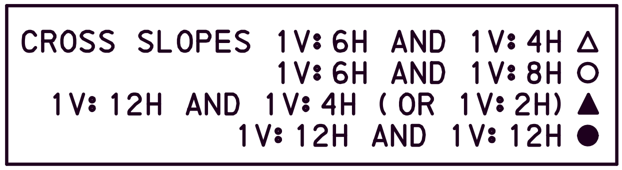



**FIGURE 10.3.6 (METRIC)**
**CAPACITY OF TYPE M INLET (MEDIAN)**
**OR TYPE S INLET AT SUMP CONDITION**



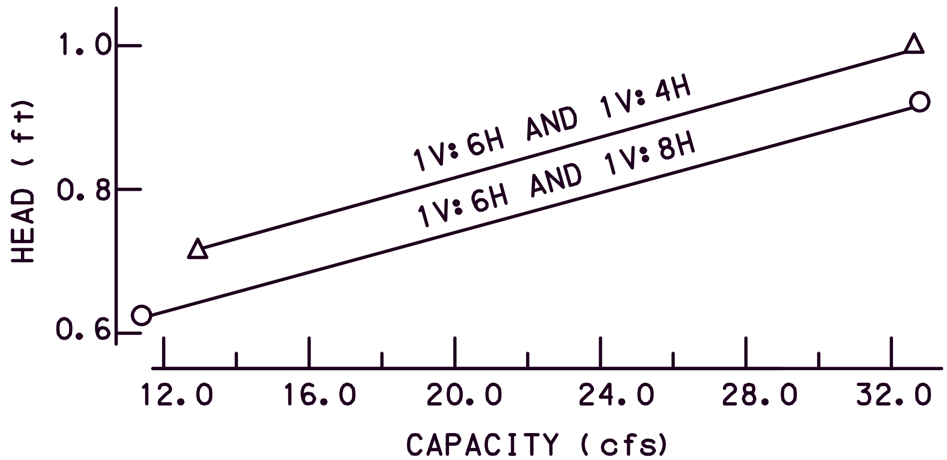




**FIGURE 10.3.5 (ENGLISH)**
**CAPACITY OF TYPE M INLET (MEDIAN)**
**OR TYPE S INLET AT SUMP CONDITION**

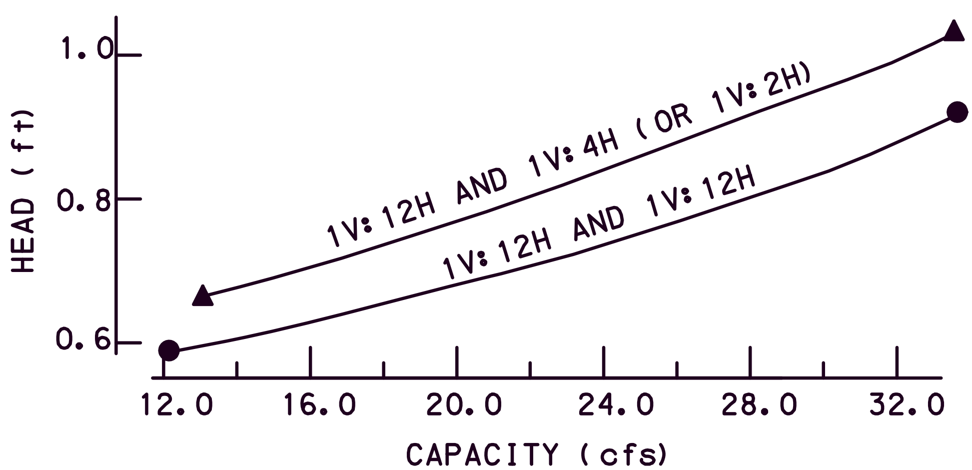



**FIGURE 10.3.6 (ENGLISH)**
**CAPACITY OF TYPE M INLET (MEDIAN)**
**OR TYPE S INLET AT SUMP CONDITION**

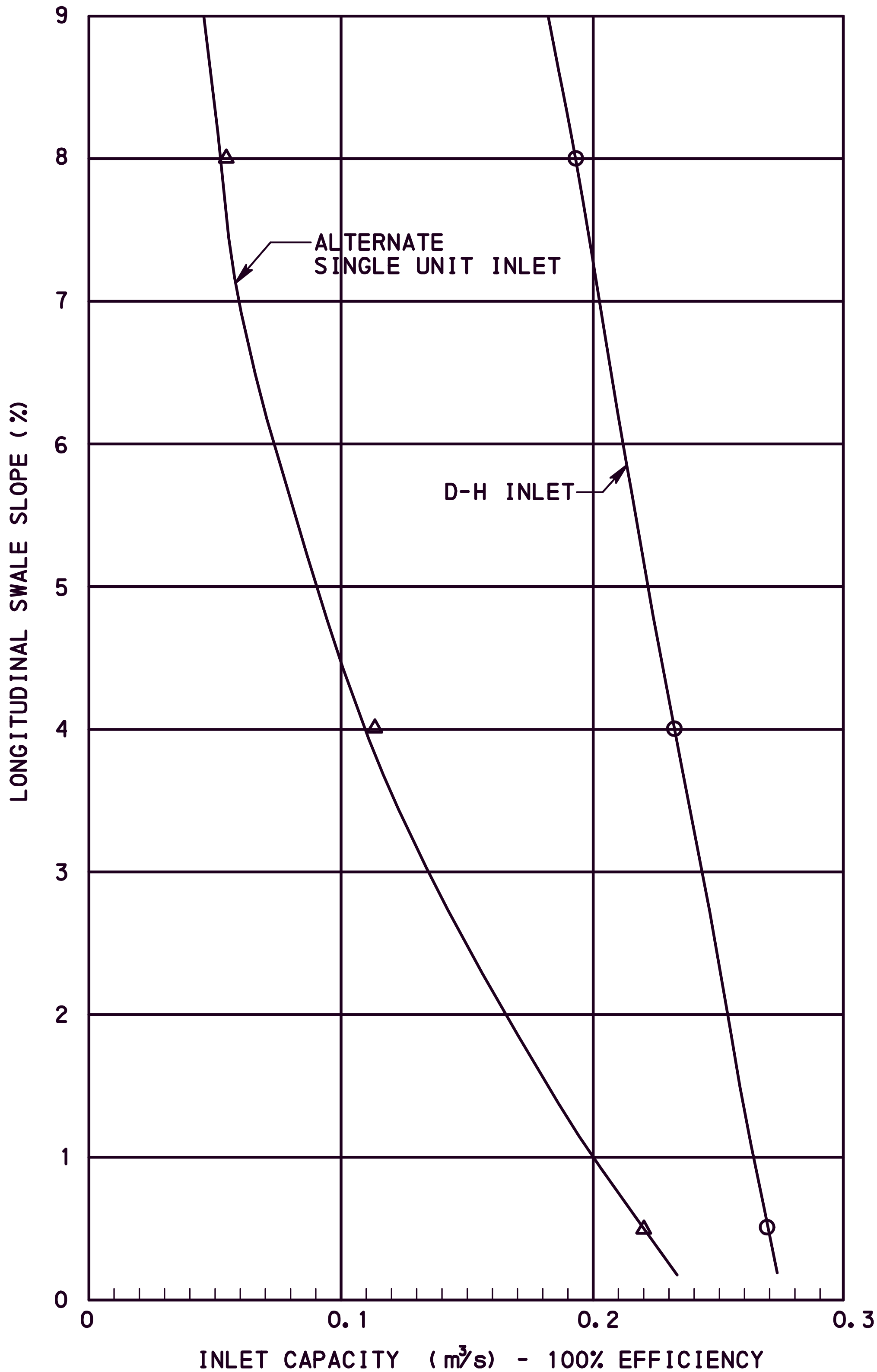



**FIGURE 10.3.7 (METRIC)**
**HYDRAULIC CAPACITIES OF D-H INLET AND ALTERNATE**

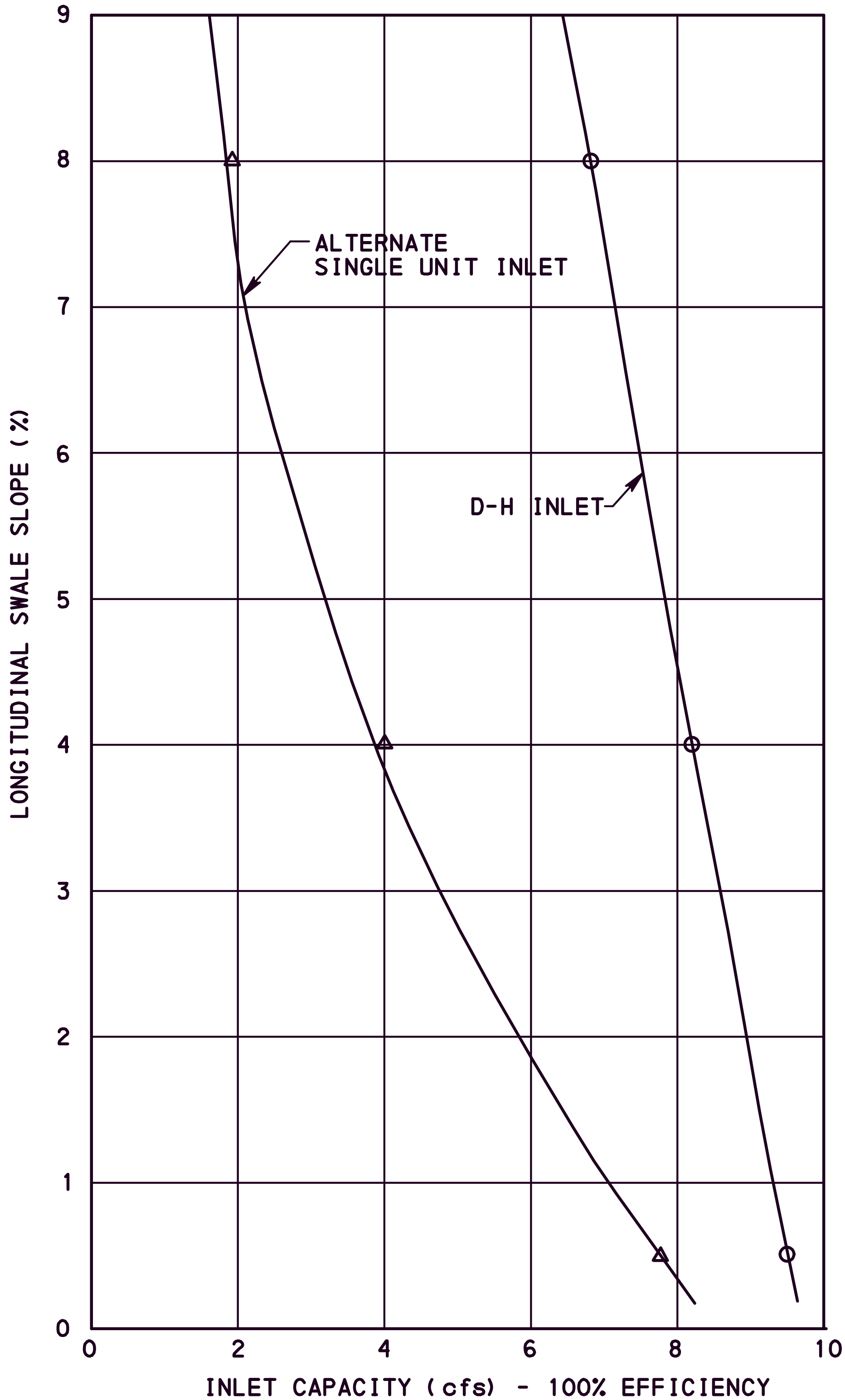



**FIGURE 10.3.7 (ENGLISH)**
**HYDRAULIC CAPACITIES OF D-H INLET AND ALTERNATE**

Preliminary inlet spacing may be estimated from the following formula giving due consideration to the percentage of water bypassing the inlet and, on curbed sections, the permissible encroachment of water on the roadway pavement.

**METRIC**

$$L = \frac{(3.63)(10^6)Q}{CIW}$$

**ENGLISH**

$$L = \frac{(43{,}560)\ Q}{CIW}$$

where:

L = Inlet spacing (m (ft)).

Q = Discharge capacity of the drainage facility (inlet, shoulder, swale, curb sections, etc.) with the least capacity ($m^3$/s (cfs)).

C = Rational method coefficient.

I = Rainfall intensity (mm/h (in/h)), generally for a 10-year storm.

W = Average width of contributing area (m (ft)).

Determine the required inside dimensions of the inlet box based on the required reinforced concrete pipe size and pipe opening. Once the minimum inside dimensions are determined, refer to Table 10.3.4 to determine the required inlet box type. For additional information, refer to Publication 72M, *Roadway Construction Standards*.

## TABLE 10.3.4
## DETERMINING INLET BOX TYPES

| INLET BOX TYPE | INSIDE WIDTH mm (in) | INSIDE LENGTH mm (in) | MAXIMUM PERMITTED PIPE DIAMETER ALONG WIDTH mm (in) | MAXIMUM PERMITTED PIPE DIAMETER ALONG LENGTH mm (in) |
|---|---|---|---|---|
| STANDARD | 610 mm (24") | 1150 mm (45 1/4") | 457 mm (18") | 914 mm (36") |
| 4 | 1220 mm (48") | 1220 mm (48") | 914 mm (36") | 914 mm (36") |
| 5 | 1524 mm (60") | 1524 mm (60") | 1066 mm (42") | 1066 mm (42") |
| 6 | 1828 mm (72") | 1828 mm (72") | 1372 mm (54") | 1372 mm (54") |
| 7 | 2134 mm (84") | 2134 mm (84") | 1676 mm (66") | 1676 mm (66") |
| 8 | 2438 mm (96") | 2438 mm (96") | 1828 mm (72") | 1828 mm (72") |
| 9 | 2744 mm (108") | 2744 mm (108") | 2134 mm (84") | 2134 mm (84") |
| 10 | 3048 mm (120") | 3048 mm (120") | 2438 mm (96") | 2438 mm (96") |
| D-H | 762 mm (30") | 2516 mm (99") | 457 mm (18") | 1828 mm (72") |

Final spacing should be confirmed based on allowable spread.

Inlet grates are cast iron or structural steel and shall conform to the dimensional requirements to ensure proper installation (1212 mm × 673 mm (47.75 in × 26.5 in)), as shown on Publication 72M, *Roadway Construction Standards*. A bicycle-safe grate shall be installed for all inlets in areas where bicycle traffic is anticipated, such as curbed roadways in urban areas or for roadways specifically established and signed as bikeways or having bike lanes. Additional information is found in HEC-22.

On curbed sections, an inlet shall be placed at the low point on sag vertical curves with flanking inlets on each side of the low point at a distance not to exceed 30 m (100 ft) or at a grade not greater than 60 mm (0.20 ft) above the sag inlet. The distance between the flanking inlet and the inlet at the low point may be computed using HEC-22, Chapter 4.

On shoulder (without swale) or curb sections, the maximum spacing of inlets shall not exceed 140 m (450 ft), except where a Type D-H Inlet or the alternate single unit inlet is used. Inlet spacing in depressed median sections and shoulder swale areas shall not exceed 280 m (900 ft).

**B. Storm Sewer Systems.**

**1.** Preliminary Layout. The first step in storm drain design is to develop a conceptual storm drain layout, including inlet, access hole, and pipe locations. This is usually completed on a plan that shows the roadway, adjacent land use conditions, intersections, and under/overpasses. Surface utilities, underground utilities, and any other storm drain systems shall also be shown. Tentative inlets, junctions, and access locations shall be identified based primarily on obvious project requirements and limitations, such as low points and intersections.

**2.** Pipe Sizing. Given the preliminary layout, it is possible to begin the hydraulic analysis necessary to size the storm drain system. The method used to size storm pipes is based on a gravity or non-pressure flow concept, which shall generally be adopted for design on the Department's projects. In areas of an extreme flat grade, where a realistic size cannot be attained by means of the usual gravity flow design, a special design based on a pressure flow concept may be considered.

Preliminary pipe size may be calculated using a full-flow assumption given the discharge and pipe slope. This approach does not account for minor losses. If a pressure flow concept is used, minor losses are to be accounted for in the Hydraulic Grade Line (HGL) calculation. An example of a computation table for a storm sewer design layout is shown in Figure 10.3.8 or HEC-22, Section 7.4. Publication 584, *PennDOT Drainage Manual*, Chapter 13 has a detailed HGL computation form.

The minimum diameter of storm pipe shall be 450 mm (18 in) for circular pipe (or equivalent size pipe arch), except pipes under a 7.6 m (25 ft) or greater fill height shall not be less than 600 mm (24 in). Storm pipes are provided in 75 mm (3 in) increments up to the 900 mm (36 in) diameter size and 150 mm (6 in) increments for those exceeding 900 mm (36 in) diameter size.

Avoid abrupt changes in direction or slope of pipe. Where such abrupt changes are required, place an inlet or manhole at the point of change.

The minimum slope in a pipe shall not be less than 0.35%. Place storm pipes on the most economical slope and at the most economical depth.

Provide 300 mm (12 in) minimum cover from the top of pipe barrel to bottom of base course. Refer to Publication 72M, *Roadway Construction Standards*, RC-30M for details concerning minimum cover over pipe under pavements. For special design and modeling of pipes, refer to Publication 15M, Design Manual, Part 4, *Structures*, Appendix H.

Ductile iron pipe may be used when: (1) the minimum cover is at least 75 mm (3 in) but less than 150 mm (6 in) from the top of pipe barrel to the subgrade elevation; and (2) high impact and concentrated heavy loadings are involved. Under these conditions, provide a ductile iron pipe with a minimum 3-edge bearing strength of 17.8 kN/m (4000 lb/ft) times the diameter in meters (feet).

A minimum drop of 50 mm (2 in) shall be provided in the inlet or other junction structure between the lowest inlet pipe invert elevation and the outlet pipe invert elevation. When there is a change in pipe size in an inlet or other junction structure, the elevation of the lowest invert of the incoming pipes shall not be less than that of the outlet pipe.

The Manning's roughness coefficients for corrugated metal pipes are included in Publication 584, *PennDOT Drainage Manual*, Table 7.4.

In general, the size of a downstream storm pipe should not be smaller than that of the upstream storm pipe(s). This requirement is not an absolute criterion and sound engineering judgment should be exercised in making the determination. As an example, it would not be economical to purposely adopt a long stretch of downstream storm pipes equal to or larger than an upstream slope pipe where the size of the slope pipe is hydraulically determined by entrance conditions.

**INTENTIONALLY BLANK**

$\Delta AC_O$ = AC (Contrib. Surface Flow Between Inlets)
$\Delta AC_B$ = AC (Bypassing Flow from Previous Inlet)
$\Delta AC_i$ = AC (Entering Inlet)
C = Runoff Factor

Sheet No. _____ of _____ By _____ Date _____

SR _____ Chkd By _____ Date _____

| INLET NUMBER | STATION | DRAINAGE AREA | | | | | | | TIME | | (I) RAINFALL INTENSITY | (Q) DISCHARGE | LENGTH OF PIPE | SLOPE OF PIPE | TYPE OF PIPE | MANNING'S "n" VALUE | SIZE OF PIPE | MEAN VELOCITY | PIPE CAPACITY FLOWING FULL | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\Delta A$ | C | $\Delta AC_O$ | $\Delta AC_B$ | $\Delta AC_O$ $+\Delta AC_B$ | $\Delta AC_i$ | $\Sigma AC_i$ | $\Delta T$ | $\Sigma T$ | | | | | | | | | | |
| — | — | (ha) | — | (ha) | (ha) | (ha) | (ha) | (ha) | (min) | (min) | (mm/h) | ($m^3$/s) | (m) | (%) | — | — | (mm) | (m/s) | ($m^3$/s) | — |
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**FIGURE 10.3.8 (METRIC)**
**COMPUTATION TABLE FOR PRELIMINARY STORM SEWER DESIGN**

$\Delta AC_O$ = AC (Contrib. Surface Flow Between Inlets)
$\Delta AC_B$ = AC (Bypassing Flow from Previous Inlet)
$\Delta AC_i$ = AC (Entering Inlet)
C = Runoff Factor

Sheet No. _____ of _____ By _____ Date _____

SR _____ Chkd By _____ Date _____

| **INLET NUMBER** | **STATION** | **DRAINAGE AREA** | | | | | | | **TIME** | | **(I)** | **(Q)** | **LENGTH OF PIPE** | **SLOPE OF PIPE** | **TYPE OF PIPE** | **MANNING'S "n" VALUE** | **SIZE OF PIPE** | **MEAN VELOCITY** | **PIPE CAPACITY FLOWING FULL** | **REMARKS** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **$\Delta A$** | **C** | **$\Delta AC_O$** | **$\Delta AC_B$** | **$\Delta AC_O + \Delta AC_B$** | **$\Delta AC_i$** | **$\Sigma AC_i$** | **$\Delta T$** | **$\Sigma T$** | **RAINFALL INTENSITY** | **DISCHARGE** | | | | | | | | |
| — | — | (acres) | — | (acres) | (acres) | (acres) | (acres) | (acres) | (min) | (min) | (in/h) | (cfs) | (ft) | (%) | — | — | (in) | (ft/s) | ($ft^3/s$) | — |
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**FIGURE 10.3.8 (ENGLISH)**
**COMPUTATION TABLE FOR PRELIMINARY STORM SEWER DESIGN**

**3.** Computation of Hydraulic Grade Line. When pressure flow methods are used to design the pipe system, the Hydraulic Grade Line computations must be provided. Pressure flow through a pipe typically results in the pressure head to be above the top of the pipe (i.e., not equal to the depth of flow in the pipe). In this case, the pressure head rises to a level represented by the hydraulic grade line (HGL). The HGL is used to aid the designer in determining the elevation to which water will rise when the system is operating under design conditions.

Preliminary methods to compute the hydraulic grade line of a pipe system shall adhere to the guidelines indicated in HEC-22, Section 7.5. The HGL shall be established to evaluate overall system performance and ensure that at the design discharge, the storm drain system does not inundate or adversely affect inlets, access holes, or other appurtenances.

The first step in calculating the HGL is to establish the location of all hydraulic controls along the pipe alignment and locations where the water surface shall not be exceeded. These may occur at the inlet, at the outlet, or at intermediate points along the alignment. The water surface elevation of the channel into which the storm drain discharges may establish the maximum tailwater.

The first reach is defined from the downstream control point, or outlet, to the first hydraulic structure or pipe grade break. Subsequent reaches are defined between hydraulic structures and/or grade breaks. The calculation proceeds on a reach-by-reach basis from the given control point and proceeds upstream. The calculation is based on application of the energy equation as major losses are calculated within each reach. The designer shall note that the procedure is based on the assumption of a uniform hydraulic gradient within a conduit reach and that minor losses under supercritical flow are ignored.

**4.** Alternate Pipe Designs. A summary of acceptable criteria for specifying alternate types of storm or culvert pipes based on the type of use is presented in Table 10.3.5. The selection of pipe alternates is also dependent upon environmental factors. Consideration to the future land use should be given. For example, pipe placed in an area not being mined presently, but which may ultimately be mined, should be designed to handle the mine acid drainage. The criteria indicated in Table 10.3.5 are applicable to all sizes of pipes. The approximate expected service life has been specified as a primary design parameter in the alternate pipe selection criteria indicated in Table 10.3.5.

In those cases where the Department's design criteria specifies that alternate pipes shall be included in the plans and proposal, design computations shall be submitted for each alternate. If the design computations determine that, for one or more of the alternates, different sizes are adequate, the construction drawings and quantities should be developed for the larger size; however, the alternate sizes should be indicated on the tabulation and/or summary sheet when a choice in size exists.

Where the pipe design is sensitive to a certain kind of metal pipe corrugation, the contractor shall be alerted by a "special provision" that a certain type of pipe corrugation is required at a particular location.

If an alternate type and size of pipe is selected and approved as a Value Engineering proposal during construction, the drawings and quantities must be adjusted accordingly by the contractor.

**5.** Combination Storm Sewer and Underdrain. Longitudinal pipes that are proposed along the low side of pavement or shoulder edges may serve as combination storm sewer and underdrain pipe to eliminate the need for base drains, and shall be designed and constructed in accordance with Publication 72M, *Roadway Construction Standards* and Publication 408, *Specifications*. In these cases, the effect of subgrade drainage should be excluded in the design of the storm sewer system.

**6.** End Sections. End sections should be used on the inlet end of pipes that accept flows at grade due to their favorable hydraulic characteristics. Headwalls are usually used on the inlet end of culverts. End sections may be used when it is desirable to conform the entrance condition to the fill slope. Both headwalls and end sections perform the same hydraulically on the inlet end. End sections are used on the outlet end of the pipe to reduce the flow depth and outlet velocity. End sections on the outlet end of pipes should be used on traversable slopes (without guide rail) within the clear zone and in highly visible areas; i.e., interchange loops and median swales. For economic reasons, the use of end sections on the outlet end of pipe culverts, at certain locations, is not required.

## TABLE 10.3.5
## ALTERNATE PIPE SELECTION CRITERIA BASED UPON LOCATION OF DRAINAGE PIPES

<table>
<tr><th colspan="2">LOCATION OF DRAINAGE PIPES</th><th colspan="2">TYPES OF PIPE</th><th>NO. OF ALTERNATES REQUIRED</th></tr>
<tr><td rowspan="4">Cross Drains Under Pavement, Shoulder, or Between Curbs; Parallel Storm Sewers Under Pavement or Between Curbs</td><td>Fill Height*</td><td>Interstate/<br>Arterials</td><td>Collectors/<br>Locals</td><td rowspan="4">2</td></tr>
<tr><td>< 0.6 m<br>(< 2 ft)</td><td>100 Years Life<br>(Pipes 1, 2, 5 & 7)</td><td>50 Years Life<br>(Pipes 1 & 3 thru 7)</td></tr>
<tr><td>0.6 m - 4.6 m<br>(2 ft - 15 ft)</td><td>100 Years Life<br>(Pipes 1, 2, 5 & 7)</td><td>50 Years Life<br>(Pipes 1 & 3 thru 7 & 8)</td></tr>
<tr><td>> 4.6 m<br>(> 15 ft)</td><td>100 Years Life<br>(Pipes 1, 2, 5 & 7)</td><td>100 Years Life<br>(Pipes 1, 2, 5 & 7)</td></tr>
<tr><td>Parallel Storm Sewers Outside of Pavement or Curbs</td><td colspan="3">50 Years Life (All pipes in LEGEND)</td><td>3</td></tr>
<tr><td>Cross Drains Outside of Pavement, Shoulder or Curbs (Cross Drains in Medians, etc.)</td><td colspan="3">50 Years Life (All pipes in LEGEND except 9)</td><td>3</td></tr>
<tr><td rowspan="3">Combination Storm Sewer and Underdrain and Other Special Drainage System</td><td>100 Years Life•</td><td colspan="2">Pipe 2, open joint, & perforated pipes 5 & 7</td><td>2</td></tr>
<tr><td rowspan="2">50 Years Life••</td><td>Fill Height*<br>< 0.6 m (2 ft)</td><td>Pipe 3, open joint, & perforated pipes 4, 5 & 7</td><td rowspan="2">3</td></tr>
<tr><td>Fill Height*<br>≥ 0.6 m (2 ft)</td><td>Pipe 3, open joint, & perforated pipes 4, 5, 7 & 8</td></tr>
<tr><td>Slope Pipes</td><td colspan="3">50 Years Life ( Pipes 4 thru 9)</td><td>2</td></tr>
<tr><td>Side Drains (Driveways, etc.)</td><td colspan="3">25 Years Life (All pipes in LEGEND)</td><td>3</td></tr>
</table>

Separate tables are provided for fill height requirements. Utilize those tables for determination of minimum and maximum fill height requirements. Specified minimum fill heights are applicable to pipes under pavement or between curbs. Specified maximum fill heights are applicable to all installations.

* Fill height is defined as the material from the top of pipe barrel to the riding surface, including the pavement structure. Refer to RC-30M for minimum cover over pipe under pavements.

• For pipes under pavement or between curbs on Interstate/Arterials.

•• For pipes other than under pavement or between curbs on Interstate/Arterials.

### LEGEND
### (Types of Pipe)

1. DIP = Ductile Iron Pipe.
2. RCP (Type A) = Reinforced Concrete Pipe, heavy duty.
3. RCP (Type B) = Reinforced Concrete Pipe, normal duty (1200 mm (48 in) max).
4. CGSP = Corrugated Galvanized Steel Pipe.
5. CASP = Corrugated Aluminized Steel Pipe.
6. CCGSP = Coated (Polymer) Corrugated Galvanized Steel Pipe.
7. CAAP = Corrugated Aluminum Alloy Pipe.
8. TP (Group I, II, III, IV or VI) = Thermoplastic Pipe, Group I, II, III, IV or VI (1500 mm (60 in) max). Thermoplastic Pipe Groups are defined in Publication 408, *Specifications,* Section 601.
9. TP (Group V - Corr PE) = Thermoplastic Pipe, Group V - Corrugated Polyethylene (900 mm (36 in) max). Thermoplastic Pipe Groups are defined in Publication 408, *Specifications,* Section 601.

NOTES:

1. Select pipes with specified years life based on the type of drainage installation, class of highway and fill height (cover). The years life indicated (100, 50 and 25) are approximate expected service lives.

2. Pipe alternates may be eliminated for the following reasons: (1) unstable support, (2) high impact and concentrated loading, (3) high embankments, (4) limited clearance, (5) steep gradients, (6) high acidity to alkalinity of soils and water or other corrosive elements, (7) high erosive forces or (8) for other pertinent reasons.

**7.** Energy Dissipators. Energy dissipation may be required to protect the channel downstream of a storm drain outlet. Protection often is required at the outlet to prevent erosion of the outfall bed and banks. Riprap aprons or energy dissipators shall be provided if high velocities are expected.

Refer to Publication 584, *PennDOT Drainage Manual*, Chapter 12 for guidance with designing an appropriate dissipator. The FHWA computer program HY-8 may be used for design calculations for energy dissipation.

**8.** Maintenance of Existing Pipes. Existing pipes may be selected to remain in place and to function beyond completion of the proposed work. These existing pipes should be inspected by the designer during the design phase to determine if they need to be cleaned. For cleaning existing pipes, the contractor is to follow the specifications presented in Publication 408, *Specifications*, Section 601. The designer shall present the location (stations), length (meters (linear feet)) and size (diameter) of each pipe to be cleaned as part of the project. The listing shall be included on the "Tabulation of Quantities" sheet(s) and "Summary" sheet(s) in the design plans and quantified under one of the following two item descriptions:

- Cleaning Existing Pipe Culverts, Diameters Up to and Including 900 mm (36 in)
- Cleaning Existing Pipe Culverts, Diameters over 900 mm (36 in)

**C. Pipe Culverts.** The function of a pipe culvert is to convey surface water across or from the highway right-of-way. (For structures within regulated waterways, see Section 10.6.) Pipe culverts are usually covered with embankment and are composed of structural material around the entire perimeter, although some are supported on spread footings with the stream bed serving as the bottom of the culvert. In all cases where drainage is collected by means of a head wall, the pipe shall be designed as a pipe culvert. When a pipe culvert is part of a storm sewer system and crosses the roadway, it shall be designed with the same design storm as the remainder of the system.

The procedure contained in Publication 584, *PennDOT Drainage Manual*, Chapter 9, and in FHWA's Hydraulic Design Series No. 5 (HDS-5), shall be used for the design of pipe culverts.

Specific information about pipe culverts is as follows:

**1.** Diameters. The minimum diameter of a pipe culvert shall be 450 mm (18 in), except pipes under a 7.6 m (25 ft) or greater fill height shall not be less than 600 mm (24 in). Culverts shall be provided in 150 mm (6 in) increments.

**2.** Inverts. Inverts of new pipe culverts shall be depressed a minimum of 150 mm (6 in) below stream invert grade at both the inlet and outlet ends, or a minimum of 300 mm (12 in) if required as a condition to obtain the waterway permit.

**3.** Lengths. Because of the difference between the lengths of metal and non-metal end sections for pipe culverts, the length of connecting pipe can vary. To avoid showing different lengths of the connecting pipe on the plans, the designer should show on the plan only the length of the metal type pipe for all alternatives.

**4.** Allowable Headwater. In culvert design, headwater is water that effectively ponds at the entrance end of the culvert. The allowable headwater elevation is that elevation above which damage may be caused to adjacent property and/or the roadway. The maximum allowable headwater (HW) is the depth of water, measured from the entrance invert, that can be ponded during the design flood. The surrounding features, flow limitations, and roadway classification must be considered for each situation.

The surrounding features that may limit the allowable headwater include the following:

- Lowest elevation of the roadway adjacent to the ponding area;
- Flowline of the roadway ditch which passes water along the roadway to another drainage basin;
- Upstream property, such as buildings or farm crops, which will be damaged if inundated; and
- Elevation established to delineate floodplain zoning.

Flow limitation factors that can affect the allowable headwater include the following:

- The debris which could plug the structure;
- Excessive ponding which would allow too much silting; or
- High hydrostatic pressure which would cause seepage along the culvert backfill.

The HW/D ratio to be considered for design is the ratio of headwater depth to the diameter, height, or rise of a culvert entrance. The following are the maximum allowable HW/D ratios for the design of new culverts:

- HW/D = 2.0: Circular and elliptical (squash) pipe culverts with diameters (or equivalent diameters) of 750 mm (30 in) or less.

- HW/D = 1.5: Circular and elliptical pipe culverts with diameters greater than 750 mm (30 in) and less than or equal to 1800 mm (72 in), and other culverts with cross sectional areas equal to or less than 2.8 $m^2$ (30 $ft^2$).

- HW/D = 1.2: Circular and elliptical pipe culverts with diameters greater than 1800 mm (72 in), and other culverts with cross sectional areas greater than 2.8 $m^2$ (30 $ft^2$).

The maximum allowable headwater ratio applies to the design flood, based on roadway classification. The headwater should also be checked for the 100-year flood to ensure compliance with floodplain management criteria. The maximum acceptable outlet velocity should be identified. The headwater should be set to produce acceptable velocities; otherwise, stabilization or energy dissipation should be provided where acceptable velocities are exceeded. For streams with debris issues, trash racks should be considered.

Occasional flowage easement shall normally be obtained for new flooding areas beyond the right-of-way line for the 100-year storm event for flow ($Q_{100}$). $Q_{100}$ shall be used to be consistent with FEMA requirements and the Pennsylvania Floodplain Management Act. Except for the Interstate Highway, which cannot be inundated at the 50-year storm event for flow ($Q_{50}$), all classes of highways may be inundated at the design Q if a practicable alternative is not available.

**5.** Erosion Control. The requirements and provisions of erosion control devices for pipe culvert outlets are specified in Chapter 13, Erosion and Sediment Pollution Control.

**D. Pavement Base Drains.** Pavement base drains are subsurface drains utilizing perforated or porous pipe installed parallel to the highway. They are used to lower the ground water level, to drain slopes or to drain the pavement structure. The pipe is placed in trenches and surrounded by coarse aggregate that is both pervious to water and capable of protecting the pipe from infiltration by the surrounding soil. Installation details are presented in Publication 72M, *Roadway Construction Standards* and in Chapter 1, Section 1.5.

To provide a functional pavement base drain system, the proper spacing of outlets is important, especially on relatively flat grades. Therefore, the various types of pipe can be made hydraulically equivalent by the proper selection of outlet spacing for each type.

Circular diameters between 100 mm (4 in) and 200 mm (8 in) typically are used and are considered adequate for normal use. Where such pipe is required to connect into existing systems, or if hydraulic circumstances exist that require greater capacities, larger pipe sizes should be specified. Publication 35, *Approved Construction Materials* (Bulletin 15) provides a listing of approved pavement base drains made from various materials.

The following method should be used to determine the maximum functional outlet spacing for pavement base drains. Roughness coefficients for the various types of pipe for pavement base drains are indicated in Table 10.3.6.

Outlet spacing is a function of the pipe diameter, pipe gradient (g) and the anticipated design infiltration rate (I). The maximum functional outlet spacing for various conditions may readily be determined from the nomograph in Figure 10.3.9.

First determine the infiltration rate by multiplying the appropriate 1 hour/1 year frequency precipitation rate obtained from Publication 584, *PennDOT Drainage Manual*, Chapter 7, Appendix A by an adjustment coefficient of 0.50 for asphaltic concrete pavement or 0.67 for portland cement concrete pavement. Enter the left side of the nomograph with the calculated design infiltration rate. Next, draw a line from the design infiltration rate through the appropriate width of pavement or maximum perpendicular drainage distance to the trench. Normally this can be simplified by passing this line through the appropriate number of lanes sloped towards each pavement base drain.

This line intercepts PIVOT LINE (2). Now enter the right side of the nomograph with the pipe gradient value. Generally, the pipe gradient should approximately follow the longitudinal grade of the highway pavement; hence a minimum gradient of 0.5% would apply. Draw a line from the pipe gradient through the pipe diameter and appropriate n-coefficient by type of pipe until it intercepts PIVOT LINE (1). By connecting the points of interception of PIVOT LINES (1) and (2) with a straight line, the maximum functional distance (L) between outlets, in meters (feet), can be obtained.

If the resultant maximum outlet spacing for the given set of conditions is too small to be practically applied on a particular project, the pipe diameter or pipe gradient may be increased or a pipe with a lower n-coefficient selected.

## TABLE 10.3.6
## ROUGHNESS COEFFICIENT "n"
## FOR MANNING'S EQUATION
## FOR PAVEMENT BASE DRAINS

| MANNING'S "n" | TYPES OF PIPE |
|---|---|
| 0.010 | Polyvinyl Chloride (PVC) with Smooth Inner Walls |
| 0.012 | Porous Cement Concrete Pipe; Helically Corrugated Circular Metal Pipe (100 mm through 200 mm (4 in through 8 in)); Corrugated High–Density Polyethylene (HDPE) with Smooth Inner Walls |
| 0.015 | Corrugated High-Density Polyethylene (HDPE) with Corrugated Inner Walls; Helically Corrugated Circular Metal Pipe (250 mm (10 in)) |

**INTENTIONALLY BLANK**

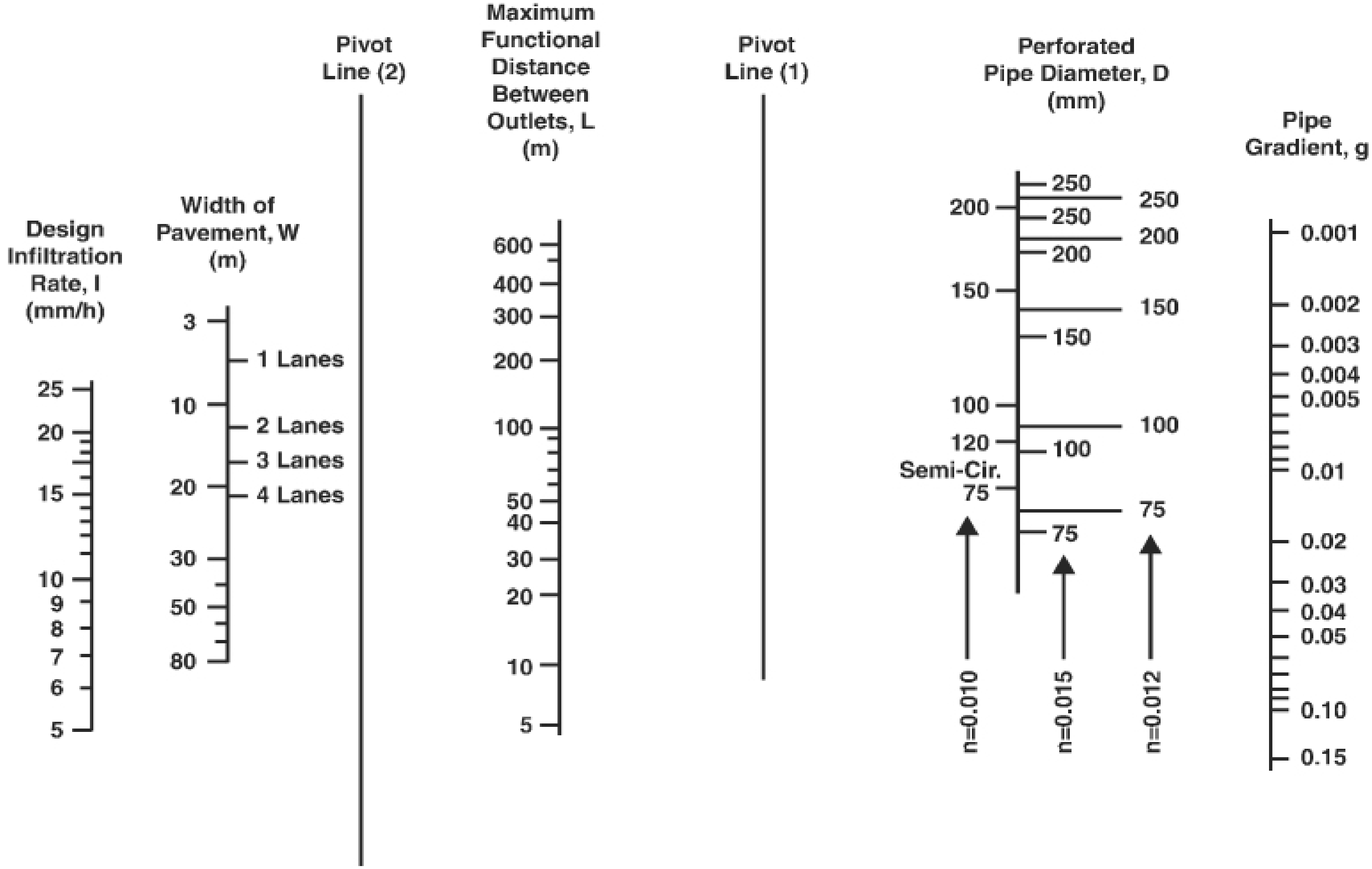


**FIGURE 10.3.9 (METRIC)**

**Nomograph For The Selection Of Maximum Outlet Spacing (L) For Pavement Base Drains**

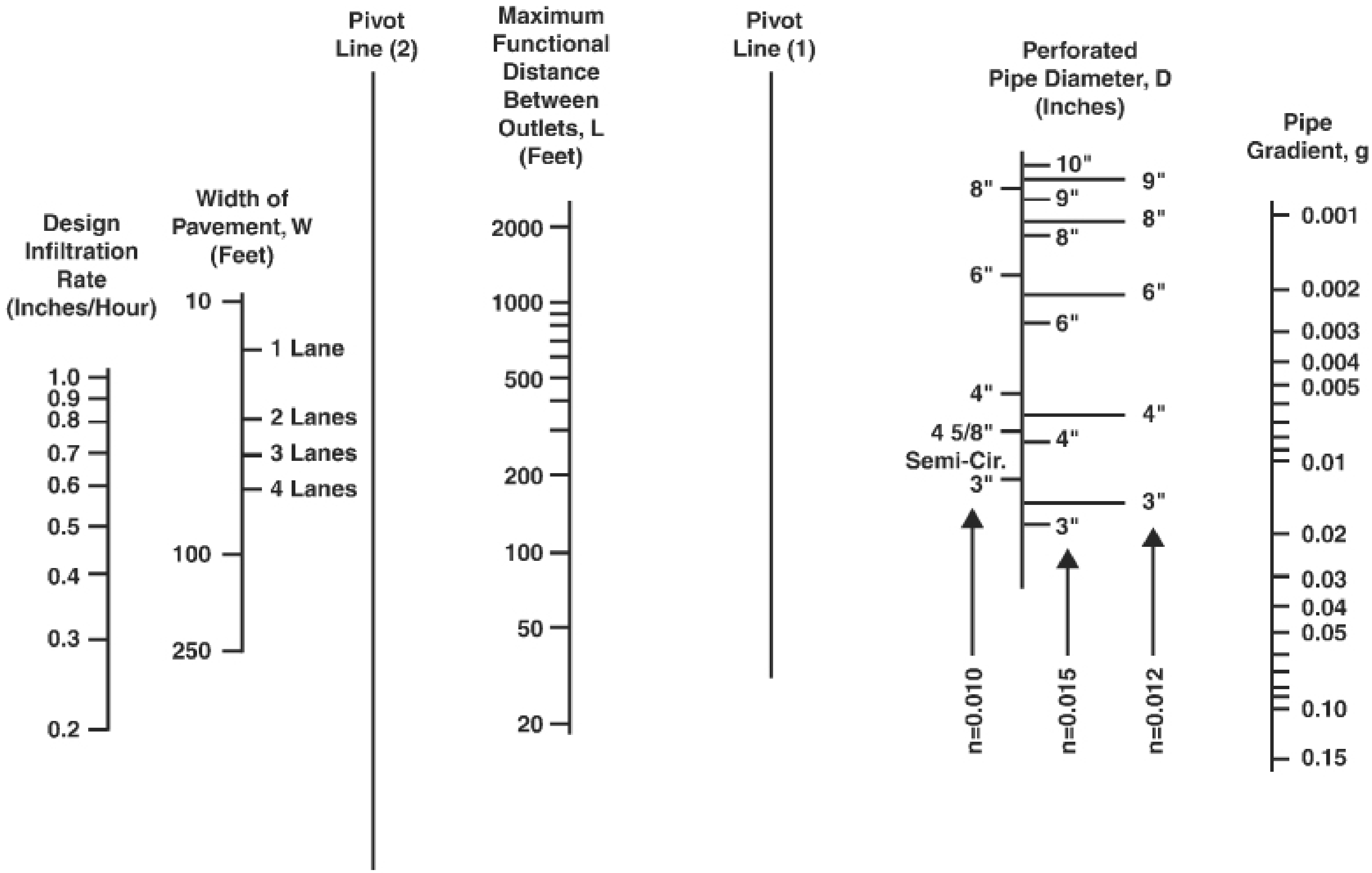


**FIGURE 10.3.9 (ENGLISH)**

**Nomograph For The Selection Of Maximum Outlet Spacing (L) For Pavement Base Drains**

Example Problem:

Given: A two-lane asphaltic concrete pavement in Delaware County.

Determine: The maximum functional outlet spacing for a perforated 100 mm (4 in) diameter, smooth-walled PVC pipe (pavement base drain on both sides of roadway). Assume a gradient of 0.5% (0.005).

Solution: From Publication 584, *PennDOT Drainage Manual*, Chapter 7, Appendix A, Table 7A.1, the 1-year, 1 hour intensity would correspond to Map A. From Map A, Figure 7A.1, Delaware County, would fall under Region 5. From Table 7A.6a and (b) the 1-year, 1-hour rainfall would be 29.6 mm/h (1.17 in/h) precipitation rate in Delaware County. This multiplied by an adjustment factor of 0.50 for asphaltic concrete pavement gives an infiltration intensity, I, of 14.8 mm/h (0.59 in/h). Enter the left side of Figure 10.3.9 at the 14.8 (0.59) location. Next extend a line through the 1 lane mark (base drain on both sides of roadway) to PIVOT LINE (2). Now extend a line from the 0.5% (0.005) pipe gradient location on the right side of the nomograph through the 100 mm (4 in), n = 0.010 mark to PIVOT LINE (1). Draw a line from PIVOT LINE (1) to PIVOT LINE (2) and read a maximum outlet spacing of 277.6 m (910 ft) from the intersection point on DISTANCE BETWEEN OUTLETS line (L).

**E. Stormwater Management Facilities.** See Chapter 13, Erosion and Sediment Pollution Control, and Publication 584, *PennDOT Drainage Manual*, Chapter 14 regarding design of stormwater management facilities.

**F. Superstructure Drainage.** See Publication 15M, Design Manual, Part 4, *Structures,* for specific instructions regarding superstructure drainage.

**G. Roadway Drainage Report.** The outline shown below is an example of a Roadway Drainage Report that would be prepared and submitted for the Department's review and approval where an individual water obstruction permit or Highway Occupancy Permit is required. Note that this outline is a guideline and may be modified to meet the specific needs of the project.

**1.** INTRODUCTION

**2.** PROJECT DESCRIPTION

**3.** EXISTING DRAINAGE CONDITIONS

**4.** PROPOSED DRAINAGE CONDITIONS

**5.** HYDROLOGIC CRITERIA AND METHODOLOGY
(Describe hydrologic criteria and solution methodology as selected specifically for the project)

**6.** HYDRAULIC CRITERIA
(Describe hydraulic criteria and solution methodology for each hydraulic structure as applicable to the project)

- **a.** Inlets
- **b.** Storm Pipes
- **c.** Pipe Culverts
- **d.** Ditches and Swales
- **e.** Pavement Base Drains

**7.** CONCLUSION

**8.** REFERENCES

**9.** DRAINAGE PLAN SHEETS WITH AREA DELINEATIONS

**10.** APPENDICES

| | |
|---|---|
| Appendix A: | Inlet Calculations |
| Appendix B: | Storm Pipe Calculations |
| Appendix C: | Circular Pipe Culvert Calculations |
| Appendix D: | Ditch and Swale Calculations |
| Appendix E: | Pavement Base Drain Calculations |

**H. Hydraulic Computation Approval.** Hydraulic design computations shall be required for all pipes with a diameter of 450 mm (18 in) or greater. These pipes refer to any closed conduit which conveys storm water runoff, including culverts, which provide cross drainage of the highway.

Hydraulic computations for roadway drainage structures shall be approved at the District Office with one copy of the submission and approval for all projects sent to the Central Office, Bureau of Project Delivery for information, according to the procedures specified in Section 10.2. The Central Office may perform a Quality Assurance review of the submission and forward any comments on major policy deviations to the District Office. One copy of the plans should accompany the hydraulic computations showing pipe sizes (alternates where required) selected for each location. The pipe sizes and types should be shown on the prints at the pipe location for review purposes.

For those roadway drainage structures where an individual water obstruction permit is required, a brief Hydrologic and Hydraulic Report prepared as per Section 10.7 should be included in the permit application as required by 25 PA Code § 105.

## 10.4 FILL HEIGHT CRITERIA AND TABLES FOR CONCRETE, METAL AND THERMOPLASTIC PIPES

The design criteria and tables referred to in this section contain the maximum and minimum allowable fill height information for reinforced concrete, metal and thermoplastic pipes. As previously indicated in Table 10.3.5, fill height is defined as the material from the top of the pipe barrel to the riding surface, including the pavement structure. Refer to Publication 72M, *Roadway Construction Standards*, RC-30M for details concerning minimum cover over pipe under pavements. In the tables found in Chapter 10, Appendix B, the type of pipe indicated is based on their corresponding diameters for circular pipes, corresponding rise × span for reinforced concrete elliptical pipes and corresponding span × rise for metal pipe arches.

**A. Reinforced Concrete Pipes and Elliptical Pipes.** The design criteria and tables including those for allowable fill heights are provided in the Publication 218M, *Standards for Bridge Design*, Drawing BD-636M titled, "Standard, Reinforced Concrete Pipes." Standard fill height tables included in BD-636M are listed in Chapter 10, Appendix B, Table 10.B.1.

**B. Metal Pipes and Pipe Arches.** Chapter 10, Appendix B, Table 10.B.2 lists those types of metal pipes and pipe arches for which allowable fill height tables have been developed. Chapter 10, Appendix B, Tables 10.B.3 through 10.B.34 provide the maximum and minimum allowable fill height information for commonly used metal pipes and pipe arches. Refer to Publication 15M, Design Manual, Part 4, *Structures*, for pipe diameters or pipe arch spans 2400 mm (96 in) or more.

The allowable fill height table for metal pipes and pipe arches were developed using the following criteria:

$\gamma_e$ = 2240 kg/m$^3$ (140 lb/ft$^3$)
$\Phi$ = 0.98 for helical pipes

Min fill heights as per SCI method (DM-4 - 95% compaction)
Live Load = HS-25 trucks (passing distance = 1.2 m (4 ft))
254 mm × 508 mm (10 in × 20 in) wheel footprint
Live Load impact factor, IM = 40(1 - 0.125H)

<u>Load Factor Design</u>
$\beta_e$ = 1.5 for flexible culverts (Group × loading)

Service Load Check
$\beta_e = 1.0$
SF = 1.3 at end of service life

Service Life
Metal Loss rates: 0.05 mm/yr (2 mil/yr) for plain galvanized pipes
0.025 mm/yr (1 mil/yr) for aluminized steel or aluminum pipes

Treatment Credits: Polymer Coating - 20 yr service life credit when design flow velocity ≤ 1.5 m/s (5.0 ft/s)
Polymer Coating - 10 yr service life credit when design flow velocity > 1.5 m/s (5.0 ft/s)

Recommended Installation Conditions: Steel-soil and water pH within the range of 5.5 to 8.5
Aluminum - soil and water pH within the range of 4 to 8.5

**C. Thermoplastic Pipes.** The maximum and minimum allowable fill heights for Thermoplastic Pipe Groups I, II, III, IV, V and VI are indicated in Chapter 10, Appendix B, Table 10.B.35. Thermoplastic pipes are considered to meet a 50-year service life (design life) requirement.

The allowable fill height table for thermoplastic pipes were developed using the following criteria:

$\gamma_e$ = 2240 kg/m$^3$ (140 lb/ft$^3$)
$\Phi = 1.0$

Constrained soil modulus for a SN material with 95% compaction
Live Load = PHL-93
254 mm × 508 mm (10 in × 20 in) wheel footprint
Live Load impact factor
Metric Units $IM = 33(1-4.1\times10^{-4}H)>0\%$
U.S. Customary Units $IM = 33(1-0.125H)>0\%$

Load and Resistance Factor Design
$\gamma_{EV} = 1.95$
$\gamma_W = 1.3$

## 10.5 WATERWAY APPROVAL

For waterway drainage structures discussed in Section 10.3, a waterway approval is considered granted if all necessary regulatory permits or approvals for environmental clearance are obtained. This approval is also required for certain encroachments.

A copy of all Regulatory permits received (including conditions and restrictions) are affixed to and made a part of the Special Provisions in the Contract Proposal.

Several waterway structures may be included in a single Hydrologic and Hydraulic Report provided these structures are involved in the same contract section and/or addressed in the same environmental documents.

Additional information and requirements regarding the various regulatory permits and approvals are described as follows:

**A. $JPA_2$ Expert System.**

**1. Purpose.** The $JPA_2$ Expert System is to assist in the preparation of Chapter 105 Permit Applications for submission to PA DEP and other agencies, help users prepare documents in a consistent standardized manner, and submit Permit Applications electronically to PA DEP for review.

Benefits of $JPA_2$ include the following: more efficient system for obtaining permit approvals, paperless repository, centralized tracking of submissions, formal correspondence between PennDOT and PA DEP, and less attrition of business knowledge.

The new $JPA_2$ system is purposely similar to its predecessor, including comparable or equivalent functionality for: navigation, security, application creation, document check out and data validation. Enhancements in the new system that improve and streamline processes will require minimal orientation for established JPA users. The addition of PA DEP Facility link, which provides access to the Facility and Sub-Facility data Screens in the PA DEP eFACTS (Environment Facility Application Compliance Tracking System), will be used by PA DEP to inventory details associated with regulated activities.

**2. Implementation.** The following permit types, including those developed by consultants, must be created and submitted using the $JPA_2$ Expert System:

- GP-11
- Small Projects
- Standard Applications

**NOTE:** *Electronic submission using PennDOT's $JPA_2$ Expert System will be the **only method** to prepare and submit GP-11, Small Projects, and Standard Applications for Department or federally-funded projects to PA DEP for their review.*

If the project is a local project, the use of the $JPA_2$ Expert System and electronic submission is not currently offered. The electronic submission is not currently allowed because the Department may be improperly identified as the permit applicant. A $JPA_2$ enhancement to facilitate submitting local applications is underway.

Other permit types such as GP-8, GP-7 and Maintenance permits may be created in the $JPA_2$ Expert System, but electronic submissions to PA DEP are not currently offered. These permit applications will have to be printed out and the paper copies submitted to the local county conservation district or Regional Office of PA DEP as required for their review. Permit applications shall be prepared and submitted to the appropriate PA DEP Regional Office only if the county conservation district is not delegated to review Chapter 105.

**3. Access to $JPA_2$.** The $JPA_2$ Expert System is a web-based system that runs on Internet Explorer web browser and is available to PennDOT Registered Business Partners. The following URL will take you directly to $JPA_2$ homepage, where you login using your ECMS user id and password:

www.dot2.state.pa.us/jpa2/jpahome.nsf

Access to $JPA_2$ Expert System is also available to users already logged into ECMS. On the ECMS homepage, click on "PennDOT Systems," then select the $JPA_2$ link.

**4. Training.** PennDOT has developed a $JPA_2$ eTraining CD and a $JPA_2$ Training Manual to assist PennDOT personnel and consultants on the use of the new system. Additionally, PA DEP has created Chapter 105 Facility Data eTraining and a Facility Data Training Manual. Links to the JPA Training Manual, PA DEP Facility Data Manual, and the PA DEP Chapter 105 eTraining are available in the $JPA_2$ Expert System online help system.

**B. Obtain Waterway Approval Process.** To obtain a waterway approval, the following procedures shall be used for all projects (Federal-Aid and 100% State):

**1.** The Engineering District shall develop all information required for a $JPA_2$ to meet the requirements of this Chapter and current directives. The Department's $JPA_2$ Expert System should be used to develop and submit the application.

The information developed shall be reviewed by the District Environmental Manager and Regulatory Permit Coordinator to assure compliance with all applicable environmental requirements. This information should include the Hydrologic and Hydraulic (H&H) Report as prepared in accordance with the "Guidelines for Preparation of Hydrologic and Hydraulic Report" in Section 10.7.

**2.** The Engineering District shall complete and sign the appropriate permit application form or letter and send the $JPA_2$ to the appropriate PA DEP Regional office responsible for issuing the permit coverage. The PA DEP Regional office will forward copies of the application to the appropriate USACE office, if required, PFBC, and other agencies if necessary.

Pursuant to the requirements of Act 14, P.L. 834 (passed in 1984), the Engineering District shall give written notice to each municipality and county (local) government in which the activity is located. Proof of written notice and receipt by local government shall be submitted to PA DEP with the application. The written notice shall be received by the local government at least 30 days before PA DEP takes a final action on the permit application. The Act 14 notification procedure may be applicable to permit amendments.

PA DEP has waived the requirement that an E&S Plan - Erosion and Sediment Pollution Control Plan - or approval be included with a Chapter 105 permit application in order to be considered administratively complete. However, the permit cannot be issued until the Plan or approval is received by PA DEP. See Chapter 10, Appendix H for detailed information.

PA DEP publishes a notice of every complete individual Water Obstruction and Encroachment Permit application in the Pennsylvania Bulletin. This notice provides a 30-day period for submittal of public comments, including requests or petitions for a public hearing. PA DEP also publishes notices of all final actions for individual permit authorizations in the Pennsylvania Bulletin.

**3.** The Bureau of Project Delivery may perform a Quality Assurance review of hydrologic and hydraulic design of the proposed water obstruction and encroachment.

**4.** The Bureau of Project Delivery will notify the Engineering District regarding technical deficiencies, if any, for permit applications reviewed.

**5.** In addition to submission of the $JPA_2$, the Engineering District shall submit one extra copy of Hydrologic and Hydraulic Report to the Bureau of Project Delivery for transmittal to FHWA for review and approval for the following categories of Federal-Aid projects:

- **a.** Significant or controversial channel changes.
- **b.** Significant or controversial backwater easements.
- **c.** Significant bridge scours.
- **d.** Permanent impoundments or causeways involving roadway embankments.
- **e.** Major bridges with costs of more than 10 million dollars.

**6.** The Engineering District also shall assume responsibility for processing and obtaining all other regulatory permits (such as the US Corps of Engineers Section 10 and US Coast Guard Bridge Permits for proposed activities in Navigable Waters of the United States).

**7.** After receipt of the permits or approvals, the Engineering District shall submit one copy of the same to the Bureau of Project Delivery for archiving.

**8.** A waterway approval is considered granted to the District Executive upon completion of the reviews by the Bureau of Project Delivery, the Pennsylvania Department of Environmental Protection, the Federal Highway Administration, the Pennsylvania Fish and Boat Commission, the US Coast Guard, the US Corps of Engineers and/or other agencies, as required and upon attainments of all necessary regulatory permits or approvals.

**9.** The project record in $JPA_2$ will be closed out after the construction project authorized by the waterway permit is completed. For the purpose of closing the record, construction shall be considered completed at the Final Inspection. Procedures for tracking environmental commitments and mitigation are described in Publication 10X, Design Manual, Part 1X, *Appendices to Design Manuals 1, 1A, 1B, and 1C*, Appendix T, Environmental Commitments and Mitigation Tracking System (ECMTS) Process.

**C. PA DEP Permit and PFBC Approval.** A water obstruction permit requirement is required by 25 PA Code Chapter 105 Regulations. A floodplain permit requirement is also regulated by 25 PA Code Chapter 106 Regulation applicable to any highway or other obstruction, constructed, owned or maintained by the Commonwealth or a political subdivision, located within the 100-year floodplain shown on the floodplain maps approved or promulgated by FEMA. Additional information and guidance concerning the design and permitting of temporary structures is located in Section 10.7.D.1.b.

For municipal structures using Federal-aid funds, the Engineering District shall obtain from the applicable municipal authority a copy of the H&H Report and forward it to the Bureau of Project Delivery for quality assurance review. For municipal structures using funds other than Federal (such as Liquid Fuel Tax funds), the municipalities or their designated agents may submit the Joint Permit Application directly to PA DEP.

Include an Engineer's certification in the H&H Report in accordance with the requirements of the 25 PA Code Chapter 105 and 106 Regulations. Request a written statement from the local municipality affirming that the proposed project is consistent with local stormwater management plans and with local floodplain management plans. If a written statement cannot be obtained, include sufficient documentation with the permit application to demonstrate consistency with local plans implemented under 25 Pa. Code §106.13(b)(7). If the review by PA DEP indicates that an application is complete and satisfactory, PA DEP will issue a "Water Obstruction and Encroachment Permit".

**1.** A number of standard conditions and restrictions normally are specified in a Water Obstruction and Encroachment Permit issued by PA DEP. The following procedures are suggested:

**a.** The Special Provisions shall specify that it is the contractor's responsibility to notify the appropriate PA DEP Regional Office in advance of the start of construction.

**b.** At the time that the Engineering District submits Form CS-4138, Acceptance Certificate, to the Construction Division, the Engineering District shall submit the "Water Obstruction and Encroachment Permit Completion Reports" directly to PA DEP for the entire project on a group basis. Encroachment Completion Report forms are available from the PA DEP Regional Offices.

**c.** A copy of each PA DEP Permit (including its conditions and restrictions) shall be affixed to and made a part of the Special Provisions in the Contract Proposal. The contractor shall take necessary actions to comply with the applicable conditions and restrictions.

**2.** Each permit should be pursuant to the requirements of Act 14, P.L. 834 as described in Section 10.5.B.2.

**3.** The following General Permits may need to be included as part of a Joint Permit Application:

**a.** BDWW-GP-1: Fish Habitat Enhancement Structures
**b.** BDWW-GP-2: Small Docks and Boat Launching Ramps
**c.** BDWW-GP-3: Bank Rehabilitation, Bank Protection and Gravel Bar Removal
**d.** BDWM-GP-4: Intake and Outfall Structures
**e.** BDWM-GP-5: Utility Line Stream Crossings
**f.** BDWM-GP-6: Agricultural Crossings and Ramps
**g.** BDWM-GP-7: Minor Road Crossings
**h.** BDWM-GP-8: Temporary Road Crossings
**i.** BDWM-GP-9: Agricultural Activities
**j.** BDWW-GP-10: Abandoned Mine Reclamation
**k.** BWQP-GP-15: Private Residential Construction in Wetlands

**4.** For those waterway structures to be constructed across stocked trout streams, PFBC generally requires that no work is to be done in the stream channel between March 1 and June 15; however, PFBC may consider the following factors in granting an approval:

**a.** Amount of work to be done in stream channel.
**b.** Adequacy of the erosion controls proposed.

**c.** The sensitivity of the particular stream involved.
**d.** Duration of the work in the channel.

**5.** In the event a waiver of the construction period restriction is requested for any bridge project involving a stocked trout stream, include the necessary information reflecting the concern of the above factors in the Hydrologic and Hydraulic Report or bridge plan submitted for a waterway approval, along with a specific request for a waiver. To address PFBC's concerns, it is suggested that the following requirements be specified in the waterway submission if a waiver of the restriction period is requested:

**a.** Clean rock or other clean granular material shall be used as fill material for temporary stream crossing(s), causeway(s) and/or cofferdam(s).

**b.** No construction equipment shall be permitted to operate in the water unless prior approval has been obtained from the PFBC.

**6.** Aids to Navigation (ATON).

**a.** Many of the Department's bridge replacement projects require aids to navigation which warn waterway users of the changing conditions ahead as well as help guide these users through or around the project area. Under Chapter 113 of the PA Fishing and Boating Regulations, placement of the aids to navigation requires an approved ATON Plan which is processed by the PA Fish & Boat Commission (PFBC). The Department submits ATON plans to the PFBC when Department projects will obstruct any portion of a recreational boating waterway. For the purposes of ATON, a recreational boating waterway is one where motorized boating, canoeing and kayaking are possible during suitable flow conditions. Two warning signs should be placed at the project area (one upstream and one downstream). Sign specifications are shown in Figure 10.5.1. The upstream sign should be within 60 m (200 ft) of the obstruction. The downstream sign should be placed near the obstruction but no further than 60 m (200 ft) from the project area. Both signs should be clearly visible. An additional sign may be warranted if a known upstream launch site exists. This additional sign should also warn boaters of the construction and indicate the distance to the project site.

All projects must be sent to the Waterways Conservation Officer Manager, PFBC, Bureau of Law Enforcement, P.O. Box 67000, Harrisburg, PA 17106-7000. Projects that restrict the entire channel will require the Department to provide safe portage around the construction site. This includes signage using specifications as shown in Figure 10.5.2. Additionally, an area suitable for removing canoes or kayaks from the waterway, a delineated pathway for portage and an area suitable for re-launching should be provided.

Note that projects in waterways predominantly used by motorized boats may also warrant additional warning devices including floating buoy structures that will require submission of PFBC Form 277, "Application for Permit to Install Floating Structures and Private Aids to Navigation," available here: http://fishandboat.com/forms_boating.htm. This form should be included with the ATON plan and not sent as a separate submission. If being submitted by PennDOT, the fee is not applicable. Forms submitted by contractors will require the fee.

**b.** The following list shows information required for a standard ATON Submission.

**(1)** Project Description including the following:

**(i)** SR-Section and Local Name.
**(ii)** Township and County.
**(iii)** Waterway.
**(iv)** Existing and proposed structure type.
**(v)** Type of obstruction necessary for construction.
**(vi)** Anticipated let date and timeframe that obstruction will be in place.
**(vii)** Proposed signage to warn boaters of construction.

**(2)** USGS Location Map of project area.

**(3)** Photos upstream and downstream of the structure keyed to a location map.

**(4)** Color coded plan view showing obstruction, safe waterway opening and approximate sign location.

**(5)** Example sign template.

**(6)** Example sign specifications.

For right-of-way purposes, the vast majority of waterways requiring ATON's will meet one of the definitions of navigable waterway as defined under Publication 378, *Right-of-Way Manual*, Appendix C. This gives the Department rights up to the high water line on most projects. In other cases, construction contracts should be specified to require contractors to place temporary ATONs outside the project limit on projects requiring ATON plans. In cases where full width causeways are needed, safe portage must be provided. The District should consider acquiring a temporary construction easement, as necessary, to provide such portage.

The PFBC funded position personnel can make a recommendation regarding waterways requiring ATONs during the pre-application field view. This recommendation must be verified with the PFBC Waterways Conservation Officer Manager at the Bureau of Law Enforcement. If a pre-application field view is not conducted, or if the District is using a GP-11, the District should consult with the PFBC Waterways Conservation Officer Manager at the Bureau of Law Enforcement to determine if an ATON plan is necessary.

Failure to properly comply with ATON requirements could result in fines, project shut-downs or other legal action.

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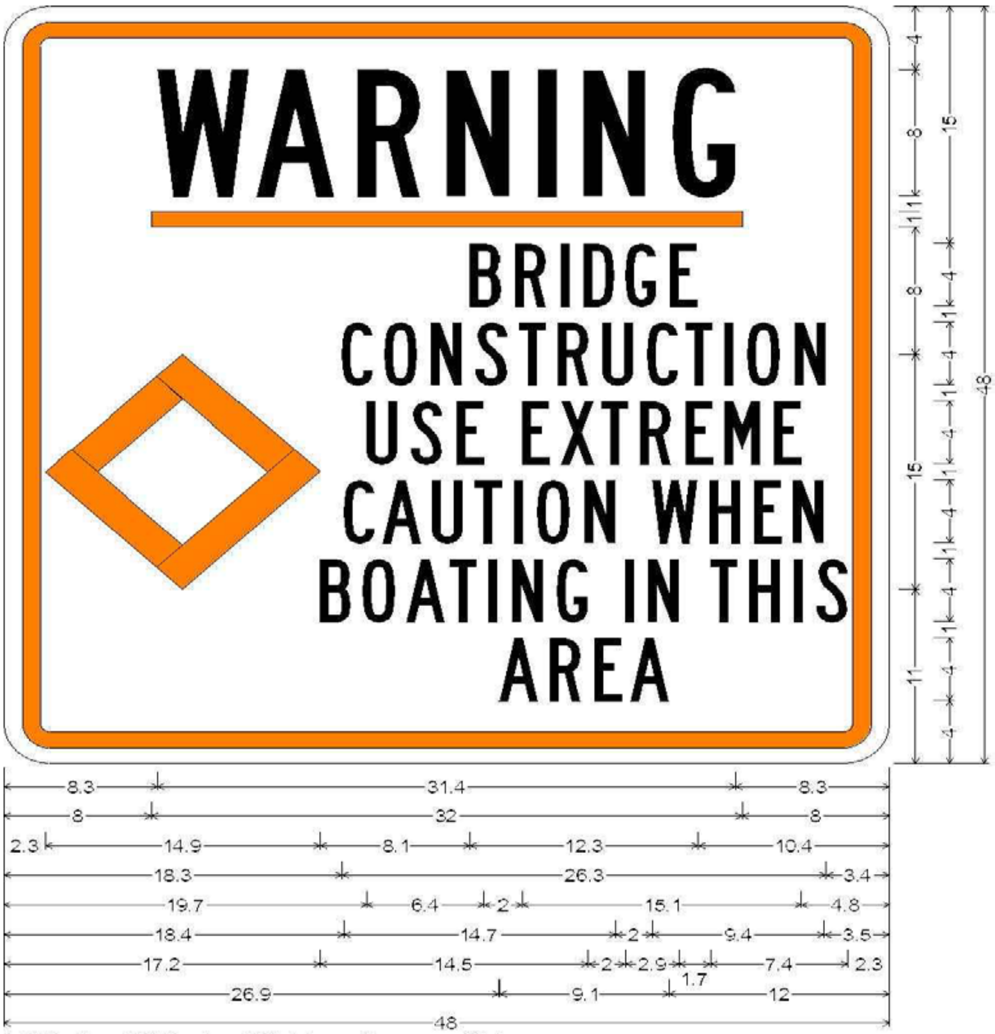
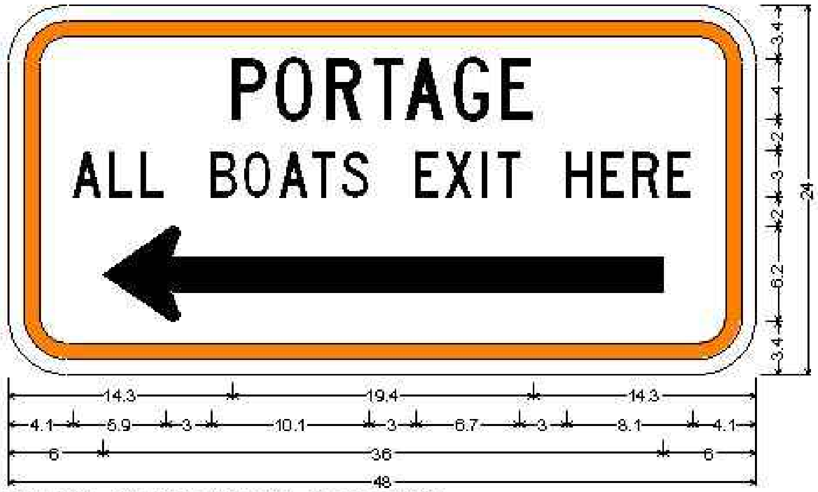
## FIGURE 10.5.1
## EXAMPLE OF ATON SIGN SPECIFICATION FOR PLACEMENT UPSTREAM AND DOWNSTREAM OF PROJECT AREA




2.5" Radius, 1.0" Border, 1.0" Indent, Orange on White;
"WARNING" Black B; Horizontal Line White; "BRIDGE" Black B; "CONSTRUCTION" Black B;
"USE EXTREME" Black B; "CAUTION WHEN" Black B; "BOATING IN THIS" Black B;
"AREA" Black B;
Table of widths and spaces.

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8.3 | W 5.0 | 0.4 | A 4.3 | 1.2 | R 3.4 | 1.5 | N 3.3 | 1.5 | I 1.0 | 1.5 | N 3.4 | 1.5 | G 3.4 | 8.3 | | | | | | | | | | |
| 8.0 | 32.0 | 8.0 | | | | | | | | | | | | | | | | | | | | | | |
| 2.3 | ◇ 14.9 | 8.1 | B 1.7 | 0.7 | R 1.7 | 0.8 | I 0.5 | 0.7 | D 1.7 | 0.6 | G 1.7 | 0.7 | E 1.5 | 10.4 | | | | | | | | | | |
| 18.3 | C 1.7 | 0.6 | O 1.8 | 0.8 | N 1.7 | 0.7 | S 1.7 | 0.6 | T 1.5 | 0.6 | R 1.7 | 0.7 | U 1.7 | 0.8 | C 1.7 | 0.4 | T 1.5 | 0.6 | I 0.5 | 0.7 | O 1.8 | 0.8 | N 1.7 | 3.4 |
| 19.7 | U 1.7 | 0.7 | S 1.7 | 0.8 | E 1.5 | 2.0 | E 1.5 | 0.6 | X 1.8 | 0.4 | T 1.5 | 0.6 | R 1.7 | 0.7 | E 1.5 | 0.6 | M 2.0 | 0.7 | E 1.5 | 4.8 | | | | |
| 18.4 | C 1.7 | 0.4 | A 2.2 | 0.6 | U 1.6 | 0.6 | T 1.5 | 0.6 | I 0.5 | 0.8 | O 1.8 | 0.8 | N 1.6 | 2.0 | W 2.5 | 0.6 | H 1.7 | 0.8 | E 1.5 | 0.6 | N 1.7 | 3.5 | | |
| 17.2 | B 1.6 | 0.6 | O 1.9 | 0.6 | A 2.1 | 0.2 | T 1.5 | 0.6 | I 0.5 | 0.7 | N 1.7 | 0.8 | G 1.7 | 2.0 | I 0.5 | 0.7 | N 1.7 | | | | | | | |
| | 1.7 | T 1.5 | 0.6 | H 1.7 | 0.7 | I 0.5 | 0.8 | S 1.6 | 2.3 | | | | | | | | | | | | | | | |
| 26.9 | A 2.1 | 0.6 | R 1.7 | 0.7 | E 1.5 | 0.4 | A 2.1 | 12.0 | | | | | | | | | | | | | | | | |

## FIGURE 10.5.2
## EXAMPLES OF ATON SIGN SPECIFICATION TO PROVIDE SAFE PORTAGE AROUND A PROJECT AREA



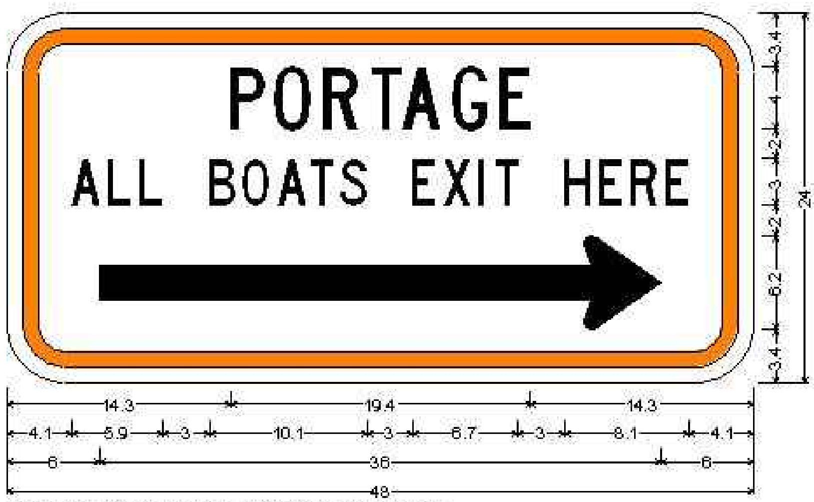

3.8" Radius, 1.0" Border, 1.0" Indent, Orange on White;
"PORTAGE" Black C; "ALL BOATS EXIT HERE" Black C;
Standard Arrow Custom 36.0" X 6.1" 180° Black;
Table of widths and spaces.

| | P | | O | | R | | T | | A | | G | | E | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14.3 | 2.2 | 0.7 | 2.3 | 0.9 | 2.1 | 0.7 | 2.0 | 0.3 | 2.5 | 0.6 | 2.2 | 0.9 | 2.0 | 14.3 |

| | A | | L | | L | | B | | O | | A | | T | | S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.1 | 1.9 | 0.5 | 1.5 | 0.5 | 1.5 | 3.0 | 1.7 | 0.5 | 1.7 | 0.5 | 1.9 | 0.2 | 1.5 | 0.5 | 1.6 |

| | E | | X | | I | | T | | H | | E | | R | | E | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.0 | 1.5 | 0.5 | 1.8 | 0.5 | 0.4 | 0.5 | 1.5 | 3.0 | 1.6 | 0.7 | 1.5 | 0.5 | 1.6 | 0.7 | 1.5 | 4.1 |

| | ← | |
|---|---|---|
| 6.0 | 36.0 | 6.0 |




3.8" Radius, 1.0" Border, 1.0" Indent, Orange on White;
"PORTAGE" Black C; "ALL BOATS EXIT HERE" Black C;
Standard Arrow Custom 36.0" X 6.1" 0° Black;
Table of widths and spaces.

| | P | | O | | R | | T | | A | | G | | E | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14.3 | 2.2 | 0.7 | 2.3 | 0.9 | 2.1 | 0.7 | 2.0 | 0.3 | 2.5 | 0.6 | 2.2 | 0.9 | 2.0 | 14.3 |

| | A | | L | | L | | B | | O | | A | | T | | S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.1 | 1.9 | 0.5 | 1.5 | 0.5 | 1.5 | 3.0 | 1.7 | 0.5 | 1.7 | 0.5 | 1.9 | 0.2 | 1.5 | 0.5 | 1.6 |

| | E | | X | | I | | T | | H | | E | | R | | E | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.0 | 1.5 | 0.5 | 1.8 | 0.5 | 0.4 | 0.5 | 1.5 | 3.0 | 1.6 | 0.7 | 1.5 | 0.5 | 1.6 | 0.7 | 1.5 | 4.1 |

| | → | |
|---|---|---|
| 6.0 | 36.0 | 6.0 |

**D. US Coast Guard Bridge Permit.** The application of a Coast Guard permit should be submitted at the time when the joint application is processed; however, this timing may vary to suit the need for individual situations. Although the Coast Guard permit may be issued only after the PA DEP permit is granted, the Coast Guard generally begins processing the permit application prior to receipt of the PA DEP permit.

The plans and location of bridges (including approaches, falsework and cofferdams) across Navigable Waters of the United States shall be approved by the US Coast Guard prior to the start of construction. The general procedure for obtaining permits from the US Coast Guard is described in Section 10.8.

As authorized by the applicable laws and regulations, a Coast Guard Bridge Permit may be waived by FHWA for those bridges which are constructed with Federal-aid funds and which cross non-tidal waters that are not used, not susceptible to use in their natural condition, or not susceptible to use by reasonable improvement as a means to transport interstate or foreign commerce. The Coast Guard may waive permitting requirements for those bridges which are constructed with non Federal-aid funds and which cross non-tidal waters as described above.

Since a Coast Guard Bridge Permit is rarely required for the Department's projects, it is recommended that the Engineering District contact the Coast Guard for a preliminary consultation of possible permit requirements on each specific bridge project involving Navigable Waters of the United States.

**E. USACE Permits.** Complete rules and regulations for various types of USACE Permits are described in 33 CFR Chapter II. The procedure for obtaining permits from the USACE is included in Section 10.9, which also includes an alternative procedure for implementing the time merger of the National Environmental Policy Act (NEPA) procedure with the USACE permit process.

**F. FHWA and Other Approvals.** FHWA review and approval of the H&H Reports shall be required for any Federally-funded waterway structure identified in item 6 of the waterway approval procedures above. On rare occasions, certain highway activities may require approvals from applicable river basin agencies such as the Susquehanna or Delaware River Basin Commissions, pursuant to interagency agreements between PA DEP and these agencies and pursuant to 18 CFR, Chapters III and VIII.

## 10.6 CRITERIA FOR APPLICABILITY OF HYDROLOGIC AND HYDRAULIC METHODOLOGIES

**A. Introduction.** Hydrologic and hydraulic (H&H) requirements are two of the engineering issues that must be considered during the early phases of highway design projects. In order to provide timely completion of highway improvement projects, the PennDOT design community must maintain an adequate level of design proficiency in a variety of H&H methodologies. To ensure that this goal is accomplished, PennDOT has defined a standard "toolbox" of H&H methodologies. The methodologies included in this H&H Toolbox were chosen to ensure that they are the best technical and practicable methodologies available for 80% to 90% of the waterway structures associated with highway design in Pennsylvania.

**B. Purpose and Scope**. The purpose of this section is to present a list of hydrologic and hydraulic methodologies acceptable to PennDOT for analysis of common highway drainage structures. This policy does not include guidance on topics such as the analysis of pavement drainage and complex storm sewer networks.

This document should enable a designer to make an initial selection of appropriate hydrologic and hydraulic methods or models. For more complete information on the details regarding the assumptions and limitations of specific methods or models, the original documentation associated with each of the methods or models and the comprehensive technical information provided in the FHWA's documentation on hydrology and hydraulics (see Chapter 10, Appendix E) should be used except where Department policy conflicts. Section 10.6.D of this document provides information regarding the selection of H&H methodologies for problems outside the scope of the standard H&H Toolbox.

**C. Models, Methodologies and Site Histories.** The following sections list the hydrologic and hydraulic methodologies in the H&H Toolbox. These methodologies, when properly selected and applied in engineering analyses, will be acceptable to PennDOT, and are preferable over equivalent alternative methodologies. It is not PennDOT's intention to replace the use of sound engineering judgment when an unlisted methodology is determined to be superior; however, use of unlisted methodologies should be coordinated carefully with PennDOT at the earliest possible opportunity during the project development process.

The level of accuracy required for a specific hydrologic or hydraulic analysis is a matter of engineering judgment that generally depends on the specific characteristics of each individual project. Factors that tend to control the final accuracy of hydrologic and hydraulic engineering studies include the selection of analytical methods or models and the level of effort invested in data collection and application of the method or model. Such factors generally are negotiated and decided during the early phases of the project.

With respect to selection of methods or models, this document offers general guidelines regarding selection criteria; however, final decisions regarding the suitability of a particular method for a particular project must be determined by engineering judgment on a case-by-case basis.

**1.** Site Flood History. An analysis of the flood history of an existing structure according to the guidelines contained in Sections 10.7.A and 10.7.B is an essential component of the hydrologic engineering process. Discrepancies between any numerical methodology such as HEC-1, TR-55, the rational formula, or a regression method, and the site history should be considered very carefully and explained very thoroughly.

Site information such as the performance of an existing structure or the local history of flooding provide important data for corroborating the results of the numerical models used in the hydrologic study, especially if one or more peak water-surface elevations can be determined. When the return periods for these high-water events can be estimated, these events can be used to perform a partial calibration of the hydrologic model.

When the known events are smaller than the design event, considerable care is required because the estimate of the design peak flow is an extrapolation from the observed historical data. If the watershed is, or has undergone, development, construction of flood control structures, reforestation, or other changes, since the observed historical events, or if future changes are anticipated, care must be taken to ensure that these factors are appropriately accounted for in the hydrologic study.

**2.** FEMA Studies. If a project site or its impacts lie within a Federal Emergency Management Agency (FEMA) study area, review the flood discharges reported in the FEMA study and incorporate into the hydrologic analysis. Verify FEMA's flood discharges by an appropriate hydrologic methodology when hydrologic conditions in the basin differ from the conditions described in the FEMA study. It should be remembered that the underlying purpose of a FEMA study is very different from a study to design an opening for a waterway structure; therefore, different levels of detail, and different methodologies may be appropriate for these two types of studies.

The hydrologic and hydraulic models used in the FEMA studies must be evaluated according to current design guidance and current modeling practices for sizing highway waterway structures. For example, the peak flows in a number of Pennsylvania FEMA studies were based on PSU-III. Use of these peak flows would not be acceptable to the Department because the data used to develop these methods is outdated. In these cases, the results of the FEMA study shall be included in the engineering analysis for comparative purposes.

If a stream gage analysis was used to develop the FEMA published flows, conduct a review of the gage analysis. Include the following in this analysis:

- Determination of period of record used in the FEMA gage analysis.
- Assessment of the gage data to determine if there is additional data since the FEMA study.
- Assessment of watershed to determine if there has been significant watershed changes that may impact the gage data (i.e., flood control, development, etc.).

If the review provides that there is more than 10 years of additional gage data available or there have been significant changes in the watershed, then conduct a new gage analysis in accordance with Section 10.6.C.4.a.

In all cases, the designs of waterway structures should be based on the most appropriate hydrologic method and associated flows. This may result in the use of flows that differ from FEMA flows. Carefully analyze and document discrepancies between the results of the FEMA study and the models selected for the project design.

**3.** 1978 Act 167 Storm Water Management Studies. If the subject drainage basin is part of a Storm Water Management Plan pursuant to 1978 Act 167, review the flood discharges reported in the plan and incorporate into the hydrologic analysis. Verify the flood discharges reported in a stormwater management plan by an independent source or methodology if actual conditions in the basin as well as map data may have changed so that the two studies are based on different hydrologic information. Explain thoroughly the use of flood discharges for design of a waterway structure that differ significantly from the Act 167 discharges.

**4.** Hydrologic Methods and Models. Hydrologic methods are used to determine the various flow rates for waterway structures: design flood, overtopping flood, flow during the 100-year storm ($Q_{100}$) and 500-year storm ($Q_{500}$), flood-of-record, probable maximum flood, etc. The hydrologic methods and models included in the PennDOT standard H&H toolbox are listed below. Brief statements on the use of the methods are included, as well as information on when the methods should not be used. If a design project does not meet the criteria for using a specific listed method and the method is selected anyway, then justification must be provided for making that selection.

For methods such as the rational formula, EFH-2, TR-55, WinTR-55, and HEC-1 that require rainfall depths, the values should be obtained from the intensity-duration-frequency curves (refer to Publication 584, *PennDOT Drainage Manual*, Chapter 7, Appendix A or to Section 10.2.C). Generally, it may be assumed that rainfall of a given return period produces a flood of the same return period. See Section 10.6.E for specific guidance on selecting magnitudes of design storms.

Guidance on the use and limitations of many of the listed methods and models is found in various sections of Publication 584, *PennDOT Drainage Manual*, "Highway Hydrology, Hydraulic Design Series No. 2" (see Chapter 10, Appendix E, Reference 14), the "Model Drainage Manual" (see Chapter 10, Appendix E, Reference 2) and the "Highway Drainage Guidelines" (see Chapter 10, Appendix E, Reference 3).

**a.** Analysis of Stream Gage Records. If a design flow rate is being computed for a location on the same "main stem" of a stream within 0.5 to 1.5 times the gaged basin area, stream gage records shall be used to compute design or flood discharges. The hydrologic analysis for the gage should follow the recommendations of "Guidelines for Determining Flood Flow Frequency, Bulletin 17B" (see Chapter 10, Appendix E, Reference 29). The statistical analysis described in Bulletin 17B often is referred to simply as the "WRC" method. Generally, a WRC analysis of a gage record takes precedence over all other hydrologic methods. When a gage record is of short duration, or poor quality, or the results are judged to be inconsistent with field observations or sound engineering judgment, then the analysis of the gage record should be supplemented with other methods.

The validity of a gage record should be demonstrated. Gage records should contain at least 10 years of consecutive peak flow data and they should span at least one wet year and one dry year. If the runoff characteristics of a watershed are changing, from urbanization for example, then a portion of the record will not be valid. If an invalid portion of a record is used, the results will be biased.

The USGS's computer program PEAKFQ performs a standard WRC analysis. The PEAKFQ program and instructions for its use are available from the USGS. The peak flow values computed from a gage record can be transposed from one location to another with the following equation:

$$\frac{Q}{Q_g} = \left(\frac{A}{A_g}\right)^b$$

where:

$Q$ = Peak discharge at project site

$A$ = Basin area above project site

$Q_g$ = WRC peak discharge at gage

$A_g$ = Area of gaged basin

$b$ = Drainage area characteristic coefficient from Table 3 in the SIR 2008-5102 report, *Regression Equations for Estimating Flood Flows at Selected Recurrence Intervals for Ungaged Streams in Pennsylvania,* for the basin's Flood Flow Region and recurrence interval (see Publication 584, *PennDOT Drainage Manual*, Section 7.12) (see Chapter 10, Appendix E, Reference 28).

**b.** Rational Method. The rational method (rational formula) is the recommended hydrologic method for drainage areas up to 80 ha (200 acres) in size. Use of the rational formula on larger drainage areas above this limit requires the use of sound engineering judgment to ensure that reasonable results are obtained. The rational method may be used with caution up to 100 ha (250 acres) with specific approval by qualified District personnel (typically the District H&H Coordinator).

The hydrologic assumptions underlying the rational formula include constant and uniform rainfall over the entire basin with a duration equal to the time of concentration ($T_c$). If a basin has more than one main drainage channel, if the basin is divided so that hydrologic properties are significantly different in one section versus another, if $T_c > 60$ min, or if storage is an important factor, then the rational method is not appropriate.

For typical roadway drainage problems where all of the conditions discussed in the preceding paragraph are met, the rational method should be applied.

When replacing pipes less than 750 mm (30 in) in diameter, the time of concentration ($T_c$) may be reduced to 5 min to compute the design discharge.

**c.** Regression Methods. Regional regression equations provide estimates of peak flows at ungaged sites. They are comparatively easy-to-use and they provide relatively reliable and consistent findings when applied by different hydraulic engineers. The three methods listed below (USGS SIR 08-5102, USGS WRIR 00-4189 and PSU-IV) are statistical methods that quantify general regional relationships between peak flow, or other runoff variables, and a watershed's physiographic, hydrologic and meteorological characteristics. PSU-IV is recommended only as a comparison method unless detailed site history justifies the flows developed using PSU-IV. USGS WRIR 00-4189 has been replaced by the USGS SIR 08-5102 method, but in a few specific scenarios, the USGS WRIR 00-4189 method may be considered as an acceptable method as further discussed in Section 10.6.C.4.c.(4).

The regression processes used to derive the equations in USGS SIR 08-5102, USGS WRIR 00-4189 and PSU-IV tend to smooth the effects of the independent variables on computed peak flow estimates. For basins with atypical hydrologic characteristics, this smoothing effect can be a problem. Atypical characteristics may include steep slopes in the watershed, watersheds with higher length to width ratios, etc. To ensure quality in these hydrologic estimates, it may be prudent to consider comparing the results of USGS SIR 08-5102, USGS WRIR 00-4189 or PSU-IV with the site's history of flooding as per Section 10.6.C.1 and/or the results of physically based hydrologic models such as HEC-1. By analyzing and explaining any differences in results from the various methods included in the study, the confidence in the final peak flow estimates can be improved.

**(1)** USGS SIR 08-5102. "Regression Equations for Estimating Flood Flows at Selected Recurrence Intervals for Ungaged Streams in Pennsylvania," Scientific Investigations Report (SIR) 08-5102 (see Publication 584, *PennDOT Drainage Manual*, Section 7.12) (see Chapter 10, Appendix E, Reference 28) is a regression analysis of streamflow data for Pennsylvania drainage basins ranging in size from approximately 259 ha (1.0 $mi^2$) up to approximately 5200 $km^2$ (2000 $mi^2$). USGS SIR 08-5102 was first incorporated into the USGS's National Stream Statistics (NSS) program Version 4.0.b (see Chapter 10, Appendix E, Reference 32 for a summary of StreamStats). The program includes regression equations for estimating a typical flood hydrograph for a given recurrence interval as well as other stream low flow statistics. Although the NSS computer program has been incorporated into the Environmental Modeling Research Laboratory's (EMRL) Watershed Modeling System (WMS), WMS 8.1, 8.2 and 8.3 contain NSS version 4.0, which uses the USGS WRIR 00-4189 regression equations. If using WMS version 8.3 or older, the hydrologic data must be exported from WMS to use in either a standalone NSS program Version 4.0.b or newer or use the equations from the USGS SIR 08-5102 publication.

**(2)** USGS WRIR 00-4189. "Techniques for Estimating Magnitude and Frequency of Peak Flows for Pennsylvania Streams", Water-Resources Investigations Report 00-4189 (see Chapter 10, Appendix E, Reference 27) is a regression analysis of streamflow data for Pennsylvania drainage basins ranging in size from approximately 390 ha (1.5 $mi^2$) up to approximately 5200 $km^2$ (2000 $mi^2$). USGS WRIR 00-4189 has been incorporated into the USGS's National Flood Frequency (NFF) program (see Chapter 10, Appendix E, Reference 18). The NFF program includes a National Urban Equation which adjusts the results of rural regression equations to account for urbanization. The program also includes regression equations for estimating a typical flood hydrograph for a given recurrence interval. The NFF computer program is incorporated into the Environmental Modeling Research Laboratory's (EMRL) Watershed Modeling System (WMS), versions 8.0 and earlier. Additionally, the NSS program through version 4.0 included the USGS WRIR 00-4189 equations; therefore, these equations are also in WMS versions 8.1, 8.2 and 8.3 under the NSS module as noted above. The NFF module has been replaced by the NSS module in WMS versions 8.2 and 8.3.

**(3)** PSU-IV. PSU-IV is a Pennsylvania regional regression method that is based on the Log Pearson III equation. PSU-IV was published in 1981 and includes regression equations that were developed with stream gage data through 1977. The PSU-IV regression equations were developed for basins from 390 ha (1.5 $mi^2$) to 390 $km^2$ (150 $mi^2$). Since USGS WRIR 00-4189 is based on data through 1997 and USGS SIR 08-5102 is based on data through 2006, PSU-IV is considered only as a comparison method. PSU-IV can be used to compare estimates from other methods but should not be used as the final hydrologic method for flow selection unless there is site flooding history that justifies its use.

The use of PSU-IV analyses as a comparison method in urban areas should be based on sound engineering judgment.

FEMA no longer accepts PSU-IV as a regression method for NFIP studies (design of flood control structures and/or the regulation of floodplain lands).

**(4)** Summary of Regression Performance. The two most recent USGS methods (USGS WRIR 00-4189 and USGS SIR 08-5102) were evaluated by PennDOT. In general the USGS SIR 08-5102 method will be the most applicable regression method, but there are some areas of the state that one of the older regression methods may be considered. When compared to observed values (i.e., stream gage analyses), severe under- and over-predictions occur using both USGS methods, and there is no real physiographic or basin characteristic pattern to the results. The USGS regression flows for watersheds with smaller drainage areas (< 13 $km^2$ (< 5 $mi^2$)) also have inconsistent results. The watersheds where USGS SIR 08-5102 highly over- or under-predicted the gage value are listed in Publication 584, *PennDOT Drainage Manual*, Chapter 7, Table 7.4. Maps showing the locations of these watersheds are located in Publication 584, *PennDOT Drainage Manual*, Chapter 7, Figures 7.2 and 7.3. The observed values were calculated using a Log Pearson III analysis with a weighted skew coefficient, while the weighted values were calculated to minimize period of record bias by computing a predicted flood frequency discharge weighted average of the observed, as well as the

USGS SIR 08-5102 computed, using the period of record of the station and the equivalent period of record for the regression equation (see Publication 584, *PennDOT Drainage Manual*, Section 7.12) (see Chapter 10, Appendix E, Reference 28).

The following procedure is recommended to determine the most appropriate design flows if regression methods are applicable.

**(5)** Recommended Methodology for use of Regression Equations. The USGS SIR 08-5102 regression equations generally perform adequately in predicting flows; however, there are instances where flows may be unrepresentatively high or low in comparison to what one would expect from a stream gage analysis. Therefore, the following set of guidelines should be followed when watershed characteristics are within the limitations of the USGS SIR 08-5102 regression equations.

**(a)** Determine the watershed in which the site is located.

**(b)** Determine if the site may be substantially affected by upstream regulation, using USGS SIR 08-5102, Appendix 3 as a guide.

**(c)** Determine if the site is in a watershed where USGS SIR 08-5102 may significantly over or under-predict the design event calculated from gage data by referring to Publication 584, *PennDOT Drainage Manual*, Chapter 7, Table 7.4 and Publication 584, *PennDOT Drainage Manual*, Chapter 7, Figures 7.2 and 7.3.

**(d)** Perform calculations using the USGS SIR 08-5102 method to estimate flows. Evaluate the predicted flows in the hydraulic model and compare to local flood history and engineering judgment.

**(e)** When the project site is located in one of the two precaution areas mentioned below and the results from USGS SIR 08-5102 are not consistent with the local flood history, it may be necessary to consider other hydrologic methods including the USGS WRIR 00-4189 method or regional gage comparison. Note for the gages/watersheds listed in Publication 584, *PennDOT Drainage Manual*, Chapter 7, Table 7.4 and Publication 584, *PennDOT Drainage Manual*, Chapter 7, Figures 7.2 and 7.3, consideration should also be given to the number of years of record and quality of data at the gaging station for which the regression flows are being compared.

**(6)** Precautions. Precautions for use of the USGS SIR 08-5102 method as a result of PennDOT's evaluation include:

**(a)** USGS SIR 08-5102 results in the watersheds identified in Publication 584, *PennDOT Drainage Manual*, Chapter 7, Table 7.4 and Publication 584, *PennDOT Drainage Manual*, Chapter 7, Figures 7.2 and 7.3 were particularly different from the gage data and should be closely evaluated for applicability. Some of these watersheds have shown to severely under-predict flows as compared to gage data within the watershed.

**(b)** Sites with drainage areas less than < 13 $km^2$ (< 5 $mi^2$) for both the USGS WRIR 00-4189 and USGS SIR 08-5102 methods.

**d.** HEC-1. HEC-1 is a generalized hydrologic simulation model that can be used with basins of almost any size and complexity. Use of the EMS-I's Watershed Modeling System (WMS) as an interface to HEC-1 is recommended since it systematizes the computation of the physiographic and hydrologic parameters required by HEC-1. When WMS is used for its graphical user interface to HEC-1, a practical upper limit in the vicinity of 300 $km^2$ to 400 $km^2$ (100 $mi^2$ to 150 $mi^2$) is recommended. HEC-1 assumes that the rainfall is spatially uniform over each sub-basin modeled.

Precipitation input in the form of a 24-hour rainfall time distribution should be applied with this method. Rainfall distribution based on the PDT-IDF data is preferred; however, the SCS Type II and Type III (Philadelphia region only) rainfall distributions may also be used. It should be noted that modeling Type

II events will generally yield higher peak flows compared to the PDT-IDF data. The SCS loss method, SCS dimensionless unit hydrograph, and the SCS lag equation are most commonly used; however, careful consideration must be given to the assumptions and limitations underlying these methods.

The SCS has published a suggested upper limit on basin size for the SCS lag equation of 800 ha (2000 acres, 3.1 $mi^2$) (NEH-4, Chapter 15). The upper limit on basin area for the SCS Loss Method (i.e., Runoff Curve Number) is not well established; however, a limit of 52 $km^2$ (20 $mi^2$) has been suggested. These limitations may be overcome by subdivision of the watershed and appropriate routing. These are suggested limits and larger subbasins may be appropriate depending on the uniformity of the characteristics (e.g., land use type, basin slope) within each watershed subbasin.

WMS uses USGS Digital Elevation Models (DEMs) to compute basin geometric parameters. Relatively large data sets are required for, and produced by, WMS for basins spanning more than eight or ten DEMs. The use of HEC-1 by itself may be prudent in these cases.

When using WMS in urban areas, care must be taken to ensure that stormwater management facilities are incorporated correctly into the model. This will require additional careful modeling and routing.

**e.** HEC-HMS. The Hydrologic Modeling System (HEC-HMS) is designed to simulate the precipitation-runoff process of a watershed. It is applicable for basins of almost any size and complexity in a wide range of geographic areas, including large river basin water supply and flood hydrology, and small urban or natural watershed runoff. It is designed to replace HEC-1, and has similar options to HEC-1, but incorporates some advances in hydrologic engineering for precipitation input and soil moisture methods.

HEC-HMS is not fully integrated within the WMS software interface and must be run in the HMS software program. WMS 7.1 and later versions provide tools for setting up, computing data for, and entering data for HMS models. These models can then be saved to HMS format and the model can be run in HMS. The results from these models can then be read into and viewed in WMS.

**f.** TR-55. "Urban Hydrology for Small Watersheds", Technical Release 55 (TR-55), Soil Conservation Service (SCS), June 1986, provides a graphical method for computing peak discharges of drainage basins with areas ranging from 4.0 ha (10 acres) up to 800 ha (2000 acres, 3.1 $mi^2$).

TR-55 is a segmental method (i.e., flow time is computed by adding the times for the overland, shallow concentrated, and channel segments). TR-55 considers hydrologic parameters such as slope, roughness, losses, rainfall, soil type, land use, and time. Although TR-55 has fewer assumptions than the rational formula, it also assumes that rainfall is uniform over the entire basin. Some hydrologists have stated that TR-55 tends to produce conservatively high estimates of peak flows. TR-55 should be used with caution when structure sizing is highly sensitive to the computed peak flow values.

This method must meet the following conditions:

**(1)** Basin drained by a single main channel or by multiple channels with times of concentration ($T_c$) within 10% of each other.

**(2)** $T_c$ between 0.1 and 10 hours.

**(3)** Storage in the drainage area is ≤ 5% and does not affect the time of concentration.

**(4)** Watershed can be accurately represented by a single composite curve number.

The "Graphical Method" module in the SCS's TR-55 computer program and the TR-55 module in WMS are equivalent to the manual graphical method described in the TR-55 report. TR-55 includes a procedure for computing a "rough" synthetic hydrograph, which can be used to size small ponds.

Refer to the TR-55 report for a complete discussion of limitations and assumptions of this methodology.

**g.** WinTR-55. WinTR-55 was released by the Natural Resources Conservation Service in January, 2005. WinTR-55 is simply a Windows-based version of the original DOS-based TR-55. TR-55 was developed to simplify TR-20, which at the time was considered computationally demanding. Assumptions were made and tables and hydrographs were interpolated to approximate results from TR-20, resulting in the TR-55 methodology. With present day technology, the TR-20 is no longer a drain on computational resources. WinTR-55 uses TR-20 as the computational engine to develop hydrographs and determine peak flows. Win TR-55 differs from WinTR-20 (Windows-based version of TR-20) in that WinTR-55 assumes a less complex watershed and simplifies the input process.

This method must meet the following conditions:

**(1)** Drainage area between 1 acre and 25 square miles.

**(2)** $T_c$ for any subbasin between 0.1 and 10 hours.

**(3)** Muskingum-Cunge reach routing method applies for subdivided watersheds.

The SCS has published a suggested upper limit on basin size for the SCS lag equation of 800 ha (2000 acres, 3.1 $mi^2$) (NEH-4, Chapter 15). The upper limit on basin area for the SCS Loss Method (i.e., Runoff Curve Number) is not well established; however, a limit of 52 $km^2$ (20 $mi^2$) has been suggested. These limitations may be overcome by subdivision of the watershed and appropriate routing. These are suggested limits and larger subbasins may be appropriate depending on the uniformity of the characteristics (e.g., land use type, basin slope) within each watershed subbasin. Refer to the WinTR-55 User's Manual for a complete discussion of limitations and assumptions of this methodology.

Precipitation input in the form of a 24-hour rainfall time distribution should be applied with this method. Rainfall distribution based on the PDT-IDF data is preferred; however, the SCS Type II and Type III (Philadelphia region only) rainfall distributions may also be used. It should be noted that modeling Type II events will generally yield higher peak flows compared to the PDT-IDF data. The SCS loss method, SCS dimensionless unit hydrograph, and the SCS lag equation are most commonly used; however, careful consideration must be given to the assumptions and limitations underlying these methods.

**h.** EFH2. EFH2 determines peak discharge by procedures contained in SCS's *Engineering Field Handbook*, Chapter 2 (see Chapter 10, Appendix E, Reference 21). This method is applicable to a rural watershed between 0.4 ha (1 acre) and 810 ha (2000 acres), and must meet the following conditions:

**(1)** Hydraulic length is between 60 m (200 ft) and 7900 m (26,000 ft).

**(2)** Average slope is between 0.5 and 64 percent.

**(3)** Valley or reservoir routing is not required.

**(4)** Watershed can be represented accurately by a single composite curve number between 40 and 98.

**(5)** Urban land uses comprise no more than 10% of the basin.

Refer to the Engineering Field Handbook, Chapter 2 for a complete discussion of the methodology and its limitations.

Rainfall is based upon precipitation frequency estimates from the intensity-duration-frequency curves (refer to Publication 584, *PennDOT Drainage Manual*), as discussed in the section above for TR-55.

**5.** Hydraulic Models. Hydraulic models are used to evaluate the effect of proposed highway structures on water surface profiles, flow and velocity distributions, lateral and vertical stability of channels, stream regimes, flood risk, and the potential reaction of the streams to changes in variables such as structure type, shape, location, and scour control measures. Listed below are the hydraulic models included among the PennDOT standard H&H design models. Associated with each model is a brief statement that describes when the model should or should not be used. If a design project does not meet the criteria for selecting a particular model, then justification must be provided if that model is used.

For hydraulic analyses that are likely to involve revisions to FEMA's Flood Insurance Rate Maps, selection of the hydraulic model should be coordinated carefully with FEMA. Additional information on FEMA's policy regarding most hydraulic models can be found in a memorandum authored by FEMA's Michael K. Buckley, P.E. dated April 30, 2001 and entitled, *Policy for Use of HEC-RAS in the NFIP* (see Chapter 10, Appendix F).

**a.** HEC-RAS. HEC-RAS is the recommended model for performing hydraulic analysis of steady, gradually varied (over distance), one-dimensional, open channel flow. HEC-RAS includes a culvert module that is consistent with HDS-5 and HY-8. The bridge hydraulics algorithms now include the WSPRO models. HEC-RAS applies conservation of momentum, as well as energy and mass, in its hydraulic analysis. HEC-RAS includes all the features inherent to HEC-2 and WSPRO plus several friction slope methods, mixed flow regime support, automatic "n" value calibration, ice cover, quasi 2-D velocity distribution, superelevation around bends, bank erosion, riprap design, stable channel design, sediment transport calculations, and scour at bridges. HEC-RAS and HEC-2 do not produce identical results. For detailed information on a comparison of HEC-RAS to HEC-2, refer to Appendix C of the "HEC-RAS River Analysis System, Hydraulic Reference Manual" (see Chapter 10, Appendix E, Reference 17).

The bridge scour routines in the hydraulic design module of HEC-RAS should not be used for bridge scour computations or to compute scour depths. Use caution when using HEC-RAS output parameters other than velocities in scour computations. For additional design guidance about scour, refer to Publication 15M, Design Manual, Part 4, *Structures,* Volume 1, Part A, Chapter 7.

**b.** HY-8. HY-8 is an interactive computer program for highway culvert analysis and includes routines for analysis and design of culverts with improved inlets and stand-alone energy dissipators. HY-8 can perform computations associated with tailwater elevations, road overtopping, hydrographs, simple flood routing, and multiple independent barrels. HY-8's most convenient features are its well-designed reports and plots, especially the culvert performance curves and the tailwater rating curves.

HY-8 is the preferred hydraulic model for analyzing isolated culverts; however, if ponding is not significant, or if upstream velocity head needs to be considered (i.e., if stream velocity is greater than 1.5 m/s (5 ft/s)), then HEC-RAS should be used.

**c.** HDS-5 and/or HDHC CD-ROM. "Hydraulic Design of Highway Culverts, Hydraulic Design Series No. 5" (see Chapter 10, Appendix E, Reference 24) contains an extensive series of well-designed, easy-to-use, nomographs for design of highway culverts. The HDHC CD-ROM is an electronic version of the HDS-5 manual.

For ordinary culvert hydraulics, HDS-5 and HY-8 provide equivalent solutions.

**d.** HEC-2. HEC-2 Version 4.6.2 is an approved water surface profile program; however, use of the more graphical HEC-RAS program is recommended. One of HEC-2's technical limitations is the normal bridge routines and standard-step backwater computations use energy conservation only. Conservation of momentum is used <u>only</u> in the special bridge routines when there are bridge piers (see Section 1.4 of HEC-2 Users' Manual).

**e.** WSPRO. The WSPRO computer program was developed by the USGS and is comparable to HEC-2, except for the fact that WSPRO had special subroutines for analysis of water surface profiles at bridge locations. All of these WSPRO subroutines have been incorporated into HEC-RAS.

WSPRO should not be used except for highway projects that cause revisions to FEMA Flood Insurance Rate Maps (FIRMs) based on WSPRO. Coordination with FEMA may allow the use of HEC-RAS in place of WSPRO.

In cases where a map revision is necessary, HEC-RAS should be considered for the engineering analyses during the project design phases and WSPRO should be used only for producing the application for a letter of map revision.

**D. Other Models.** Many hydrologic and hydraulic models exist other than those that are listed in Section 10.6.C. Although some models perform one type of computation better than other available models, it is necessary for PennDOT to concentrate its efforts on the programs in PennDOT's H&H toolbox in order to develop and maintain agency-wide expertise. If a model not included in the forgoing list is used for a specific problem, then the project engineer should ensure that model is appropriate and that approvals are obtained from the Department.

Examples of acceptable two-dimensional hydraulic modeling programs are the FESWMS (Finite Element Surface-Water Modeling System) and TUFLOW; both programs interface with Aquaveo's SMS (Surface-water Modeling System) software. The FESWMS program receives funding from FHWA and was developed by Dr. Dave Froehlich, P.E. FESWMS is a 2-D finite element model. The TUFLOW model was developed by BMT WBM Pty Ltd in Australia. TUFLOW offers a one-dimensional (1-D) and two-dimensional flood and tide simulation software. TUFLOW is a finite difference model that can handle a wide range of hydraulic situations, including mixed flow regimes, weir flow, bridge decks, box culverts, and robust wetting and drying. 2-D models are useful in situations of flows with significant horizontal velocity components other than in the downstream direction (i.e. 2-D flow patterns) as well as situations with time-variant flow patterns such as those in tidal environments. Examples below include common situations encountered by PennDOT where a two-dimensional model may be needed; however, this list is not all inclusive (for further information, refer to Chapter 10, Appendix E, Reference 33):

- When the stream slope is very flat and bridge piers cause localized effects on water surface elevations (WSE). 1-D models will average these localized increases in WSE across the entire cross section and apply the calculated WSE increase across the entire floodplain width, which is not realistic. The 1-D model may also overestimate the magnitude and upstream extent of the pier-induced WSE increase.

- When the hydraulics at the project site are affected by a confluence that changes location for different flood events and causes 2-D characteristics in the floodplain.

- When flow is split between multiple structures cross a wide floodplain.

- When a structure is on a severe channel bend (making the velocity vary between the inside and outside of the bend) and scour is a major concern.

- When a project is anticipated to cause WSE increases in a highly-developed area and flooding impacts need to be more accurately defined.

Models for the analysis of pavement drainage, analysis of storm sewer networks, and analysis of runoff water quality are not listed since they are not included in the H&H toolbox. If a highway design project requires one of these models, the engineer should ensure that appropriate coordination occurs within PennDOT and any outside agencies with review responsibilities or regulatory authority.

**E. Design Storms.** Inundation of the travelway dictates the level of traffic service provided by a highway facility. The travelway overtopping flood level identifies the upper limit of serviceability, and it provides one of the important definitions of the term "design flood". The minimum magnitude of design floods for all drainage structure design projects shall be selected from Table 10.6.1.

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**TABLE 10.6.1**
**DESIGN FLOOD SELECTION GUIDELINES**

| FUNCTIONAL CLASSIFICATION | MAXIMUM EXCEEDANCE PROBABILITY (%) | MINIMUM RETURN PERIOD (YEARS) |
|---|---|---|
| Interstate and Limited Access Highways | 2 | 50 |
| Principal Arterial System | 2 | 50 |
| Minor Arterial System | 4 | 25 |
| Rural Collector System, Major | 4 | 25 |
| Other Collector Systems | 10 | 10 |
| Local Road and Street Systems | 10 | 10 |

Note: Federal Policy states that the design flood for encroachments by through lanes of Interstate highways shall not be less than the flood with a 2 percent chance of being exceeded in any given year. Interstate highways should be designed to accommodate the 2% (50-year) flood event.

**1.** Use of a return period smaller than listed in Table 10.6.1 must be justified in the hydraulic analysis for the project and kept with the project's files. Such justification must be based on the following kinds of factors:

**a.** Comparison to adjacent roadway sections,

**b.** Considerations involving existing site conditions,

**c.** Considerations involving right-of-way limitations and constraints imposed by adjacent land use or development, and

**d.** Limitations based on the project's scope.

**2.** For the purposes of this document, the design flood is assumed to result from the storm with the same return period; therefore, the terms "design flood" and "design storm" have the same meaning herein.

**3.** For most highway design projects, it often is important to extend the hydrologic and hydraulic analysis to include consideration of floods of magnitudes other than the design floods listed in the above table. These additional floods are referred to collectively as "check floods" and they may include the following kinds of floods:

**a.** The regulatory environmental design flood as specified in 25 PA Code §105.161(c), §105.191, §105.201 and elsewhere.

**b.** Storms and floods which may be required according to Stormwater Management Plans adopted according to 1978 Act 167 (the Stormwater Management Act).

**c.** The 100-year flood for evaluation of impacts on FEMA's floodplain mapping.

**d.** The overtopping flood, or greatest flood which must be passed, as discussed in 23 CFR 650, § 650.115 and § 650.117; and the overtopping flood discussed in Publication 15M, Design Manual, Part 4, *Structures*, PP Chapter 7.

**e.** The specific superflood discussed in Publication 15M, Design Manual, Part 4, *Structures*, PP Section 7.2.3 for evaluation of the potential effects of scour and evaluation of foundation stability.

**f.** The Probable Maximum Precipitation, Probable Maximum Storm or the Probable Maximum Flood for projects involving a high risk factor resulting from such considerations as the volume of impounded water.

**F. Adjustments to Peak Flow Estimates.** Adjustments to peak flow estimates may be prudent when a waterway encroachment is associated with a potential for loss of property, increased hazards to life or safety, or public inconveniences. These adjustments can be applied by increasing the return interval (probability) of the design storm and then computing the corresponding design peak discharge, or by applying a multiplier to increase the estimated design discharge to a value outside a given confidence interval as discussed in Chapter 9 of the PSU-IV Manual (see Chapter 10, Appendix E, Reference 4).

A parametric sensitivity analysis also can be used to help evaluate the quality of a peak flow estimate. For example: precipitation amount, curve number, and time-of-concentration can be varied by small amounts and the peak flow can be recomputed. From these recomputed estimates of peak flow, the sensitivity of peak flow to potential future changes in the values of the parameters, or to errors in the estimates of the parameters, can be evaluated.

## 10.7 GUIDELINES FOR PREPARATION OF HYDROLOGIC AND HYDRAULIC REPORT

**A. Overview.** There are two options for preparing a Hydrologic and Hydraulic (H&H) Report. The applicability of the report option is based on the complexity of the project, the nature of the stream and floodplain, the cost of the structure and other pertinent factors. The two options and their applicability are outlined below:

- **Abbreviated H&H Report as outlined in Section 10.7.B** may be used for structure rehabilitation and replacement projects that have:
  - no significant reduction in the existing waterway opening
  - no significant changes to grades of approach roadways
  - no significant changes to overtopping characteristics
  - no significant change of alignment
  - total widening of the structure is 7.2 m (24 ft) or less

- **Full H&H Report as outlined in Section 10.7.C** is required for all new alignment projects, structure rehabilitation and replacement projects that do not meet the requirements of an abbreviated H&H Report, or projects that meet one of the following:
  - significant change to the grades of the approach roadways
  - structures equal to or greater than 30 m (100 ft) in length (classified as a stream enclosure per PA DEP regulations)
  - structures located in densely developed areas where the potential for flooding impacts would be significant

**Hydrologic and Hydraulic QA/QC Checklists** are required for H&H Report submissions. For local projects, the decision on whether the QA/QC Checklists are required is decided by the District. The checklists target the primary technical H&H components, as required for typical PennDOT bridge and culvert replacement projects. More specifically the checklists comprise:

- Hydrology per acceptable methods in Section 10.7.C and Publication 584, *PennDOT Drainage Manual*, Chapter 7
- HEC-RAS computer model reviews for bridges and culverts
- HY-8 computer model reviews for simple culvert replacements
- Scour per Publication 15M, Design Manual, Part 4, *Structures*, Chapter 7 and HEC-18
- H&H Report per Section 10.7.C
- Abbreviated H&H Report per Section 10.7.B

The H&H Checklists are in Excel spreadsheet format. The Checklists are located in Chapter 10, Appendix D and the Excel files for the blank Checklists can be found on the PennDOT H&H webpage at the following address.

www.dot.state.pa.us/Internet/Bureaus/pdDesign.nsf/H&HHomepage?OpenFrameset

The instructions on the first sheet of the checklist provide guidance on the use of the checklists. Depending on the project type, not all checklists will be required for an H&H Report submission. **The applicable completed checklists will be required as an attachment to the H&H Report before submission to PennDOT for review**. If a paper copy of the H&H Report is submitted for review, the checklists should be attached to the transmittal letter. If an electronic copy of the report is submitted for review through the $JPA_2$ Expert System, the completed checklists should be uploaded to the "PennDOT Files" section of the $JPA_2$ Expert System. This is an internal check that is not part of the permit application to PA DEP and information stored in the "PennDOT Files" section of $JPA_2$ Expert is not transferred to PA DEP when the permit is submitted. Note that the Scour checklist will be a mandatory requirement for open-bottom structures; the Scour checklist is to be included with the scour computations, whether they are located in the Foundations Report or the H&H Report.

**For all H&H reports the H&H Electronic Files should be attached to the report as applicable.**

H&H reports shall be prepared by a registered Professional Engineer and shall be affixed with their seal and certification which shall read as follows: "I (name) do hereby certify pursuant to the penalties of 18 Pa. C.S.A. Section 4904 to the best of my knowledge, information and belief, that the information contained in the accompanying plans, specifications, and reports has been prepared in accordance with accepted engineering practice, is true and correct, and is in conformance with Chapter 105 of the rules and regulations of the Department of Environmental Protection."

Additional information and guidance concerning the design and permitting of temporary structures is located in Section 10.7.D.1.b.

**B. Abbreviated H&H Report Outline.** The abbreviated H&H Report outline may be used for structure rehabilitation and replacement projects that meet the requirements outlined in Section 10.7.A.

**1. Site Data.**

**a.** Location map on USGS quadrangle.

**b.** PA DEP and PA Fish and Boat stream classifications. Note that if the stream is classified as High Quality (HQ) or Exceptional Value (EV) designated use per 25 PA Code Chapter 93, an antidegradation analysis may be required. See Chapter 13, Section 13.7 for additional information.

**c.** Stream bed material description.

**d.** Color photographs of the existing structure and upstream and downstream channel.

**e.** Site inspection records indicating the dates and other information relative to the site inspection made by the Engineer conducting the hydrologic and hydraulic analysis.

**2. Hydrologic Analysis.**

**a.** Determine the drainage area above the proposed crossing from USGS maps or other appropriate sources.

**b.** Determine flood discharge(s) using an acceptable hydrologic method per Section 10.6.C.4 for the design flood and flood frequencies per Section 10.6.E.

**3. Hydraulic Analysis.**

**a.** Hydraulic Modeling Requirements: Refer to Chapter 10, Appendix C for the Hydraulic Modeling Requirements for H&H Reports.

**b.** Bridges.

**(1)** Model existing versus proposed conditions using HEC-RAS. Provide velocities and backwater elevations for all cross sections in the hydraulic model.

**(2)** Perform scour analysis and size riprap protection per Publication 15M, Design Manual, Part 4, *Structures*, Volume 1, Part A, Chapter 7.

**(3)** Provide comments and/or computations on temporary stream crossings, stream diversion, cofferdams, etc. and the need for erosion control devices.

**c.** Culverts.

**(1)** Model existing versus proposed conditions using HEC-RAS, HY-8, or "Hydraulic Design of Highway Culverts, Hydraulic Design Series No. 5" for culverts with or without improved inlets (see Chapter 10, Appendix E, References 17, 13, or 24).

**(2)** Provide comments and/or computations on temporary stream crossings, stream diversion, cofferdams, etc. and the need for erosion control devices.

**4. Risk Assessment.** If an alternatives analysis was completed, provide a brief narrative in the H&H Report as to why the final alternative was selected. A risk assessment should consider capital costs and risks, and other economic, engineering, social and environmental concerns. The abbreviated H&H Report may simply *summarize* a separate risk assessment located in the environmental document or project file.

**5. Summary Data Sheet.** The summary data sheet presented in Figure 10.7.1 shall be included with all H&H reports. See instructions in Section 10.7.C.5. Note: the Excel file for the blank Summary Data Sheet can be found on the PennDOT H&H webpage at the following address:

www.dot.state.pa.us/Internet/Bureaus/pdDesign.nsf/H&HHomepage?OpenFrameset

**6. Drawings.**

**a.** Roadway or structure plans indicating the following information:

**(1)** Layout of existing and/or proposed structures, stream channels and wetlands. The plan should include contours and other relevant topographic features.

**(2)** Flood limits of the existing and/or proposed structures and/or channels (can be shown on a topographic plan or cross sections from HEC-RAS).

**(3)** Temporary stream crossing, access road, cofferdam, diversion facility, etc. if applicable (can be copied from E&S plan).

**(4)** The magnitude, frequency and pertinent water surface elevation for the PennDOT design flood and the 100-year flood.

**(5)** If a backwater analysis is conducted, provide a plan drawing showing the location and orientation of all cross sections used for backwater analysis. The drawing shall be to scale and show contouring and all important hydraulic features. The limits of the hydraulic model must extend a minimum of 150 m (500 ft) upstream and 150 m (500 ft) downstream from the existing and proposed crossings. See the HEC-RAS Hydraulic Reference Manual for specific cross section location recommendations and requirements for bounding structure sections.

**Items 6.b and 6.c below do not require separate drawings provided that the information is available in the HEC-RAS model submitted with the report.**

**b.** Profile of stream for the limits of the study.

**c.** Cross section output of all cross sections used for backwater analysis.

**7. H&H Electronic Files.** Attach the electronic files for the hydrologic and hydraulic models as applicable.

**C. Full H&H Report Outline.** The full H&H Report outline should be used for projects as detailed in Section 10.7.A.

**1. Site Data.**

**a.** Location Map.

**(1)** The purpose is to show the proposed highway alignment, watershed boundary and reach of the river.

**(2)** Type:

**(i)** USGS quadrangle sheet or map of equal detail.
**(ii)** Aerial photographs.

**b.** Existing Structures (including relief or overflow structures):

**(1)** Locate (by map) existing structures including those upstream and downstream from the proposed crossing.

**(2)** Describe each structure fully, giving:

**(i)** Type of structure, including span lengths and pier orientation.

**(ii)** Cross section beneath structure, noting stream clearance to superstructure and skew with direction of current during extreme floods.

**(iii)** All available flood history, high water marks with dates of occurrence, nature of flooding (including overtopping of approach fills), damages and source of information.

**(3)** Compare stream and existing structure locations with the proposed crossing.

**(4)** Indicate whether existing structures are to remain in place.

**c.** Locate and determine elevations of all available high water marks along the stream giving dates of occurrence. Describe or list critical flood elevations of interest in evaluating possible damage (indicate datum used). Provide details of gage records and precipitation records.

**d.** Comment on fish habitats and other environmental concerns and on whether the stream flow is continuous or intermittent. Note that if the stream is classified as High Quality (HQ) or Exceptional Value (EV) designated use per 25 PA Code Chapter 93, an antidegradation analysis may be required. See Chapter 13, Section 13.7 for additional information.

**e.** Comment on drift, ice, nature of stream bed and bank stability.

**f.** Color photographs showing existing structures (including nearest upstream and downstream structures), past floods, main channel and floodplain with enough detail to coordinate the hydraulic model. Include a photo location map that shows the location and orientation of each photograph.

**g.** List factors affecting water stages:

**(1)** High water from other streams.
**(2)** Reservoirs (existing or proposed) and approximate date of construction.
**(3)** Flood control projects (give status, e.g., control structures, operator, and operating policy).
**(4)** Other controls.

**h.** Indicate if debris can be a problem at the structure site (include pertinent facts to justify the statement).

**i.** Site inspection records indicating the dates and other information relative to the site inspection made by the Engineer conducting the hydrologic and hydraulic analysis. Obtain information from PennDOT maintenance, mail carriers, municipal officials, school bus drivers, or local residents including dates, names and other information regarding discussions.

**j.** Indicate date of Line and Grade approval.

**2. Hydrologic Analysis.**

**a.** Determine the drainage area above the proposed crossing from USGS maps or other appropriate sources.

**b.** List flood records available on the river being studied.

**c.** Determine design flood discharge(s) and the discharge(s) as per Section 10.6.C.4 of other frequencies per Section 10.6.E.

**d.** Plot flood-frequency curve for the site (refer to prepared flood frequency analysis for stream under study if available). Use probability paper or probability scale.

**e.** Plot a stage-discharge-frequency curve for the site (with and without the proposed construction).

**f.** Published FEMA flows and the method used to determine them should be compared with the peak flows calculated with current PennDOT-acceptable methods.

**3. Hydraulic Analysis.**

**a.** Hydraulic Modeling Requirements: Refer to Chapter 10, Appendix C for the Hydraulic Modeling Requirements for H&H Reports. HEC-RAS electronic files must be submitted with the H&H Report; refer to the HEC-RAS Checklist in Chapter 10, Appendix D for the HEC-RAS files required to perform a technical review.

**b.** Bridges.

**(1)** Determine allowable velocity and permissible backwater.

**(2)** Compute and plot flow-distribution charts indicating distribution of flow across the valley at the proposed bridge site.

**(3)** Compute backwater for various trial bridge configurations for various discharges according to Section 10.6.

**(4)** Compute mean velocities through trial bridge lengths for various discharges.

**(5)** Estimate scour depth for proposed bridge piers and abutments (refer to Publication 15M, Design Manual, Part 4, *Structures,* Volume 1, Part A, Chapter 7).

**(6)** Make economic assessment (evaluate costs of bridge versus probable flood damage for various bridge lengths).

**(7)** Determine and indicate the recommended bridge opening based on the allowable velocity, permissible backwater with due considerations given to economic, safety and environmental factors.

**(8)** Include comments and/or computations on:

**(i)** Types and alignment of piers.

**(ii)** Stream stability (HEC-20).

**(iii)** Need for stream instability countermeasures (HEC-23).

**(iv)** Channel changes (HDS-6, HEC-11, and HEC-15).

**(v)** Bank protection, riprap or other erosion control provisions (HEC-11). For requirements to calculate scour, refer to Publication 15M, Design Manual, Part 4, *Structures*, Volume 1, Part A, Chapter 7.

**(vi)** Temporary stream crossings, access roads and cofferdams.

**c.** Culverts.

**(1)** Determine allowable headwater (AHW) depth per the HW/D ratios in Section 10.3.C. If the proposed culvert is replacing a bridge and is not hydraulically acting like a culvert, (i.e., under embankment fill that would cause ponding at the culvert inlet) the AHW design criteria do not apply.

**(2)** Determine type(s) of culvert in accordance with the Department's current structural criteria or policies. For long or steep culverts, investigate the benefits of using side tapered improved inlets. For a box culvert, the structure shall be countersunk with baffles per Section 10.11. Refer to Publication 584, *PennDOT Drainage Manual*, Chapter 9, Appendix A for "Joint Program Guidance for the Analysis of Environmental Impacts and Other Issues for Short Span Structures."

**(3)** Determine size(s) of culvert for various discharges in accordance with the allowable headwater (AHW) depth with due considerations given to economic, safety, damage and environmental factors, using the method of hydraulic analysis as set forth in the following:

**(i)** Use HEC-RAS, HY-8, or "Hydraulic Design of Highway Culverts, Hydraulic Design Series No. 5" for culverts with or without improved inlets (see Chapter 10, Appendix E, References 17, 13, or 24).

**(ii)** For culverts with energy dissipators, use HEC-14 and HY-8.

**(iii)** Use HDS-6, HEC-11, HEC-15, HEC-20, and HEC-23, as appropriate.

**(iv)** Other proven hydraulic principles may be used only if cases are not covered in the above references.

**(4)** Provide economic analysis (evaluate costs of culvert versus probable flood damages for various culvert sizes).

**(5)** Provide comments and/or computations on temporary stream crossings, stream diversion facilities and the need for erosion control devices.

**d.** Channel Changes.

**(1)** Determine the permissible flood limits.

**(2)** Compute water surface profiles for the existing streams and alternate designs of the new channels.

**(3)** Evaluate the comparative effects of the existing and new channels.

**(4)** Provide economic analysis (evaluate costs of channel versus probable flood damage).

**(5)** Determine the location and size of the recommended channel with due consideration given to environmental concerns and similarity to the existing stream.

**(6)** Describe bank and channel protection. Discuss freeboard; horizontal and vertical limits of protection; design criteria; and design procedure.

**(7)** Provide comments and/or computations for temporary stream crossings.

**(8)** If the channel change involves a fishable stream, provide comments and/or computations for the required items as indicated in "Channel Construction Involving Fishable Streams" in Section 10.10.

**e.** Embankment Encroachments Paralleling Floodplains.

**(1)** Evaluate the effect of encroachment on water stages. Compute water surface profile for waterway.
**(2)** Tabulate changes in stream velocities.
**(3)** Evaluate scour and erosion of roadway embankment and stream channel.
**(4)** Make flood damage analysis to estimate and evaluate the probable flood damage.
**(5)** Describe bank channel protection needed for flow, wave action, and superelevation.

**4. Risk Assessment or Analysis.**

**a.** A risk assessment or analysis using the base flood (100-year flood), with consideration given to capital costs and risks, and to other economic, engineering, social and environmental concerns, shall be included for the applicable design alternative(s) of any waterway structure. Refer to 23 CFR 650 Subpart A, Section 650.105 for an explanation and definition of "risk analysis." Generally, the risk analysis involves monetary figures in the calculation of the risk and other factors, whereas the risk assessment only involves narrative description of the relevant factors.

**b.** Risk analysis shall be performed and included for the following types of waterway structures:

**(1)** Encroachments at sensitive urban areas associated with new locations.

**(2)** Any encroachment determined to be a "significant encroachment" as defined in 23 CFR 650 Subpart A, Section 650.105.

The risk analysis, based on the least total expected cost (LTEC) design process, shall be performed in accordance with the procedure as specified in FHWA's Hydraulic Engineering Circular No. 17, "The Design of Encroachments on Floodplains Using Risk Analysis".

**c.** Risk assessment shall be performed and included for all other waterway structures not specified in items 2(a) and 2(b) above. Where appropriate, the simplified economic assessment as referred to in this section shall be included and considered in the risk assessment.

**d.** Risk assessment or analysis shall include the hydraulic data for the overtopping flood if this information is an important factor in the selection of the roadway grade and the type and size of waterway structures. Where the overtopping is to occur for floods of a lesser frequency than the 100-year flood, there should be a discussion of the consequences of overtopping to the highway and highway users including the traffic ADT. As defined in 23 CFR 650 Subpart A, Section 650.105, the term "overtopping flood" means the flood described by the probability of exceedance and water surface elevation at which flow occurs over the highway, over the watershed divide or through structure(s) provided for emergency relief.

**e.** For encroachments which are associated with new highway locations or which are related to highway replacement projects where existing waterway openings will be reduced, the risk assessment or analysis should be expanded, as appropriate, to include discussion of the following environmentally related matters with respect to the impacts of the proposed encroachments due to occurrence of a 100-year flood, the design floods as discussed in Section 10.6.E, as well as more frequent floods (such as average annual flood, 1.5-, 2-, 5-, 10-, 25-, and 50-year floods):

**(1)** Potential for changes to the ecology or the aquatic habitat of the stream channel and floodplains.

**(2)** Changes in flow regime due to the ponding upstream of the highway structure and whether or not this ponding can result in a change in the erosion and deposition balance of the stream channel.

**(3)** Increased frequency of inundation which may destroy bank denning animals and nesting fowl in the upstream ponding areas and which may reduce wetland areas downstream as a result of flood peak attenuation.

**(4)** Consideration of the local community or development potential of the area with respect to public safety or the creation of a public nuisance as a result of the ponded water.

It is anticipated that the environmental concerns of the above items are normally nonexistent or below the threshold of measurement for highway projects. However, this information should be included for each specific applicable project to provide regulatory agencies a basis for issuing the permits.

**f.** The detail of risk assessment or analysis shall be commensurate with the risk associated with the encroachment and with other economic, engineering, social or environmental concerns.

**5. Summary Data Sheet.** The summary data sheet presented in Figure 10.7.1 shall be included with all H&H reports, indicating the following information: Note: the Excel file for the blank Summary Data Sheet can be found on the PennDOT H&H webpage at the following address:

www.dot.state.pa.us/Internet/Bureaus/pdDesign.nsf/H&HHomepage?OpenFrameset

**a.** Location Data.

**(1)** Project MPMS number.

**(2)** Name of County.

**(3)** Name of the USGS Quadrangle the project is located within.

**(4)** Latitude at project site (12° 34' 56" N).

**(5)** Longitude at project site (12° 34' 56" W).

**(6)** Name of Municipality.

**(7)** Highway route number and section (SR 1234-567).

**(8)** Highway station of existing bridge crossing (Station 1234+56.78).

**(9)** Existing highway segment/offset (1234/5678).

**(10)** List the Functional Classification of the roadway (See Table 10.6.1).

**b.** Channel/Watershed Data

**(1)** Name of stream (if the stream is unnamed, indicate as a tributary to a known stream).

**(2)** Drainage area at the crossing (square miles).

**(3)** Hydrology method selected to develop peak flows.

**(4)** Indicate the FEMA Flood Zone Designation. Note: If the site does not have a FEMA designation, list as not applicable (A, AE, B, C, X, N/A).

**(5)** Indicate the applicable USACE river basin (Ohio, Delaware, Susquehanna, Great Lakes).

**(6)** Normal flow depth in the existing stream (estimated from field view / stream banks).

**(7)** Quantify any temporary wetland impacts (acres).

**(8)** Quantify any permanent wetland impacts (acres).

**(9)** Quantify all individual types of temporary fill material below the ordinary high water elevation and above the existing streambed/ground (cubic yards). Note: The ordinary high water level is the point on the bank or shore up to which the water, by its presence and action or flow, leaves a distinct mark indicated by erosion, destruction of or change in vegetation or other easily recognizable characteristic.

**(10)** Quantify all individual types of permanent fill material (e.g. embankment, riprap) below the ordinary high water elevation and above the existing streambed/ground (cubic yards).

**c.** Bridge/Culvert Characteristics.

**(1)** Describe the type of bridge or culvert.

**(2)** Indicate the number of spans.

**(3)** The skew angle is defined as the angle between the flow direction and a line drawn perpendicular to the bridge face. A skew angle of 0 degrees occurs when a bridge crosses the waterway perpendicular to the flow direction (degrees).

**(4)** Normal Clear Span is the perpendicular distance from abutment face to abutment face. For multiple span bridges, the normal clear span length of each span should be provided. This is the width component in the PA DEP JPA Facility Data (feet).

**(5)** Out-to-out length is the length of the structure in the direction of flow. This distance will be greater than the perpendicular structure length in situations where the bridge is skewed to flow direction (feet).

**(6)** The Total Length of Channel Impacted is the distance from the upstream edge of project impacts (including wing walls and riprap) to the downstream edge (feet).

**(7)** The low chord elevation is the lowest beam elevation on the underside of the bridge (feet).

**(8)** Minimum underclearance is smallest distance measured from the streambed to the bridge low chord. For a culvert, minimum underclearance describes the diameter or height of the opening (feet).

**(9)** Open area is the hydraulic opening area of the bridge or culvert (square feet).

**d.** Hydraulic Data.

**(1)** List the Hydraulic Method used in the study.

**(2)** Enter the existing and proposed hydraulic data for the PennDOT Design event (specify the year event), PA DEP Chapter 105 event (specify the year event), and the 100-year event. If any of the events are duplicated, repeat the values in the table. When HEC-RAS is used, the hydraulic data should be reported from the upstream bounding cross section.

**(i)** Q - Enter the flow rate corresponding to the return period (cfs).

**(ii)** WSE - Enter the water surface elevation corresponding to the return period (feet).

**(iii)** Velocity - Enter the channel velocity corresponding to the return period (ft/s).

**(3)** Indicate the overtopping event for the existing and proposed structure. This is generally described in relation to an event, rather than a specific year. For example the overtopping event may be described as greater than the 25-year event (> 25-year).

**6. Drawings.**

**a.** Roadway plans (preferably 1:500 (1"=50') scale) and profile indicating the following information:

**(1)** Layout of existing and/or proposed structures, stream channels and wetlands.

**(2)** Adjacent topographic features with key elevations or contours shown.

**(3)** Flood limits of the existing and/or proposed structures and/or channels.

**(4)** Occasional Flowage Easement (Flood Easement), if provided.

**(5)** Temporary stream crossing, access road, cofferdam, diversion facility, etc. (can be copied from the E&S plan). See Section 10.10 for the items required for fishable streams.

**(6)** The magnitude, frequency and pertinent water surface elevation for the specified floods.

**b.** Profile of stream for the limits of the study (consult the HEC-RAS Manual for specific recommendations), showing slopes of bed, normal surface and flood water surface. The profile shall be a drawing to scale and can be printed from the HEC-RAS output.

**c.** Plan drawing showing the location and orientation of all cross sections used for backwater analysis. The drawing shall be to scale and show contouring and all important hydraulic features. The limits of the hydraulic model must extend a minimum of 150 m (500 ft) upstream and 150 m (500 ft) downstream from the existing and proposed crossings. See the HEC-RAS Hydraulic Reference Manual for specific cross section location recommendations and requirements for bounding structure sections.

**d.** Cross section output of all cross sections used for backwater analysis.

**e.** Floodway maps and flood profiles where there are detailed FEMA Flood Insurance Studies.

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## FIGURE 10.7.1
## SAMPLE SUMMARY DATA SHEET

# Summary Data Sheet

**Location Data**

| | | | |
|---|---|---|---|
| MPMS # | | Municipality | |
| County | | State Route - Section | |
| Location - U.S.G.S. Quadrangle | | Station | |
| Latitude | | Segment/Offset | |
| Longitude | | Functional Classification | |

**Channel/Watershed Data**

| | | | |
|---|---|---|---|
| Stream Name | | Normal Stream Flow Depth | |
| Drainage Area | | Temporary Wetland Impacts | |
| Hydrology Method Used | | Permanent Wetland Impacts | |
| FEMA Flood Zone | | Temporary Fill below OHW | |
| River Basin (USACE) | | Permanent Fill below OHW | |

**Bridge/Culvert Characteristics**

| | Existing Structure | Proposed Structure |
|---|---|---|
| Bridge Type | | |
| Number of Spans | | |
| Skew (relative to flow direction) | | |
| Normal Clear Span (Width) | | |
| Out-to-out Length (Dir of Flow) | | |
| Total Length of Channel Impacted | | |
| Low Chord Elevation | | |
| Minimum Underclearance | | |
| Open Area | | |

**Hydraulic Data**

| | | Existing Structure | | | Proposed Structure | | |
|---|---|---|---|---|---|---|---|
| Hydraulic Method Used | | | | | | | |
| Return Period | Designation | Q | WSE | Velocity | Q | WSE | Velocity |
| | PennDOT Design | | | | | | |
| | PA DEP Chap 105 | | | | | | |
| 100-year | FEMA | | | | | | |
| | | | | | | | |
| | | | | | | | |
| Overtopping Event | | | | | | | |

**D. Abbreviated and Full H&H Reports.**

**1. Design Considerations Included in Drawings.**

**a.** Backwater Computations. Backwater computations are required to determine the geometry of bridge openings. However, for some permits, these computations may be waived by the regulatory agency for one of the following flooding cases:

**(1)** The proposed bridge is a reconstruction project or an extension of the existing structure where the history of the existing structure and the scope of the proposed project can be utilized as justification to waive the computations.

**(2)** The proposed bridge is a minor structure where the costly expenditure for the hydraulic report preparation is not warranted and where the existing field condition coupled with a sound engineering judgment can be utilized as a basis to determine the opening.

**(3)** The backwater determination is of no value and the uniform flow condition is reasonably applicable to the proposed bridge.

However, in the above cases, the hydraulic analysis based on Manning's equation (refer to Section 10.3) should be indicated in the Hydrologic and Hydraulic Report. The provision for applying Manning's equation assuming uniform flow conditions in these cases should not be construed as the Department's acceptance of this formula as a valid method for sizing a bridge opening. It merely serves as a routine hydraulic record for those projects for which the comprehensive hydraulic analysis by the backwater computations is not warranted or is of no significance.

**b.** Temporary Drainage Facilities. The temporary stream crossing item and other temporary facilities shall be included in the Hydrologic and Hydraulic Report. The approximate length of time that it remains in the stream shall be indicated. If a temporary stream crossing is not required, a statement should be included on the plan in the report describing how traffic or construction equipment can be detoured without entering and disturbing the stream. All temporary facilities to facilitate the permanent structure construction shall be covered in the Report. Joint Agency Guidance developed by PennDOT and PA DEP related to evaluating and permitting temporary structures is included in Chapter 10, Appendix G. This guidance should be followed for permitting temporary structures. This guidance is in addition to meeting the design requirements for temporary crossings as specified in Chapter 18, Section 18.5 and Publication 15M, Design Manual, Part 4, *Structures*, Volume 1, Part A, Chapter 5.

**c.** Occasional Flowage Easements. When designing a drainage structure, increases in headwater or backwater can be balanced against the structure size and cost. In fact, culvert or bridge design sometimes becomes an economic problem in which structure costs for various headwater elevations are balanced against the estimated costs of possible damage or inconvenience. In some cases, the cost of securing an occasional flowage easement (flood easement) for the structure can be significantly less than the additional expenses required to provide a larger structure.

If the headwater pool created by the recommended size of the structure can result in apparent flood damages, an "occasional flowage easement" shall be provided for this structure. The "occasional flowage easement" shall be designated and indicated on the plans of the Hydrologic and Hydraulic Report and on other appropriate drawings as required.

The use of an "occasional flowage easement" shall be limited to rural and/or other low real estate value areas. In all other areas (residential, commercial, industrial, etc.), the drainage structure should be designed to accommodate the flood discharges without creating increases in flood damages.

To enable an appraiser to make a written report for the actual taking of "occasional flowage easements", the District Right-of-Way Administrator shall be furnished maps and/or drawings showing the maximum elevation of the headwater pool, the flood frequency (usually based on a 100-year flood) and duration data and other available pertinent information for the approved structure. If the flood duration data cannot be determined by means of an analytical method, it should be estimated on the basis of an extensive field investigation. In this case, it may be advisable to give an over-predicted rather than an under-predicted flood duration.

For the purpose of making an economic analysis to determine the recommended size of the structure in the Hydrologic and Hydraulic Report, the cost of the "occasional flowage easement" used in the analysis may be estimated on the basis of an assumption that the property affected shall be flooded permanently and, therefore, determination of the flood duration data may be omitted. The preliminary cost estimate of the "occasional flowage easement" based on this assumption shall be made by the District Right-of-Way Administrator upon written request. The District Right-of-Way Administrator shall be furnished maps and/or drawings showing the maximum elevation of the design flood headwater pool, the extent of the easement required and other pertinent information as needed. The cost of the easement should be estimated by a qualified appraiser rather than by the designer who prepares the Hydrologic and Hydraulic Report.

**d.** Fish Passage. Where a culvert is to be installed in a fishable stream, fish passage treatment should be provided in accordance with Section 10.10 and Section 10.11.

**e.** Multi-Cell Structures. Concerning the minimum individual span width for multi-cell structures, each structure shall be evaluated on its own merit. After evaluating the upstream characteristic and debris problems that are anticipated, the minimum individual span width of a multi-cell structure shall be 4 m (14 ft).

**f.** Alternate Structure Types. Where the Department's policy requires that alternate structure types be included for bidding in accordance with the alternate design, low cost bridge or short span bridge procedure, all alternate structures should be identified in the Hydrologic and Hydraulic Report. Separate hydraulic analysis should be developed for any alternate structure where the analysis included in the report cannot be reasonably applied to this alternate structure. In some instances, providing an "equivalent effective waterway" may be sufficient to demonstrate the hydraulic adequacy of an alternate structure. Adequate fish passage measures should be provided for the prime as well as all alternate types of structures.

**g.** PS&E Construction and Structural Plans. For all waterway structures, the construction and structural plans to be submitted for PS&E approvals shall show: (1) the magnitude, return period, and water surface elevations for the design flood and the 100-year flood, if different from the design flood, (2) if available, the magnitude, water surface elevations and dates of occurrence of the flood of record, if greater than the 100-year flood, and (3) if required, the magnitude, return period, and water surface elevations for the overtopping flood.

The waterway structures, including roadway encroachments, should be designed to minimize the flood hazards to properties by:

**(1)** Limiting backwater to a maximum of 0.3 m (1 ft) based on a 100-year flood unless where:

**(i)** Higher water levels can be tolerated with minimal damage or
**(ii)** Mitigation is provided.

**(2)** Protecting against excessive backwater at crossings resulting from debris or ice blockage or extraordinary large floods by providing:

**(i)** Relief at or below the 100-year flood level by roadway overtopping or other practicable means or

**(ii)** Bridge superstructure clearance above the 100-year flood elevation where relief is not provided.

**h.** FEMA Considerations. For any encroachment into the FEMA regulatory floodway which shall result in an increase of the water surface elevation during a 100-year flood, no permit may be issued by PA DEP unless documentation is obtained from the applicable municipalities certifying to the effect that the project is consistent with the local floodplain and storm water management programs. This documentation should be obtained by the Engineering District and included in the report. Where there is a need for revising the flood insurance study, the Engineering District should also coordinate with the municipality and FEMA to effect the necessary revision. If any hydrologic or hydraulic data used in the report deviates from the flood insurance study, the Engineering District Office should receive a written clarification or confirmation from FEMA.

**2. Coordination with FEMA and Local Municipalities.** All projects affecting waterways within National Flood Insurance Program (NFIP) study areas will follow the standard procedures for compliance with floodway regulations (such as, but not limited to, 44 CFR 65.3, 44 CFR 65.12, 23 CFR 650, 42 USC 50, 25 PA Code §105 and §106, and 12 PA Code §113).

Different project scenarios require different interactions with FEMA and/or local Municipalities on the part of PennDOT to comply with the above regulations. Those scenarios are described below.

**Scenario 1:** If the proposed project is **not** located in a FEMA (detailed or approximate) study area.

PennDOT Requirements: No coordination with FEMA. Notify the local Municipality of a significant encroachment, as defined in 23 CFR 650 A Section 650.105 (q), such as an interruption to emergency vehicle routes, or other significant risk.

**Scenario 2:** If the proposed project is located in a **FEMA Approximate study area** and does **not cause increases** to the 100-year water surface elevations of the Proposed conditions model when compared to the Existing conditions model.

PennDOT Requirements: No coordination with FEMA is required. Send a courtesy copy of the H&H Report to the local Municipality's Floodplain Manager.

**Scenario 3:** If the proposed project is located in a **FEMA Detailed study area (**with or without floodway) and does **not cause increases** to the 100-year water surface elevations of the Proposed conditions model when compared to the Existing conditions model, and one or more of the following occurs:

**a.** the hydrologic analysis produces different peak flow values than used in FEMA flood study

**b.** flow values are not provided by FEMA in its Flood Study

**c.** PennDOT's estimates of existing 100-year water surface elevations differ from the values reported in current effective FEMA studies

**d.** if a project is located in a **detailed FEMA study area with a floodway** and the proposed project will alter the floodplain or floodway boundaries

PennDOT Requirements:

If PennDOT's hydrologic analysis produced a different value for the 100-year peak flow from FEMA's, then both PennDOT's and FEMA's peak flow values should be included among the flow values used in the hydraulic models and report.

If PennDOT's estimates of existing 100-year water surface elevations differ from the values reported in current effective FEMA studies, the amount of the difference should be tabulated and briefly explained in the H&H report. See Chapter 10, Appendix C for more information about modeling.

No coordination with FEMA is required. The final H&H Report and modeling shall be shared with the local Municipality. The local municipalities responsible for the NFIP map can use PennDOT's data locally to supplement the existing FEMA data and to help the municipality implement their commitment under the NFIP and the PA Flood Plain Management Act (1978 Act 166) in order to regulate development in floodplain areas. It should be noted that PennDOT is not required to comply with local ordinances. The cover letter to the local municipality should include the following content:

**i.** An explanation that the purpose of the letter is to inform the municipality that PennDOT's analysis has produced results that differ from the current effective NFIP model.

**ii.** A short explanation that highlights the differences.

**iii.** A statement that PennDOT is not required to revise the NFIP map because the proposed project does not result in a regulated increase in the 100-year water surface elevation.

**iv.** A statement that PennDOT is providing a copy of the analysis for consideration during the next regular update to the NFIP map.

**v.** Where flow values are newly developed in the absence of FEMA flow values, the letter shall simply state that the information is provided for use by the municipality in fulfilling its obligations and responsibilities under the NFIP and PA Act 166 of 1978.

**Scenario 4:** If the proposed project is located in **FEMA study area** (Approximate, detailed without floodway, or detailed with floodway) and **causes increases** to the Proposed model's 100-year water surface elevations when compared with the Existing model's 100-year water surface elevations by any of the following:

**a.** by less than or equal to 1-foot in an approximate FEMA study area

**b.** by less than or equal to 1-foot in a detailed FEMA study area when no fill will occur in the floodway

**c.** by less than or equal to 1-foot in a detailed FEMA study area with no designated floodway

PennDOT Requirements: No coordination with FEMA is required unless there is a change to the floodway geometry (then follow Scenario 5). PennDOT District will forward one copy of final Hydrologic and Hydraulic (H&H) Reports to the local Municipality to supplement the existing FEMA data and to help the Municipality implement their commitment under the NFIP and the PA Flood Plain Management Act. The cover letter to the Municipality shall include a statement that PennDOT is not required to revise the NFIP map and that PennDOT is providing a copy of the analysis for consideration during the next regular update to the NFIP map.

**Scenario 5:** If the proposed project is located in a **FEMA study area** (Approximate, detailed without floodway, or detailed with floodway) and **causes increases** to the Proposed 100-year water surface elevations when compared with the Existing 100-year water surface elevations by any of the following:

**a.** by greater than 1-foot in an approximate FEMA study area

**b.** by greater than 1-foot in a detailed FEMA study area if no fill will occur in the floodway

**c.** by greater than 0.00-foot in a detailed FEMA study area if fill will occur in the floodway

**d.** by greater than 1-foot in a detailed FEMA study area with no designated floodway

PennDOT Requirements: A Conditional Letter of Map Revision (CLOMR) application is to be prepared and sent to FEMA. A CLOMR does not revise an effective NFIP map. The FEMA MT-2 Forms 1, 2, and 3 and the final H&H Report and models must be submitted to FEMA along with the CLOMR fee. Coordination with the local Municipality and affected property owners must occur as prescribed in the MT-2 forms prior to submission of the CLOMR application to FEMA.

If the project will increase the 100-year flood elevation to a structure(s), PennDOT must certify that PennDOT will purchase and remove the structure(s) before FEMA can approve a CLOMR (see 44 CFR 65.12(a)(5)). For example, if the project is located in a FEMA detailed floodway (as in

Scenario 5c) and a structure is inundated to a depth of 4 feet by the 100-year flood before the project is constructed, but will be inundated to a depth of 4 feet 2 inches after the project is constructed, that structure must be purchased and removed by PennDOT before the project is built. Certification that the structure(s) will be purchased and demolished is required before FEMA can approve the CLOMR.

No later than six months after completion of construction, a Letter of Map Revision (LOMR) is to be prepared and sent to FEMA as an official amendment to the effective NFIP map. A LOMR may change flood insurance risk zones, floodplain and/or floodway boundary delineations, planimetric features, and/or Base Flood (100-year) Elevations. The FEMA MT-2 Forms 1, 2, and 3 and the final H&H Report and models must be submitted to FEMA along with the LOMR fee. Coordination with the local Municipality and affected property owners must occur as prescribed in the MT-2 forms prior to submission to of the CLOMR request to FEMA.

The address for submitting H&H Reports to FEMA is:

Federal Insurance and Mitigation Division Director
FEMA Region III
615 Chestnut Street, 6th Floor
Philadelphia, PA 19106-4404

One copy of the transmittal letter will be sent to:

Chief, Floodplain Management Division
Department of Community and Economic Development
Keystone Building, 4th Floor
Harrisburg, PA 17120

One copy of the transmittal letter will be sent to:

Bureau of Project Delivery
Highway Delivery Division
Highway Design and Technology Section
Hydrology and Hydraulics Unit
Keystone Building, 7th Floor
400 North Street
Harrisburg, PA 17120

Figure 10.7.2 presents an example transmittal letter.

Sources for additional information, guidance, and forms pertaining to NFIP maps include:

**a.** "Procedures for Compliance with Floodway Regulations", USACE, May 1990.
**b.** FEMA's Internet site on flood hazard mapping (www.fema.gov).

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# FIGURE 10.7.2
# EXAMPLE TRANSMITTAL LETTER FOR H&H REPORTS WITHIN AN IDENTIFIED FLOOD HAZARD ZONE ON A FEMA NFIP MAP

QQ-Return-Address
QQ-Date

1QQ County, 2QQ Township
S.R. 3QQ, Section 4QQ
Segment 5QQ, Offset 6QQ
over 7QQ
Final Hydrologic and Hydraulic Report
NFIP Community: QQ-name / QQ-number / QQ-date

Federal Insurance and Mitigation Division Director
FEMA Region III
615 Chestnut Street, 6th Floor
Philadelphia, PA 19106-4404

Dear Sir/Madame:

Enclosed for your use is one (1) copy of the final Hydrologic and Hydraulic report for the subject project. This project lies within an identified flood hazard zone on a FEMA National Flood Insurance Program (NFIP) Map.

The hydraulic analysis shows that the proposed project does not increase 100-year water surface elevations; therefore, PennDOT is not required by regulations to revise the NFIP Map.

DELETE THIS COMMENT. DELETE THE FOLLOWING PARAGRAPH WHEN IT DOES NOT APPLY.
PennDOT's hydraulic analysis produced 100-year water surface elevations that differ from the values reported in the current effective NFIP study. These differences are summarized and tabulated in the report. The analysis also shows that the proposed project causes NO increase in 100- year water surface elevations.

DELETE THIS COMMENT. DELETE THE FOLLOWING PARAGRAPH WHEN IT DOES NOT APPLY.
PennDOT's hydrologic analysis shows that the 100-year peak flow has (increased/decreased) from the value reported in the current effective NFIP study. Using the existing physical geometry, the effect of the change in 100-year peak flow on existing water surface elevations has been analyzed and tabulated in the report.

We have received both the Chapter 105 Water Obstruction and Encroachment Permit and the Pennsylvania State Programmatic General Permit (PASPGP) from the Pennsylvania Department of Environmental Protection for the subject project.

Should you have any questions, please contact QQ-name, District Regulatory Permit/H&H Coordinator at QQ-phone.

Sincerely,

QQ-Name
District Executive
Engineering District, QQnum-0

Enclosures

# FIGURE 10.7.2 (CONTINUED)
# EXAMPLE TRANSMITTAL LETTER FOR H&H REPORTS WITHIN AN IDENTIFIED FLOOD HAZARD ZONE ON A FEMA NFIP MAP

QQ-District/QQ-Initials/Project

cc: QQ-Name
Chief, Floodplain Management Division
Department of Community and Economic Development
Keystone Building, 4th Floor
400 North Street
Harrisburg, PA 17120

QQ-Name
Bureau of Project Delivery
Highway Delivery Division
Highway Design and Technology Section
Hydrology and Hydraulics Unit
Keystone Building, 7th Floor
400 North Street
Harrisburg, PA 17120

Local Municipality/Municipalities
District Executive
Circulation and File Copies

## 10.8 PROCEDURE FOR OBTAINING PERMITS FROM THE US COAST GUARD

The Commandant, US Coast Guard, Washington, DC, approves the plans and locations of bridges (including approaches, false work and cofferdams) across Navigable Waters of the United States, prior to the start of construction. The general procedure for obtaining permits from the US Coast Guard is described in this section.

**A. Navigable Waters of the United States.**

**1.** The term "Navigable Waters of the United States" is construed to mean those waters of the United States, including the territorial seas adjacent thereto, the general character of which is navigable, and which, either by themselves or by uniting with other waters, form a continuous waterway on which boats or vessels may navigate or travel between two or more States or to or from foreign nations. A stream which otherwise conforms with the above definition would not change its navigable character because of the existence of natural or artificial obstructions such as falls, shallows, rapids, dams or bridges.

**2.** The Federal Government has the power to improve the navigable capacity of streams and declare such waters to be Navigable Waters of the United States in order to regulate the use thereof and navigation thereon. The erection of dams or other structures on navigable waters would not change their navigable character unless a clear intent to do so was manifested by Congress under its authority to regulate commerce among the States and foreign nations.

**B. Jurisdiction of Coast Guard Districts.** As indicated in Figure 10.8.1, there are three Coast Guard Districts with jurisdiction over the construction of bridges across the navigable waters in Pennsylvania. Applications for Permits shall be made to the Commander of the District in which the proposed bridge will be located. The addresses and zones of jurisdiction in Pennsylvania for these Districts are as follows:

**1.** Commander (aowb)
Fifth Coast Guard District
LANTAREA
Federal Building
431 Crawford Street
Portsmouth, VA 23704-5004
Tel: 757-398-6222
Zone of Jurisdiction: East of 79º W Longitude

**2.** Commander (obr)
Eighth Coast Guard District
1222 Spruce Street
St. Louis, MO 63103-2398
Tel: 314-539-3900, ext. 378
Zone of Jurisdiction: South of 41º N Latitude and
West of 79º W Longitude

**3.** Commander (obr)
Ninth Coast Guard District
1240 East 9th Street
Cleveland, OH 44199-2060
Tel: 216-902-6085
Zone of Jurisdiction: North of 41º N Latitude and
West of 79º W Longitude

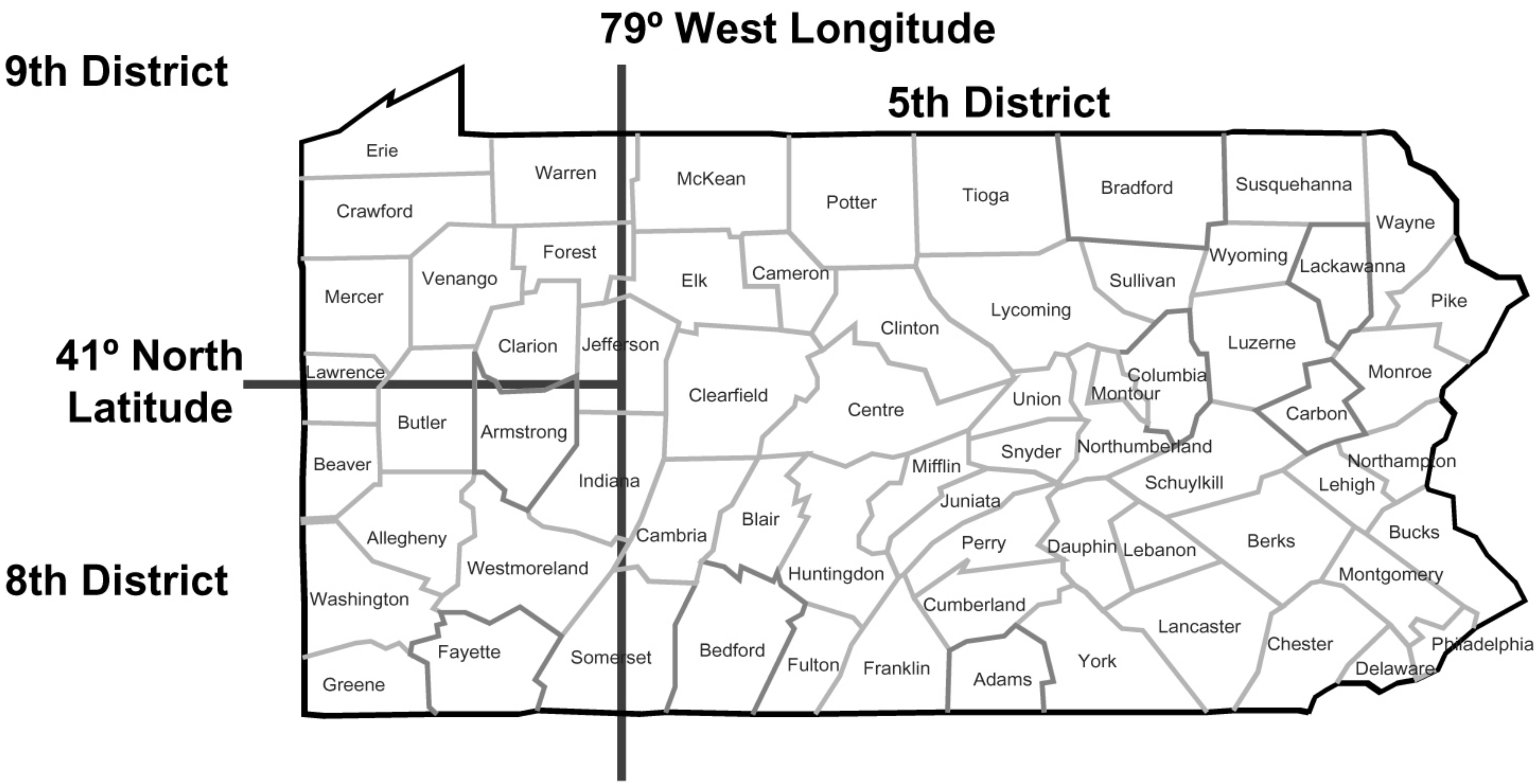


**FIGURE 10.8.1**
**US COAST GUARD DISTRICT BOUNDARIES**
**IN PENNSYLVANIA**

Generally, streams in Pennsylvania that flow into the Atlantic Ocean are in the Fifth Coast Guard District; streams that flow into the Mississippi River are in the Eighth Coast Guard District; and streams that flow into the Great Lakes are in the Ninth Coast Guard District.

An exception to the zones of jurisdiction as described above is found in the headwaters of the Allegheny and Beaver Rivers, navigable portions of which are in the Ninth Coast Guard District (above Latitude 41° N). Applications for bridge permits across these rivers shall be directed to the Eighth Coast Guard District.

**C. Navigable Waters in Pennsylvania Requiring Coast Guard Bridge Permits.** As mentioned before, a permit shall be obtained from the Coast Guard for the construction of a bridge (including approaches, false work and cofferdams) across a Navigable Water of the United States. Although the general term "Navigable Waters of the United States" was previously defined, it is impossible to make a complete list of these waters in Pennsylvania because of the detailed research and inquiries that must go into each determination by the Commandant of the Coast Guard.

A permit may be waived (subject to the Coast Guard's and/or FHWA's determination) for those bridges which cross non-tidal waters that are not used, susceptible to use in their natural condition, or susceptible to use by reasonable improvement as a means to transport interstate or foreign commerce.

The administrative determinations made by each Coast Guard District for the Navigable Waters of the United States in Pennsylvania are as follows:

**1.** Eighth Coast Guard District (St. Louis). The approval and permit of the Commandant, US Coast Guard is required for bridges over the following named rivers in Pennsylvania within the Eighth Coast Guard District:

| | | |
|---|---|---|
| **a.** | Allegheny River: | Mouth to East Brady, Pennsylvania, Kilometer 115.87 (Mile 72.0) |
| **b.** | Monongahela River: | Mouth to Kilometer 207.12 (Mile 128.7) |
| **c.** | Youghiogheny River: | Mouth to Kilometer 31.06 (Mile 19.3) at West Newton, Pennsylvania |
| **d.** | Ohio River: | The entire length |
| **e.** | Beaver River: | Mouth to Kilometer 34.60 (Mile 21.5) |
| **f.** | Mahoning River: | Mouth to upstream limits of Warren, Ohio, Kilometer 65.98 (Mile 41.0) |
| **g.** | Shenango River: | Mouth to New Castle, Pennsylvania, Kilometer 7.56 (Mile 4.7) |

All other navigable streams within this District are considered to be in the Advance Approval Category for bridges. In such cases, assume the clearances provided for high water stages and for the passage of drift are adequate to meet the reasonable needs of navigation.

**2.** Fifth Coast Guard District (Portsmouth). The Susquehanna River and Codorus Creek are the only waterways in the Fifth Coast Guard District Zone of responsibility in Pennsylvania which are in the advance approval category. All tributaries to the Susquehanna River and Codorus Creek are also included in this advance approval category. Except for the above waterways, no formal administrative determination has been made by the Commandant of the Coast Guard regarding the navigational status of the rivers in Pennsylvania within the Fifth Coast Guard District's zone of responsibility. Although the status of some reaches of the Delaware, Lehigh and Schuylkill Rivers and Chester Creek has not been officially determined by the Coast Guard, these waterways are generally considered as "navigable waters" of the United States and, therefore, a permit from the Coast Guard is required for any bridge across some reaches of these waterways. A bridge permit may also be required for any other streams within this District, the general character of which is navigable or which is actually navigated by boats or vessels.

**3.** Ninth Coast Guard District (Cleveland). The approval and permit of the Commandant of the US Coast Guard is required for bridges over the following navigable waterways within the Ninth Coast Guard District:

**a.** Erie Harbor: Located on Lake Erie including the entire channel.

**b.** Elk Creek: From its mouth at Lake Erie near Lake City, Pennsylvania, upstream (south) approximately 762 m (2500 ft), to the head of the authorized Federal River and Harbor Navigation Improvement Project.

There are no Advance Approval Category waterways over which the Ninth Coast Guard District exercises jurisdiction in Pennsylvania. A bridge permit from the Coast Guard may also be required for any other stream within this District, the general character of which is navigable or which is actually navigated by boats or vessels.

**D. Applications for Bridge Permits.** To evaluate if a Coast Guard permit is required, make a determination using 23 USC 144 (h) based on information obtained in data gathering and through coordination with the Coast Guard as per 23 CFR 650, Subpart H, Sections 805 through 807. For any bridge which requires a permit from the Coast Guard, the application for the permit shall be filed by the Engineering District Office to the Coast Guard.

The District Executive shall submit the following information for transmittal to the Coast Guard for the bridge permit:

**1.** A letter from the Department of Environmental Protection certifying that there is reasonable assurance that construction of the proposed structure does not violate the water quality standards of the Commonwealth of Pennsylvania.

**2.** Two copies of the Environmental Document (Categorical Exclusion, Environmental Assessment or Environmental Impact Statement).

**3.** A statement pertaining to the cost of the bridge as follows:

**a.** Cost of bridge with navigational increment.
**b.** Increase in cost attributable to added clearances provided for navigation.

**4.** A statement concerning the planned disposition of the existing bridge, if any. If an existing bridge not owned by the Department is to be removed, show consent of the owner for its removal.

**5.** An original and five copies of the following (size of 8.5 in × 11 in):

**a.** A map of the vicinity showing the location of the bridge site and the location of any wildlife and waterfowl refuges, recreation areas, public parks or historic sites in the vicinity or in the way of the bridge or its approaches. This map should also include an arrow indicating north, show other bridges in proximity to the proposed bridge and sufficient local characteristics to permit ready identification. The work site should be outlined in red.

**b.** A plan of the bridge showing the bridge in both plan and elevation views. Outline the navigational opening(s) in red. Navigational clearances may be described as follows:

**(1)** The minimum horizontal clearance, normal to the axis of the navigational channel, between the faces of the piers or inside any protection works.

**(2)** The maximum vertical clearance that will be available at the highest point of the navigation span(s).

**(3)** The least clear height, with respect to the appropriate recognized datum at the site, of the lowest part of the superstructure of the navigation span(s) shall be clearly indicated.

**(4)** The elevation of the lowest part of the superstructure should be shown at the channelward face of each pier, at the midpoint of the span and, in the case of a haunched bridge, 7.5 m (25 ft) channelward of each pier.

**(5)** Other related data to be shown as appropriate, including:

**(a)** Dimensions of the navigation channel. If stream is navigable from bank-to-bank, this may be omitted.

**(b)** Harbor lines, if established.

**(c)** Soundings and elevations, in meters (feet), with respect to the established government datum.

**(d)** The direction of the current (indicated by an arrow).

**(e)** The direction of true north.

**(f)** Where appropriate, vertical clearance should be shown above normal pool elevation and the 2% flowline elevation or, on a free-flowline river, above low water elevation and the 2% flowline elevation. The information on 2% flowline elevation may be obtained from the local Corps of Engineers' office.

Only those structural details necessary to illustrate the effect of the proposed structure on navigation should be shown. Drawings should be on 8.5 in × 11 in sheets; show a simple title block in the lower right-hand corner of each sheet. The title block should identify the Department, the bridge and the date of plans.

The information required for the application of the Coast Guard Bridge Permit may be submitted to the Central Office, Bureau of Project Delivery at the time of the waterway submission or at any other appropriate time.

As the required information may vary with individual situations, the District Executive is authorized to contact the appropriate Coast Guard District for information on specific navigation requirements or other particular requirements prior to preparing the materials required for the formal application. However, copies of all correspondence on this matter should be forwarded to the Central Office, Bureau of Project Delivery for information.

For any bridge to be constructed over a stream in the Advance Approval Category, a formal application to the Coast Guard is not required. However, since the Coast Guard recommends that they be advised whenever a bridge is planned over a stream of any consequence, it is suggested that the Engineering District Office forward one set of the preliminary bridge drawings to the Coast Guard for information for those bridges to be constructed under the Advance Approval Category. It would be advisable to obtain a letter of no objection from the Coast Guard as a record.

The need for pier protection from possible ship collision should be evaluated for all bridge piers placed in navigable waterways with substantial commercial navigational traffic.

## 10.9 PROCEDURE FOR OBTAINING PERMITS FROM THE US ARMY CORPS OF ENGINEERS

This section describes the Department's procedures for obtaining permits from the US Army Corps of Engineers (USACE) for highway improvement projects. It also serves as a general guide to various USACE regulations, including the Section 404 Permit, the Section 10 Permit, and the Pennsylvania State Programmatic General Permit (PASPGP).

It is the Pennsylvania Department of Environmental Protection's (PA DEP's) responsibility to coordinate. To avoid confusion and duplication of effort, PA DEP, in conjunction with the USACE, has developed a Joint Permit

Application (JPA) for activities in, along and across waters (and wetlands) of the Commonwealth. Once a joint permit is submitted to PA DEP, it is considered on record for both state and federal agencies.

The USACE shall receive a copy of the waterway submission from PA DEP thru the JPA process. Upon receipt of the submission, the USACE shall act on confirmation of the applicability of the nationwide permit or process an individual Department of the Army permit (USACE Section 404 permit).

The most common type of USACE permits applicable to highway projects is the Section 404 Permit regarding discharges (placements) of dredged or fill material into waters of the United States. This type of permit is conditionally exempted for maintenance, including emergency reconstruction of bridge abutments or approaches and transportation structures and for temporary sedimentation basins. For projects involving emergency reconstruction, there are different funding requirements between federal sources and 100% state sources. For federal-aid procedures, refer to 23 CFR Part 668; for state procedures, refer to the 4 PA Code § 67.

A "nationwide permit" has been issued by USACE to permit certain discharges of fill material into waters of the United States throughout the Nation. The specific categories of discharges of fill material covered in the nationwide permit, the validity of which is contingent upon the issuance of a Section 401 water quality certification by the State, are indicated in 33 CFR Part 330. The issuance of a water obstruction permit by PA DEP also constitutes approval for the water quality certification. Among highway activities covered in this nationwide permit are:

**1.** Certain repair, rehabilitation or replacement of the structure and fill which does not deviate from the plans of the original structure or fill.

**2.** Certain outfall structures and associated intake structures.

**3.** Certain bank stabilization activities less than 150 m (500 ft) in length and less than an average of 2.5 $m^3$ of fill material per running meter (1 $yd^3$ of fill material per running foot) along the bank.

**4.** Certain highway crossings that involve less than 150 $m^3$ (200 $yd^3$) of fill material placed in waters.

**5.** Certain fill placed for bridges across Navigable Waters of the United States provided a permit is obtained from the US Coast Guard.

**6.** Certain discharges of fill material that do not exceed 7.5 $m^3$ (10 $yd^3$).

**7.** Federal-aid projects classified as "categorical exclusion".

**8.** Discharge of concrete into tightly sealed forms or cells.

**9.** Certain activities performed at a location above the headwaters of the waters of the United States. All USACE's Districts in Pennsylvania have accepted 8 $km^2$ (3 $mi^2$) of drainage area as a general rule-of-thumb for determination of the headwaters.

The USACE is responsible for administering Federal regulations under two separate authorities: Section 404 of the Clean Water Act (CWA) of 1972 and Section 10 of the Rivers and Harbors Act of 1899.

**A. Section 404.** Under the authority of the Section 404(b)(1) Guidelines of the CWA, the USACE exercises jurisdiction over the waters (both navigable and otherwise) of the United States. Section 404 applies to the disposal of dredged or fill material into lakes, rivers and wetlands. Federal regulations on the USACE's permit program are contained in 33 CFR Parts 320-331.

Accordingly, the Department shall obtain approval from the USACE in the form of a Section 404 Permit for all proposed encroachments (not including bridges) involving the placement of dredged or fill materials in the waters of the United States in Pennsylvania. Bridges are not included because placement of pilings for linear projects, such as bridges, generally does not have the effect of a discharge of fill material. All Section 404 permit applications shall comply with the Guidelines in order for the Permit to be issued. The USACE is authorized to determine whether a project complies with the Guidelines.

Section 404 permits are issued through the four USACE Districts which exercise jurisdiction in Pennsylvania (see list below). Some nationwide and regional permits have been issued to cover specific types of discharges. Permit applicants shall provide sufficient information to complete a 404(b)(1) evaluation, which is prepared by the permitting office.

The final determination of acceptability of any proposed discharge of dredged or fill material considers the probable impact, including cumulative impacts of the proposed discharge, on the public interest. The CWA directs that 404(b)(1) Guidelines be promulgated by the Administrator of the USEPA in conjunction with the USACE.

**B. Section 10.** In addition to dredged or fill discharge permits, the USACE also issues permits for any structures or work that impact the course, capacity, or condition of a navigable water of the United States under Section 10 of the Rivers & Harbors Act of 1899 (33 US Code (USC) Section 403). The Section 10 permit program is managed by the same USACE Districts as the Section 404 permits. Section 10 and Section 404 permits are typically handled jointly. The USACE coordinates Section 10 permits with the US Coast Guard, which issues a notice to navigation.

**C. Regional General Permit.** The USACE, in coordination with PA DEP, administers a Regional General Permit known as the Pennsylvania State Programmatic General Permit (PASPGP). The PASPGP is a federal CWA, Section 404 Permit for various construction activities involving the discharge of dredge and fill material into waters of the United States. In most cases, a PASPGP can be issued by PA DEP or a county conservation district (with approved Chapter 105 water obstruction and encroachment permits). The validity of the PASPGP is contingent upon the issuance of a Section 401 Water Quality Certification (WQC) by the Commonwealth.

The PASPGP incorporates federal and state permitting standards in one process, and thereby eliminates the need for dual and often redundant permitting procedures. This permit provides a coordinated approach to environmental protection. It divides regulated activities into the following three categories based on the size of the activity and compliance with state and federal permit review standards:

**1.** Category 1. These activities are not forwarded to the USACE for review and can normally be processed by the appropriate PA DEP regional office or delegated county conservation districts without the need for additional federal review. They include:

- **a.** Activities waived at Chapter 105, Section 105.12 (except waiver #1, #2, and #14); and
- **b.** Activities authorized by a general permit (except for the gravel removal portion of the GP-3 and GP-15).

**2.** Category 2. These activities are published in the Pennsylvania Bulletin for public comments and as notice to the federal agencies, and can normally be processed by the appropriate PA DEP regional office or delegated county conservation districts without the need for additional federal review. They include:

- **a.** Activities impacting less than one acre of wetland and other bodies of water; and
- **b.** Activities impacting less than 76 m (250 ft) of stream.

**3.** Category 3. These activities are reviewed individually by the USACE and PA DEP to ensure compliance with the terms and conditions of PASPGP. They include:

- **a.** Activities impacting wetlands within the 14-county range of the bog turtle;
- **b.** Activities impacting more than 76 m (250 ft) of stream;
- **c.** Activities involving dams, weirs, fill or stream channelization in the Juniata and Susquehanna Rivers; and
- **d.** Activities in French, LeBoeuf, Muddy, Conneauttee Creeks or Conneaut Outlet.

Procedurally, the USACE evaluates Category 3 applications, and either determines that the proposed action qualifies under PASPGP, or requires an individual 404 permit review.

**4.** Non-Qualifying Activities for Authorization. The following activities do not qualify for authorization under PASPGP, and require separate Section 404 and Chapter 105 authorizations, processed by the USACE and PA DEP:

**a.** Activities impacting more than one acre of water or wetlands; and

**b.** Activities in the following waterbodies:

- Delaware River
- Beaver River
- Little Beaver River
- Mahoning River
- Monongahela River
- Ohio River
- Lake Erie

and portions of the:

- Schuylkill River
- Lehigh River
- Youghiogheny River
- Allegheny River
- Kiskiminetas River
- Ten Mile Creek

**D. Chapter 105/PASPGP General Permit Registration Form.** The USACE, in coordination with PA DEP, uses a registration process for a Chapter 105/PASPGP General Permit. The registration process incorporates federal and state permit application requirements to facilitate the concurrent issuance of state and federal permits through one application. General permit registrations require submittal of the following items:

**1.** Project sketch plan
**2.** Project location information
**3.** Consultant information
**4.** Threatened and endangered species reviews.

The registration package also includes a single and complete project screening process developed to assist the applicants, county conservation districts and PA DEP in determining that all environmental impacts related to the project have been evaluated, minimized and properly permitted. The permit registration process allows the permit applicants, as well as PA DEP and delegated county conservation districts, to ensure that projects meet the requirements of Chapter 105 and PASPGP. The General Permit Registration package is available on PA DEP's website, from Chapter 105 delegated county conservation districts and from PA DEP regional offices.

For copies of PASPGP, contact the Baltimore District Corps of Engineers, Pennsylvania Section, (see address below) or visit the USACE website. For general information on the PASPGP process, contact one of the six PA DEP Regional Offices or the Division of Waterways, Wetlands and Erosion Control.

**E. Nationwide Permit (NWP).** The NWP program is used when PASPGP cannot be used. The NWP program includes a notification provision that requires the following agencies to be contacted:

**1.** The US Fish and Wildlife Service (USF&W) and also National Marine Fisheries Service (NMFS) in the Coastal Zone Management (CZM) areas, regarding the presence of endangered or threatened species or critical habitat areas affected by the project.

**2.** The Pennsylvania Historical and Museum Commission (PHMC) regarding the presence of any historic properties affected by the proposed project.

Refer to 33 CFR Part 330 and current Department directives for a complete listing of the specific categories of discharge of fill material covered in the NWP.

**F. Agency Coordination Meeting.** The USACE is one of the Federal environmental resource agencies that participates in the Department's Agency Coordination Meeting (ACM) process. In this capacity, the USACE participates fully in the Department's ACM process, as described in Publication 10, Design Manual, Part 1, *Transportation Program Development and Project Delivery Process*, Chapter 3. Coordination with the USACE is also undertaken via agency coordination letters.

**G. USACE Districts.** As indicated in Figure 10.9.1, there are four USACE Districts which exercise jurisdiction in Pennsylvania. They are:

**1.** US Army Corps of Engineers, Baltimore District
Attention: CENAB-OP-R
P.O. Box 1715
Baltimore, MD 21203-1715

**2.** US Army Corps of Engineers, Buffalo District
Attention: CELRB-CO-SR
1776 Niagara Street
Buffalo, NY 14207-3199

**3.** US Army Corps of Engineers, Philadelphia District
Attention: CENAP-OP-R
100 Penn Square East
2nd and Chestnut Street
Philadelphia, PA 19107-3390

**4.** US Army Corps of Engineers, Pittsburgh District
Attention: CELRP-OP-F
Federal Building
1000 Liberty Avenue
Pittsburgh, PA 15222-4186

Figure 10.9.1 shows the boundaries of the Civil Works Districts. Note that the boundaries of the Pittsburgh, Baltimore, and Buffalo Civil Works Districts do not coincide with their Regulatory Districts. The Pittsburgh Regulatory District includes those streams draining into the Potomac River and that are located in the Baltimore Civil Works District. Also, the Pittsburgh Regulatory District includes Erie and Crawford Counties and those streams draining into Lake Erie; these are all located in the Buffalo Civil Works District.

Verify in advance with the USACE about which District above has regulatory jurisdiction.

**H. Navigable Waters in Pennsylvania Requiring USACE Permits.** A permit shall be obtained from the USACE for excavations, fills and construction of any structures (exclusive of bridges) in Navigable Waters of the United States. The administrative determinations made by each USACE District for the Navigable Waters of the United States in Pennsylvania are as follows:

**1.** Philadelphia District: The navigable waters in the Philadelphia District where permits are required are:

**a.** All tidal waters and their tributaries to the head of tide
**b.** Delaware River-----Delaware State Boundary to Hancock, New York and beyond
**c.** Lehigh River--------114 km (71 mi) to the S.R. 0940 Bridge in Carbon County
**d.** Manayunk Canal---3.2 km (2 mi) from Flat Rock Dam to Lock Street, Manayunk
**e.** Schuylkill River----177 km (110 mi) to Port Carbon

Section 10 permits are required for all construction activities in the above waters.

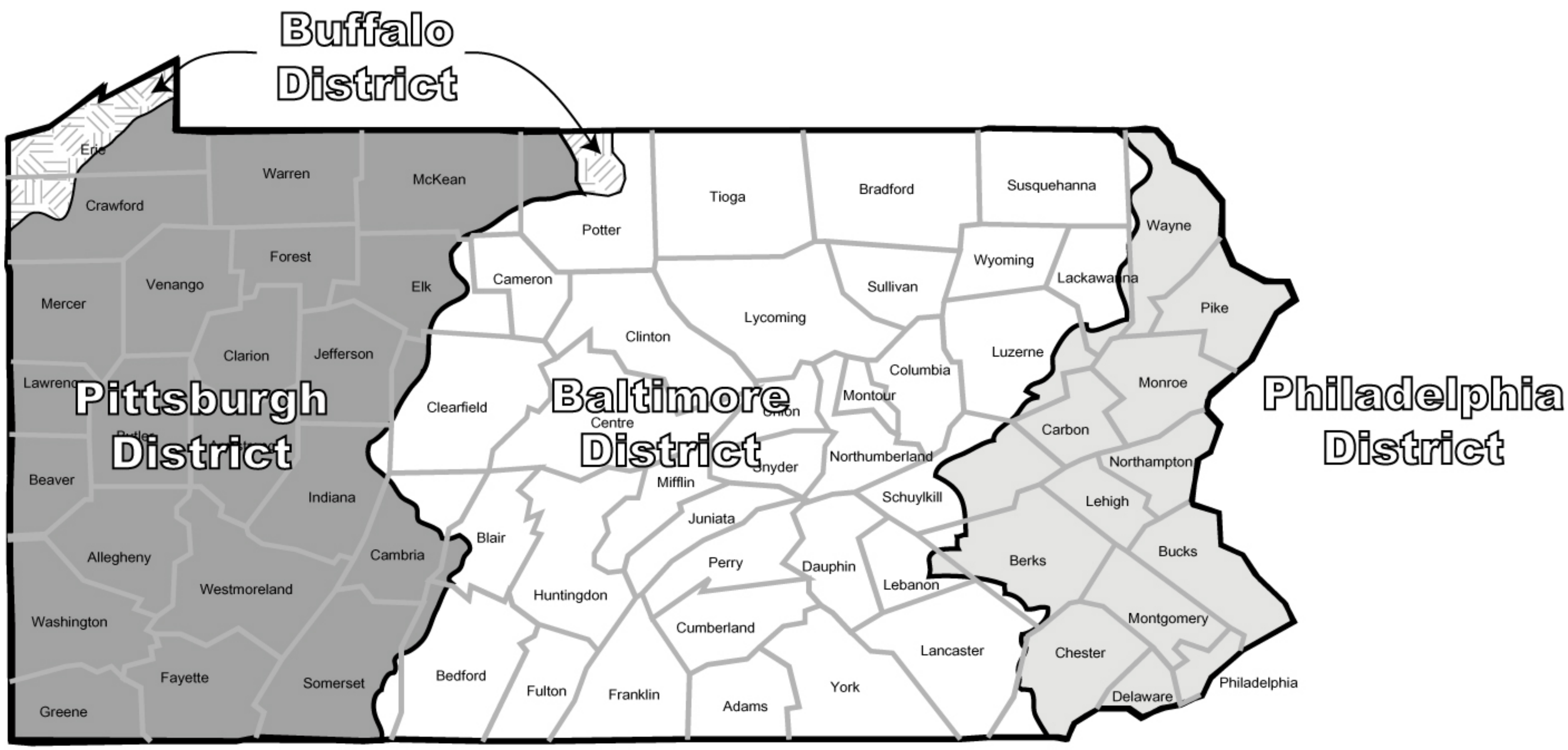


**FIGURE 10.9.1**
**US CORPS OF ENGINEERS DISTRICT BOUNDARIES IN PENNSYLVANIA**

**2.** Baltimore District: The Baltimore District exercises jurisdiction over the Susquehanna River from its mouth upstream as far as Lock Haven, Pennsylvania on the West Branch and Athens, Pennsylvania on the North Branch. The only tributary to the Susquehanna River over which the District exercises jurisdiction is Codorus Creek.

**3.** Pittsburgh District: The navigable waters in the Pittsburgh District, where permits are required, are the Ohio, Allegheny, and Monongahela Rivers, and their respective tributaries, as listed below (with jurisdiction in kilometers (miles) above mouth in parentheses):

**a.** Ohio River and Tributaries.

**1.** Ohio River (head to Ohio State Boundary)
**2.** Chartiers Creek (3.06 km (1.9 mi))
**3.** Beaver River (Entire Length) (34.60 km (21.5 mi))
**4.** Mahoning River (Tributary of Beaver River) (mouth to Ohio State Boundary)
**5.** Shenango River (Tributary of Beaver River) (2.90 km (1.8 mi))
**6.** Raccoon Creek (2.90 km (1.8 mi))
**7.** Little Beaver River (mouth to Ohio State Boundary)

**b.** Allegheny River and Tributaries.

**1.** Allegheny River (mouth to New York State Boundary)
**2.** Kiskiminetas River (43.13 km (26.8 mi))
**3.** Conemaugh River (Tributary of Kiskiminetas River (83.20 km (51.7 mi))
**4.** Crooked Creek (2.41 km (1.5 mi))
**5.** Mahoning Creek (2.25 km (1.4 mi))
**6.** Redbank Creek (2.41 km (1.5 mi))
**7.** Clarion River (144.84 km (90.0 mi))
**8.** Tionesta Creek (0.48 km (0.3 mi))

**c.** Monongahela River and Tributaries.

**1.** Monongahela River (mouth to West Virginia State Boundary)
**2.** Youghiogheny River (50.21 km (31.2 mi))
**3.** Ten Mile Creek (4.35 km (2.7 mi))
**4.** Cheat River (5.47 km (3.4 mi))

**d.** Lake Erie-------Ohio State Boundary to New York State Boundary. The entire length of Lake Erie is considered navigable for work below elevation 573.4.

**4.** Buffalo District: The navigable waters in the Buffalo District where the permits are required are:

**a.** Erie Harbor-----Located on Lake Erie (includes entrance channel)
**b.** Elk Creek-------Authorization Federal Project

Note: For projects in Pennsylvania, the Buffalo District has delegated its authority for regulatory permits to the Pittsburgh District.

Note that the provisions for permit requirements for the above listed waterways merely represent the views of the Department of the Army since jurisdiction of the United States can be conclusively determined only through judicial proceedings. Also note that the administrative determination of the navigable waters made by the USACE differs from that made by the US Coast Guard in many cases.

**I. USACE Water Resources Development Projects.** Figure 10.9.1 identifies the boundaries of the four USACE Districts with jurisdiction in Pennsylvania. Approvals for work affecting a USACE project shall be obtained from the District Engineer of the appropriate USACE District.

**J. Application for Permits from the USACE.** As indicated in Section 10.9, the USACE shall receive a copy of the waterway submission from PA DEP thru the Joint Permit Application process. Upon receipt of the submission, the USACE shall act on confirmation of the applicability of the nationwide permit or process an individual Department of the Army permit (USACE Section 404 permit).

Whenever an individual USACE permit is required, it should be prepared and submitted through the $JPA_2$ Expert System. The standard application form, as indicated in 33 CFR 325 (ENG Form 4345, "Application for Department of the Army Permit"), is to be prepared and submitted to the USACE. The application form is to include a complete description of the proposed activity including necessary drawings, sketches, or plans sufficient for public notice; the location, purpose, and need for the proposed activity; scheduling of the activity; the names and addresses of adjoining property owners; the location and dimensions of adjacent structures; and a list of authorizations required by other federal, interstate, state, or local agencies for the work, including all approvals received or denials already made.

The Joint Permit Applications are generally submitted after the National Environmental Policy Act (NEPA) or other environmental documents have been approved and the projects are in final design. This practice may not be considered effective for complex projects since the processing of the USACE permits during the final design stage may not provide sufficient lead time to meet the desired letting schedules. For these projects, the USACE permit action should be initiated concurrently with the NEPA process. The recommended procedure for the time merger of these actions is indicated in the following item.

**K. Advance Processing of Department of the Army Permit.** The required permit action, as to whether or not the proposed highway fill activities are subject to an individual USACE permit, should be determined during the Engineering and Environmental Scoping Field Views or at a time soon afterward. This determination should be completed by the Engineering District before an environmental document is prepared. If it is determined that an individual USACE permit is required and that an advance processing of the permit during the NEPA process is recommended, the Engineering District should submit the necessary information required for processing the permit application to the Bureau of Project Delivery in accordance with the following timings based on the applicable environmental procedures indicated:

**1.** Environmental Impact Statement (EIS):

**a.** Single or Preferred Build Alternative Recommended. Submit the Section 404 information as soon as the draft EIS is approved for distribution.

**b.** Multiple Build Alternatives Without Preferred Build Alternative Recommended. Submit the Section 404 information after the pre-final EIS identifying a selected alternative is reviewed by the FHWA Division and submitted to the FHWA Regional Office, but before the final EIS is approved.

**2.** Environmental Assessment (EA):

**a.** Single or Preferred Build Alternative Recommended. Submit the Section 404 information as soon as the EA is approved for availability.

**b.** Multiple Build Alternatives Without Preferred Build Alternative Recommended. Submit the Section 404 information after the revised EA is prepared, but before the Finding Of No Significant Impact (FONSI) is approved.

**3.** Categorical Exclusion (CE). Submit the Section 404 information as soon as the CE is approved and final design is initiated, preferably before the hydrologic and hydraulic report is submitted for a waterway approval.

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If an advance processing of the USACE permit during the NEPA process stage is recommended, the following information shall be submitted by the Engineering District to the Bureau of Project Delivery for processing the permit:

- Completed ENG Form 4345, "Application for Department of the Army Permit".

- Two copies of the environmental documents, as required.

- One set of original 8.5 in × 11 in drawings and five sets of the prints of the same, showing all pertinent features of the design layouts as well as those of all applicable and practical alternates of the temporary construction facilities.

For Department projects, the District Executive signs the application for a USACE permit. However, for municipal projects using Federal-aid funds, the Engineering District Office shall obtain from the applicable municipal authority and, after their review, submit to the Bureau of Project Delivery the above specified information including the completed permit application form (ENG Form 4345) signed by an appropriate municipal official.

Advancing the USACE permit submissions in the NEPA process stage requires that bridge, hydraulic and roadway design engineers be involved in the development of project concepts and continue to be involved as the concepts are refined. Certain designs should be prepared when details are needed to respond to the environmental and related engineering concerns raised as part of the NEPA process as to supply adequate information for the USACE permit applications. Detailed engineering design may not be required for the purpose of preparing the information required for submitting a permit application. Available information on location, fill quantities and facility design should be sufficient to focus on major permit issues. Additional detailed information may always be supplemented, as needed, after a permit application is submitted.

A USACE Section 404 permit submission should be prepared to cover the entire project limits for which an environmental document has been developed.

For a highway project involving both individual and nationwide permit activities, a single USACE permit submission should be developed to cover all of these activities. Pertinent information should be included in the submission to identify as to which type of the permit action (individual or nationwide permit) will be applicable to each specific location of the fill activity. In this case, the Engineering District should obtain from the PA DEP Regional Office a water quality certification covering all fill activities for the entire highway project unless all of the activities are covered by the PA DEP water obstruction permits.

**L. Application for Approvals for Work in USACE Water Resources Projects Areas.** The information required to obtain approval from the USACE for proposed work affecting a USACE water resources project area may vary with the nature of the project and/or the USACE District in which it is located. In many cases, the USACE will not grant an official approval until the final construction and structural drawings are developed. However, in some cases, the USACE may grant the approval based on a submission of the Hydrologic and Hydraulic Report.

For any proposed work which may affect the USACE water resources facilities, the District Executive may submit the Hydrologic and Hydraulic Report directly to the USACE for approval or comments. Upon receipt of the approval or comments from the USACE, the District Office shall take further actions that are required, if any, at the time the waterway approval is issued or at any appropriate time as deemed proper. It is the District Executive's responsibility to coordinate with the local flood control or water resources authorities, if necessary.

If the proposed work involves occupation of lands acquired by the Federal Government or alteration of the USACE facilities, a consent agreement shall be obtained from the USACE. It is the District Executive's responsibility to obtain the consent agreement directly from the USACE. In general, the consent agreement can be granted from the USACE only subsequent to the development of final plans.

**M. Preliminary Consultation with the USACE.** The District Executive is authorized to contact the USACE for a preliminary consultation for the proposed work involved. The preliminary consultation may often be necessary in order to avoid the unnecessary expense of preparing plans for work for which none are required, or for preparing materials that do not meet the requirements of the USACE. Copies of all correspondence with the USACE should be forwarded to the Central Office, Bureau of Project Delivery for information.

## 10.10 CHANNEL CONSTRUCTION INVOLVING FISHABLE STREAMS

**A. Design Procedures.** In order to give full consideration to the effects of channel construction on aquatic habitat, the following items shall be made part of the design procedures:

**1.** The stream affected shall be checked as to its inclusion in the stockable warm water and trout streams list. The stream of interest shall also be checked for inclusion on PFBC's list of Pennsylvania Stream Sections that Support Wild Trout Reproduction. PFBC updates its list annually, which is available through its website. PFBC shall be consulted if there is any question regarding its applicability. If the stream is on the list or is a private fishable stream, every effort should be made to avoid any channel encroachment caused by the highway section.

**2.** Where stream relocation is necessary, consideration should be given for the seeding of all disturbed areas, using rip rap for slope protection at locations where severe bank erosion would occur and placing stone deflectors or gabions (stone-filled wire baskets) for channel bottom protection to aid restoration of fish habitat. The relocated channel should bear resemblance to a natural stream having meandering alignment, varied stream widths, pools, chutes, boulders, etc. Sub-channels with an elevated floodplain should be provided (see Figure 10.10.1), if the new channel is wider than the existing one to accommodate flood discharges.

**3.** For stream relocation where excessive turbidity during construction shall affect fish life, consideration should be given to using a temporary channel for stream divergence.

**4.** When existing channels must be widened to provide for the design flood discharge, bench widening design should begin at the edge of stream 0.3 m (1 ft) (or more) above the stream bed whenever normal flow conditions permit (see Figure 10.10.1).

If the normal flow stream depth is greater than 0.3 m (1 ft), then the District Office should make a recommendation as to the depth of bench as part of the Hydrologic and Hydraulic Report submission. The depth indicated should be such as to preclude extreme channel widening. All disturbed areas should be seeded. The application of this design procedure should reduce the problem of construction equipment encroaching into the natural channel. In addition, the existing channel acts as a sub-channel for the passage of fish during low flow periods.

**5.** A low flow fish passage treatment, as indicated in Section 10.11, should be provided in a culvert to maintain a minimum flow for fish passage. Follow BD-632M unless specific project coordination with PFBC is required.

**6.** To further reduce stream turbidity and the destruction of fish habitat during construction, one of the following or similar types of stream crossings shall be used:

**a.** If the normal flow stream depth is greater than 0.3 m (1 ft), a battery of pipes with rock material in the embankment should be provided. These pipes should be of adequate strength to sustain embankment and vehicular loadings and of sufficient capacity (hydraulic computations necessary) to pass normal flow discharge with due consideration given to backwater effects.

**b.** If the stream bed is of earth or erodible material and the normal flow stream depth is less than 0.3 m (1 ft), a layer of rock approximately 0.3 m (1 ft) in depth by 6.0 m (20 ft) in width should be provided.

The above types of stream crossings are not all-inclusive. Other types of crossings may be considered. In every case, however, the Engineering District Office should make a recommendation as to the type and location of the stream crossing as part of the Hydrologic and Hydraulic Report submission.

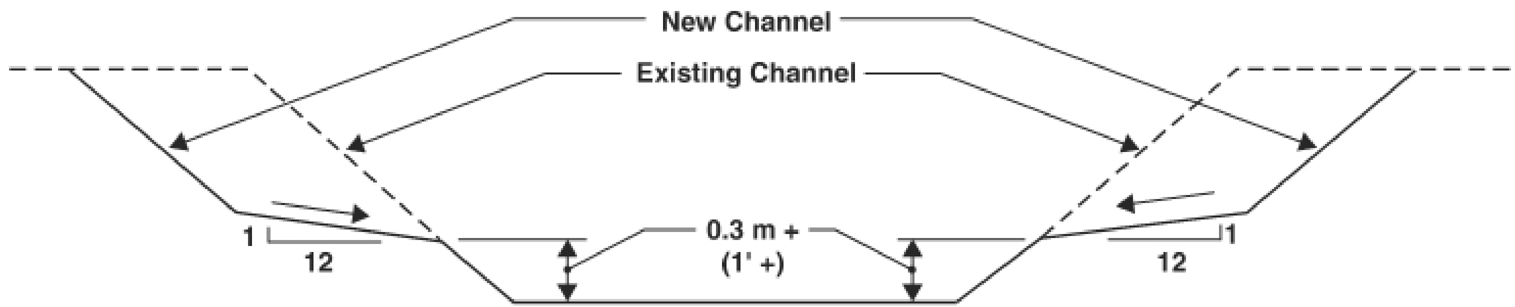


**FIGURE 10.10.1**
**Elevated Flood Plain**

**B. No Construction Crossing.** The following condition does not require a constructed crossing. If the stream bed is rock or non-erodible material and normal flow stream depth is less than 0.3 m (1 ft), a designated stream crossing should be made at the time of construction at the job site. This requirement for the temporary stream crossing is also applicable to non-fishable streams:

**1.** When existing channels are to be cleaned, a clam bucket, drag line or other types of construction equipment capable of working outside of the existing channel should be specified in the proposal to lessen the effects of the construction operation.

**2.** As indicated in Section 10.5, PFBC generally requires that no work is to be done in the stocked trout stream between March 1 and June 15. In the event a waiver of this restriction period is necessary, proper justifications, as required in Section 10.5, shall be provided.

**C. Plan Requirements.** Items in Section A above, with the exception of Item 1, shall be included in the plans of the Hydrologic and Hydraulic Report submission. In addition, they shall be designated on the final construction plans and included as part of the drawings and contract proposal.

## 10.11 LOW FLOW FISH PASSAGE THROUGH HIGHWAY CULVERTS

**A. Purpose.** The purpose of this Section is to provide general guidance regarding the design of economical and functional low flow fish passage systems through highway culverts.

**B. Background.** For culvert locations on streams with continuous flow, the ability to accommodate migrating and resident fish is an important design consideration. Excessive velocity, inadequate water depth, and high outlet elevations are the most frequent causes of fish passage problems. Culverts should be designed to simulate the natural stream bottom conditions by maintaining desirable flow depths and velocities. Constructing depressed culverts with baffles will help to simulate natural conditions by promoting the deposition and retention of stream bed material inside the culvert. The stream bed material between the baffles will increase the roughness coefficient of the culvert bottom, which helps to maintain the minimum flow depth and reduce velocities. Baffles or weir plates have been added for this purpose. Detailed guidelines for the design of baffle systems are provided apart from the description of other fish passage methods.

**C. Policy/Procedure.**

**1.** Arrangements for fish passage should be provided in culverts in streams having continuous flow.

**2.** The Hydrologic and Hydraulic Report shall contain information as to whether the stream flow is continuous or intermittent. The report shall contain all necessary information to support the choice of providing or not providing the fish passage through the culvert.

**3.** The proposed fish passage arrangements shall be indicated on the plans for the proposed culvert and be designed in accordance with BD-632M.

**D. Design Guidelines.**

**1.** The normal flow depth at any point in the culvert may vary from 0.08 m to 0.2 m (3 in to 8 in) depending upon the species and size of fish, but in any case, it shall not be less than 0.08 m (3 in).

**2.** A stable condition is required at the inlet and outlet ends of the culvert for a good fish passage system. Choked rip-rap or similar measures should be provided at the inlet and outlet ends of the culvert.

**3.** Measurement of Streambed Slope is needed to design a fish passage. Slope is a function of elevation drop and distance. Calculation of a bed slope of a certain section of a stream depends on the location of the measurement points. Selection of the measurement points is not an exact science. It is rather a matter of personal judgment. Multiple measurements will likely result in slightly different slopes, and streambed slopes will change over time. An approximate slope can be obtained and is all that is necessary for analysis of fish passage through culverts. An approximate slope is obtained by reviewing the profile of the surveyed streambed and measuring the slope between two points. To develop the stream bed profile, the elevation of the stream thalweg is measured and plotted. Elevations of plunge pools may be included in the streambed profile, but caution should be exercised if using these points as one of the two slope measurement points. Since the survey extends 100 ft to 500 ft upstream and downstream of the structure, the slopes are measured over a length of 200 to 1000 ft. This distance will average out any localized extreme slopes. When measuring the streambed slope, judgment should be used to select measurement points that are most representative of the average streambed slope. Two or more measurements of slope should be averaged to obtain the average streambed slope.

**4.** The selection of the type (see E below) of fish passage depends upon the conditions of the stream site, ease of installation, and maintenance.

**E. Fish Passage Methods/Alternates.**

**1.** Culverts with Fish Baffles (see Figures 10.11.1 and 10.11.2). This section provides guidance to designers on the hydraulic properties of culverts with baffles, configured according to Publication 218M, *Standards for Bridge Design*, Drawing BD-632M titled, "Standard, R.C. Box Culvert." BD-632M provides miscellaneous details for stream grades less than or equal to 4 percent and for grades greater than 4 percent.

Two methods of modeling culverts with fish baffles are provided as follows:

**a.** Standard Method. The standard method represents the most simplified method of modeling culverts and requires the following:

**(1)** Box culverts with fish baffles designed in accordance with BD-632M are to be modeled assuming that the 0.3 m (1 ft) depression below the natural stream bed elevation is filled in with sediment. For example, a 3.0 m × 1.8 m (10 ft × 6 ft) culvert opening depressed 0.3 m (1 ft) in accordance with BD-632M should be modeled with a 3.0 m × 1.5 m (10 ft × 5 ft) hydraulic opening.

**(2)** The Manning's n-value for the bottom of the hydraulic opening should be assumed to be the Manning's n-value for the natural channel material of the stream and the Manning's n-value for the sides and top of the culvert should be for the material of the culvert.

**(3)** This modeling approach represents culverts filled with sediment between the baffles up to the depressed depth and can be applied to culverts with fish baffles under any flow condition.

Figure 10.11.1 is a graphic representation of the standard method for modeling the hydraulics of a depressed culvert.

**b.** Alternate Method. An alternate method of modeling culverts with fish baffles has been developed through research conducted by FHWA in the 1970's. Details of the research are contained in the publication, *Design Consideration and Calculations for Fishways Through a Box Culvert* by R. M. Chang and Jerome M. Norman. This alternate method involves the use of special fish baffle Manning n-values in conjunction with modeling the full opening of the culvert. The assumption is that all sediment will be flushed from the culvert from high stream velocities leading up to the critical event. In many cases, this approach will result in a more hydraulically efficient culvert than the standard method for the full flow condition. The use of special fish baffle Manning's n-values and full opening of the culvert requires the following:

**(1)** Proof that the culvert is flowing full for selected design events.

**(2)** Consideration of roadway overtopping which may occur before the culvert flows full.

**(3)** Downstream tailwater submergence which may reduce velocities in the culvert.

**(4)** $D_{50}$ of streambed material to determine critical velocity to flush the sediment from the culvert.

**(5)** Velocity through the culvert during design events to determine if sediment is removed from the culvert.

**(6)** The hydraulic opening modeled is the full opening.

Table 10.11.1 and Table 10.11.2 present Manning's n-values for the alternate method for culverts with fish baffles for slopes greater than 4 percent and for slopes less than or equal to 4 percent. Figure 10.11.2 is a graphic showing the alternate method for modeling culvert hydraulics.

**Because of the complexities in using the special fish baffle n-values, the alternate method of modeling culverts with fish baffles may be used only in special circumstances with approval from the Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section, Hydrology and Hydraulics Unit.**

**2.** Open Bottom Culverts (see Figure 10.11.3). Some culverts are supported on spread foundations to permit retention of the natural streambed. RC frame culverts, open bottom metal plate arches or slab bridges are included in this category. While open bottom culverts may be a preferred type from the standpoint of fish passage, rock protection required for protection against scour may encompass a large area of the streambed beneath the structure. Thus the ability to retain the natural streambed may be limited. Additionally, open bottom culverts may not always be the most advantageous from a hydraulic, structural, or foundation point of view.

**F. Multi-Cell Culvert Installations.** In multi-cell culvert installations, it is generally sufficient to install baffles in only one barrel. The other(s) then act(s) as a free channel. The only requirement regarding the free flow barrel is that a weir of a sufficient height (usually 450 mm (18 in)) be installed across the inlet to deflect low flow through the baffled culvert. (See Publication 218M, *Standards for Bridge Design*, Drawing BD-632M, for twin cell details.)

For multi-cell depressed culverts, weirs may be required at the entrance of some cells to provide adequate flow depths in the primary cell.

In certain cases, it is possible to place the invert of the primary barrel lower than the others to increase the depth of flow in the primary barrel.

**G. Conclusions.** Each stream and each site have different conditions that require consideration in the design of a fish passage system. During the project development process, direct coordination is recommended between the Department and PFBC to establish the design considerations for each specific stream and site. This coordination should occur as early as practical during the design phase to ensure that all project objectives are met.

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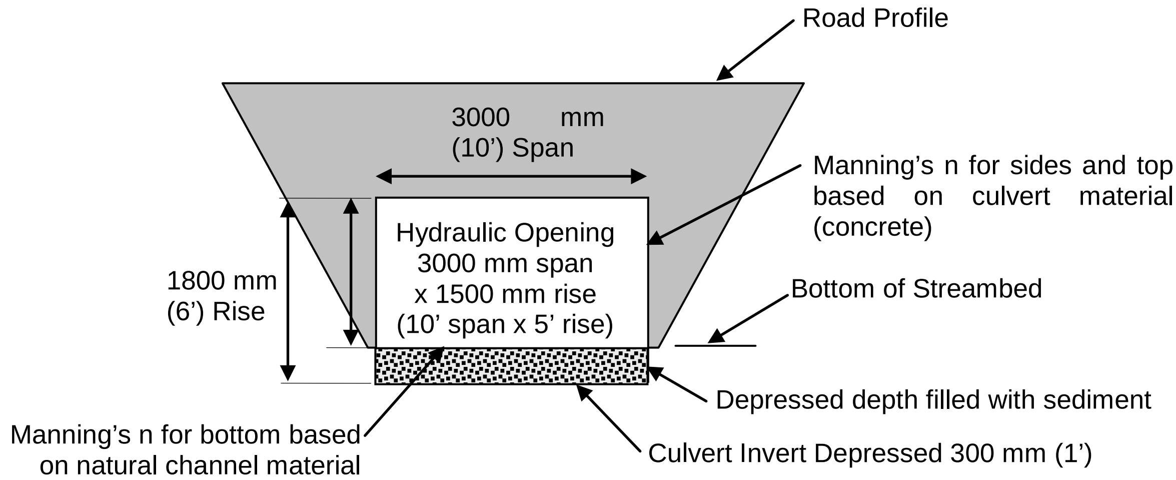
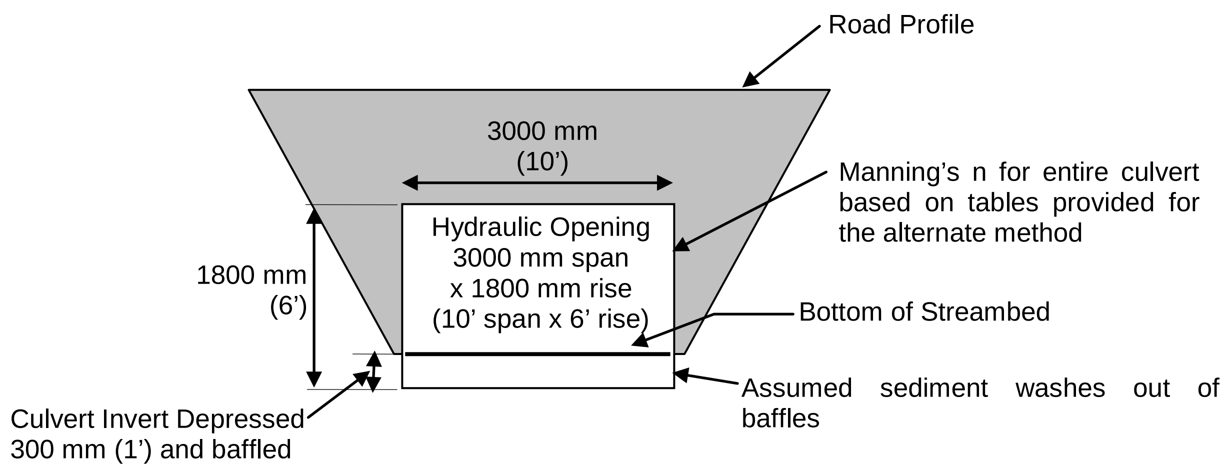



**FIGURE 10.11.1**
**DEPRESSED CULVERT WITH FISH BAFFLES**
**USING THE STANDARD METHOD**




NOTE: Using the Alternate Method must be approved by Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section, Hydrology and Hydraulics Unit.

**FIGURE 10.11.2**
**DEPRESSED CULVERT WITH FISH BAFFLES**
**USING THE ALTERNATE METHOD**

# TABLE 10.11.1 (METRIC)
# MANNING'S "n" VALUES FOR ALTERNATE METHOD OF MODELING BOX CULVERTS WITH FISH BAFFLES AND SLOPE > 4%

| RISE OF CULVERT (mm) | SPAN OF CULVERT (mm) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1800 | 2100 | 2400 | 2700 | 3000 | 3300 | 3600 | 3900 | 4200 | 4500 | 4800 | 5100 | 5400 | 5700 | 6000 | 6300 | 6600 | 6900 | 7200 |
| 1200 | 0.046 | 0.048 | 0.049 | 0.047 | 0.046 | 0.044 | 0.043 | 0.042 | 0.041 | 0.040 | 0.039 | 0.038 | 0.037 | 0.037 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 |
| 1350 | 0.045 | 0.047 | 0.048 | 0.046 | 0.045 | 0.044 | 0.043 | 0.041 | 0.040 | 0.040 | 0.039 | 0.038 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 |
| 1500 | 0.044 | 0.046 | 0.047 | 0.046 | 0.044 | 0.043 | 0.042 | 0.041 | 0.040 | 0.039 | 0.038 | 0.038 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 |
| 1650 | 0.044 | 0.045 | 0.047 | 0.045 | 0.044 | 0.043 | 0.042 | 0.041 | 0.040 | 0.039 | 0.038 | 0.038 | 0.037 | 0.036 | 0.036 | 0.035 | 0.034 | 0.034 | 0.033 |
| 1800 | 0.043 | 0.045 | 0.046 | 0.045 | 0.044 | 0.042 | 0.041 | 0.040 | 0.040 | 0.039 | 0.038 | 0.037 | 0.037 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 |
| 1950 | 0.042 | 0.044 | 0.045 | 0.044 | 0.043 | 0.042 | 0.041 | 0.040 | 0.039 | 0.039 | 0.038 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 |
| 2100 | 0.042 | 0.043 | 0.045 | 0.044 | 0.043 | 0.042 | 0.041 | 0.040 | 0.039 | 0.038 | 0.038 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 |
| 2250 | 0.041 | 0.043 | 0.044 | 0.043 | 0.042 | 0.041 | 0.040 | 0.039 | 0.039 | 0.038 | 0.037 | 0.037 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.034 | 0.033 |
| 2400 | 0.040 | 0.042 | 0.044 | 0.043 | 0.042 | 0.041 | 0.040 | 0.039 | 0.038 | 0.038 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 | 0.033 |
| 2550 | 0.040 | 0.042 | 0.043 | 0.042 | 0.041 | 0.040 | 0.040 | 0.039 | 0.038 | 0.037 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 | 0.033 |
| 2700 | 0.039 | 0.041 | 0.043 | 0.042 | 0.041 | 0.040 | 0.039 | 0.039 | 0.038 | 0.037 | 0.037 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.034 | 0.033 | 0.033 |
| 2850 | 0.039 | 0.041 | 0.042 | 0.041 | 0.040 | 0.040 | 0.039 | 0.038 | 0.038 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 | 0.033 | 0.033 |
| 3000 | 0.038 | 0.040 | 0.042 | 0.041 | 0.040 | 0.039 | 0.039 | 0.038 | 0.037 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 | 0.033 | 0.032 |
| 3150 | 0.038 | 0.040 | 0.041 | 0.040 | 0.040 | 0.039 | 0.038 | 0.038 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.034 | 0.033 | 0.033 | 0.032 |
| 3300 | 0.037 | 0.039 | 0.041 | 0.040 | 0.039 | 0.039 | 0.038 | 0.037 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 | 0.033 | 0.033 | 0.032 |
| 3450 | 0.037 | 0.039 | 0.040 | 0.040 | 0.039 | 0.038 | 0.038 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 | 0.033 | 0.032 | 0.032 |
| 3600 | 0.036 | 0.038 | 0.040 | 0.039 | 0.039 | 0.038 | 0.037 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 | 0.033 | 0.033 | 0.032 | 0.032 |
| 3750 | 0.036 | 0.038 | 0.040 | 0.039 | 0.038 | 0.038 | 0.037 | 0.037 | 0.036 | 0.035 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 | 0.033 | 0.033 | 0.032 | 0.032 |
| 3900 | 0.036 | 0.037 | 0.039 | 0.039 | 0.038 | 0.037 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.034 | 0.033 | 0.033 | 0.032 | 0.032 | 0.032 |
| 4050 | 0.035 | 0.037 | 0.039 | 0.038 | 0.038 | 0.037 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 | 0.033 | 0.033 | 0.032 | 0.032 | 0.032 |
| 4200 | 0.035 | 0.037 | 0.038 | 0.038 | 0.037 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.034 | 0.033 | 0.033 | 0.032 | 0.032 | 0.032 | 0.031 |
| 4350 | 0.034 | 0.036 | 0.038 | 0.038 | 0.037 | 0.036 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 | 0.033 | 0.033 | 0.032 | 0.032 | 0.032 | 0.031 |
| 4500 | 0.034 | 0.036 | 0.038 | 0.037 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.034 | 0.033 | 0.033 | 0.033 | 0.032 | 0.032 | 0.032 | 0.031 |
| 4650 | 0.034 | 0.036 | 0.037 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 | 0.033 | 0.033 | 0.032 | 0.032 | 0.032 | 0.031 | 0.031 |
| 4800 | 0.033 | 0.035 | 0.037 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.034 | 0.033 | 0.033 | 0.033 | 0.032 | 0.032 | 0.032 | 0.031 | 0.031 |

NOTES:

1. Use of the Alternate Method of Modeling Box Culverts with Fish Baffles requires approval from the Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section, Hydrology and Hydraulics Unit.
2. Manning's n values for standard baffle configuration in culvert on slope as per BD-632M. For other baffle configurations, see reference in Note 2.
3. n-values calculated based on methodology in Design Considerations and Calculations for Fishways through a Box Culvert by Fred F. M. Chang and Jerome M. Norman (Sept. 1976, FHWA).
4. Above n values assume full flow.
5. n-values are for the entire culvert, bottom, top, and sides.

## TABLE 10.11.1 (ENGLISH)
## MANNING'S "n" VALUES FOR ALTERNATE METHOD OF MODELING BOX CULVERTS WITH FISH BAFFLES AND SLOPE > 4%

| RISE OF CULVERT (ft) | SPAN OF CULVERT (ft) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 4.0 | 0.046 | 0.048 | 0.049 | 0.047 | 0.046 | 0.044 | 0.043 | 0.042 | 0.041 | 0.040 | 0.039 | 0.038 | 0.037 | 0.037 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 |
| 4.5 | 0.045 | 0.047 | 0.048 | 0.046 | 0.045 | 0.044 | 0.043 | 0.041 | 0.040 | 0.040 | 0.039 | 0.038 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 |
| 5.0 | 0.044 | 0.046 | 0.047 | 0.046 | 0.044 | 0.043 | 0.042 | 0.041 | 0.040 | 0.039 | 0.038 | 0.038 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 |
| 5.5 | 0.044 | 0.045 | 0.047 | 0.045 | 0.044 | 0.043 | 0.042 | 0.041 | 0.040 | 0.039 | 0.038 | 0.038 | 0.037 | 0.036 | 0.036 | 0.035 | 0.034 | 0.034 | 0.033 |
| 6.0 | 0.043 | 0.045 | 0.046 | 0.045 | 0.044 | 0.042 | 0.041 | 0.040 | 0.040 | 0.039 | 0.038 | 0.037 | 0.037 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 |
| 6.5 | 0.042 | 0.044 | 0.045 | 0.044 | 0.043 | 0.042 | 0.041 | 0.040 | 0.039 | 0.039 | 0.038 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 |
| 7.0 | 0.042 | 0.043 | 0.045 | 0.044 | 0.043 | 0.042 | 0.041 | 0.040 | 0.039 | 0.038 | 0.038 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 |
| 7.5 | 0.041 | 0.043 | 0.044 | 0.043 | 0.042 | 0.041 | 0.040 | 0.039 | 0.039 | 0.038 | 0.037 | 0.037 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.034 | 0.033 |
| 8.0 | 0.040 | 0.042 | 0.044 | 0.043 | 0.042 | 0.041 | 0.040 | 0.039 | 0.038 | 0.038 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 | 0.033 |
| 8.5 | 0.040 | 0.042 | 0.043 | 0.042 | 0.041 | 0.040 | 0.040 | 0.039 | 0.038 | 0.037 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 | 0.033 |
| 9.0 | 0.039 | 0.041 | 0.043 | 0.042 | 0.041 | 0.040 | 0.039 | 0.039 | 0.038 | 0.037 | 0.037 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.034 | 0.033 | 0.033 |
| 9.5 | 0.039 | 0.041 | 0.042 | 0.041 | 0.040 | 0.040 | 0.039 | 0.038 | 0.038 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 | 0.033 | 0.033 |
| 10.0 | 0.038 | 0.040 | 0.042 | 0.041 | 0.040 | 0.039 | 0.039 | 0.038 | 0.037 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 | 0.033 | 0.032 |
| 10.5 | 0.038 | 0.040 | 0.041 | 0.040 | 0.040 | 0.039 | 0.038 | 0.038 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.034 | 0.033 | 0.033 | 0.032 |
| 11.0 | 0.037 | 0.039 | 0.041 | 0.040 | 0.039 | 0.039 | 0.038 | 0.037 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 | 0.033 | 0.033 | 0.032 |
| 11.5 | 0.037 | 0.039 | 0.040 | 0.040 | 0.039 | 0.038 | 0.038 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 | 0.033 | 0.032 | 0.032 |
| 12.0 | 0.036 | 0.038 | 0.040 | 0.039 | 0.039 | 0.038 | 0.037 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 | 0.033 | 0.033 | 0.032 | 0.032 |
| 12.5 | 0.036 | 0.038 | 0.040 | 0.039 | 0.038 | 0.038 | 0.037 | 0.037 | 0.036 | 0.035 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 | 0.033 | 0.033 | 0.032 | 0.032 |
| 13.0 | 0.036 | 0.037 | 0.039 | 0.039 | 0.038 | 0.037 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.034 | 0.033 | 0.033 | 0.032 | 0.032 | 0.032 |
| 13.5 | 0.035 | 0.037 | 0.039 | 0.038 | 0.038 | 0.037 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 | 0.033 | 0.033 | 0.032 | 0.032 | 0.032 |
| 14.0 | 0.035 | 0.037 | 0.038 | 0.038 | 0.037 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.034 | 0.033 | 0.033 | 0.032 | 0.032 | 0.032 | 0.031 |
| 14.5 | 0.034 | 0.036 | 0.038 | 0.038 | 0.037 | 0.036 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 | 0.033 | 0.033 | 0.032 | 0.032 | 0.032 | 0.031 |
| 15.0 | 0.034 | 0.036 | 0.038 | 0.037 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.034 | 0.033 | 0.033 | 0.033 | 0.032 | 0.032 | 0.032 | 0.031 |
| 15.5 | 0.034 | 0.036 | 0.037 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 | 0.033 | 0.033 | 0.032 | 0.032 | 0.032 | 0.031 | 0.031 |
| 16.0 | 0.033 | 0.035 | 0.037 | 0.037 | 0.036 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.034 | 0.033 | 0.033 | 0.033 | 0.032 | 0.032 | 0.032 | 0.031 | 0.031 |

NOTES:

1. Use of the Alternate Method of Modeling Box Culverts with Fish Baffles requires approval from the Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section, Hydrology and Hydraulics Unit.
2. Manning's n values for standard baffle configuration in culvert on slope as per BD-632M. For other baffle configurations, see reference in Note 2.
3. n-values calculated based on methodology in Design Considerations and Calculations for Fishways through a Box Culvert by Fred F. M. Chang and Jerome M. Norman (Sept. 1976, FHWA).
4. Above n values assume full flow.
5. n-values are for the entire culvert, bottom, top, and sides.

## TABLE 10.11.2 (METRIC)
## MANNING'S "n" VALUES FOR ALTERNATE METHOD OF MODELING BOX CULVERTS WITH FISH BAFFLES AND SLOPE ≤ 4%

| RISE OF CULVERT (ft) | SPAN OF CULVERT (ft) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1800 | 2100 | 2400 | 2700 | 3000 | 3300 | 3600 | 3900 | 4200 | 4500 | 4800 | 5100 | 5400 | 5700 | 6000 | 6300 | 6600 | 6900 | 7200 |
| 1200 | 0.034 | 0.035 | 0.035 | 0.034 | 0.033 | 0.032 | 0.032 | 0.031 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 |
| 1350 | 0.033 | 0.034 | 0.035 | 0.034 | 0.033 | 0.032 | 0.031 | 0.031 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 |
| 1500 | 0.033 | 0.034 | 0.035 | 0.034 | 0.033 | 0.032 | 0.031 | 0.030 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 |
| 1650 | 0.032 | 0.033 | 0.034 | 0.033 | 0.032 | 0.032 | 0.031 | 0.030 | 0.030 | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 |
| 1800 | 0.032 | 0.033 | 0.034 | 0.033 | 0.032 | 0.031 | 0.031 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.025 | 0.025 |
| 1950 | 0.031 | 0.032 | 0.033 | 0.032 | 0.032 | 0.031 | 0.030 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 |
| 2100 | 0.031 | 0.032 | 0.033 | 0.032 | 0.031 | 0.031 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.028 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 |
| 2250 | 0.030 | 0.031 | 0.032 | 0.032 | 0.031 | 0.030 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 |
| 2400 | 0.030 | 0.031 | 0.032 | 0.031 | 0.031 | 0.030 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 |
| 2550 | 0.029 | 0.031 | 0.032 | 0.031 | 0.030 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.028 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 |
| 2700 | 0.029 | 0.030 | 0.031 | 0.031 | 0.030 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 |
| 2850 | 0.029 | 0.030 | 0.031 | 0.030 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.028 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 |
| 3000 | 0.028 | 0.030 | 0.031 | 0.030 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 |
| 3150 | 0.028 | 0.029 | 0.030 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 |
| 3300 | 0.028 | 0.029 | 0.030 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 |
| 3450 | 0.027 | 0.029 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 | 0.024 |
| 3600 | 0.027 | 0.028 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.028 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 | 0.024 |
| 3750 | 0.027 | 0.028 | 0.029 | 0.029 | 0.028 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.024 |
| 3900 | 0.027 | 0.028 | 0.029 | 0.029 | 0.028 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 | 0.024 | 0.024 |
| 4050 | 0.026 | 0.028 | 0.029 | 0.028 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 | 0.024 | 0.024 |
| 4200 | 0.026 | 0.027 | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 | 0.024 | 0.024 | 0.024 |
| 4350 | 0.026 | 0.027 | 0.028 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 | 0.024 | 0.024 | 0.024 |
| 4500 | 0.026 | 0.027 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.024 | 0.024 | 0.024 |
| 4650 | 0.025 | 0.027 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 | 0.024 | 0.024 | 0.024 | 0.024 |
| 4800 | 0.025 | 0.027 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.024 | 0.024 | 0.024 | 0.024 |

NOTES:

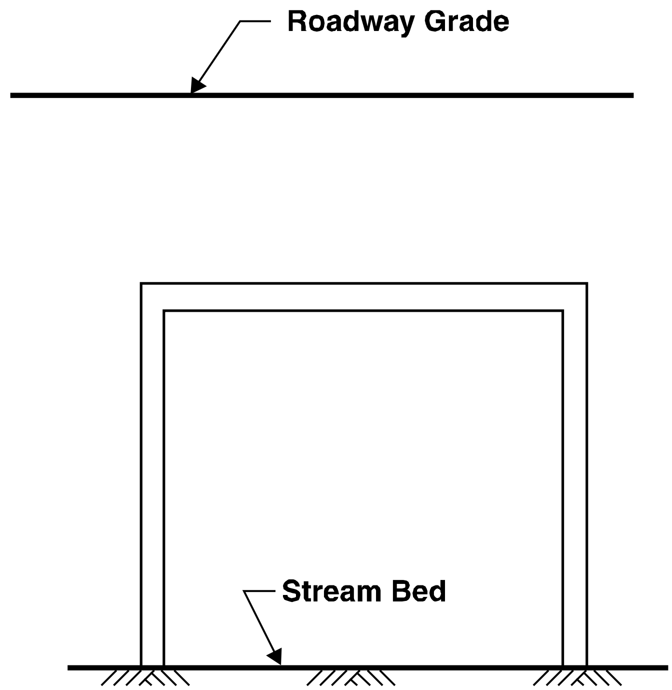
1. Use of the Alternate Method of Modeling Box Culverts with Fish Baffles requires approval from the Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section, Hydrology and Hydraulics Unit.
2. Manning's n values for standard baffle configuration in culvert on slope as per BD-632M. For other baffle configurations, see reference in Note 2.
3. n-values calculated based on methodology in Design Considerations and Calculations for Fishways through a Box Culvert by Fred F. M. Chang and Jerome M. Norman (Sept. 1976, FHWA).
4. Above n values assume full flow.
5. n-values are for the entire culvert, bottom, top, and sides.

## TABLE 10.11.2 (ENGLISH)
## MANNING'S "n" VALUES FOR ALTERNATE METHOD OF MODELING BOX CULVERTS WITH FISH BAFFLES AND SLOPE ≤ 4%

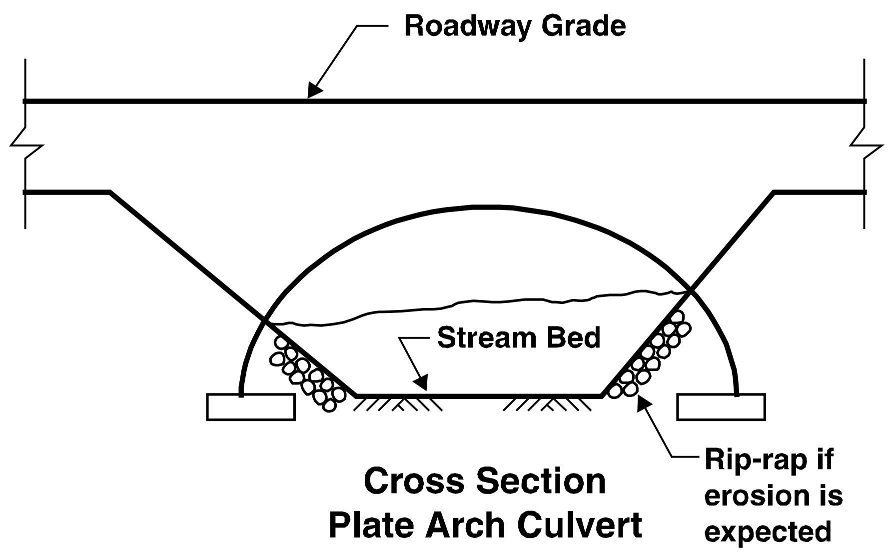
| RISE OF CULVERT (ft) | SPAN OF CULVERT (ft) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 4.0 | 0.034 | 0.035 | 0.035 | 0.034 | 0.033 | 0.032 | 0.032 | 0.031 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 |
| 4.5 | 0.033 | 0.034 | 0.035 | 0.034 | 0.033 | 0.032 | 0.031 | 0.031 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 |
| 5.0 | 0.033 | 0.034 | 0.035 | 0.034 | 0.033 | 0.032 | 0.031 | 0.030 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 |
| 5.5 | 0.032 | 0.033 | 0.034 | 0.033 | 0.032 | 0.032 | 0.031 | 0.030 | 0.030 | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 |
| 6.0 | 0.032 | 0.033 | 0.034 | 0.033 | 0.032 | 0.031 | 0.031 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.025 | 0.025 |
| 6.5 | 0.031 | 0.032 | 0.033 | 0.032 | 0.032 | 0.031 | 0.030 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 |
| 7.0 | 0.031 | 0.032 | 0.033 | 0.032 | 0.031 | 0.031 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.028 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 |
| 7.5 | 0.030 | 0.031 | 0.032 | 0.032 | 0.031 | 0.030 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 |
| 8.0 | 0.030 | 0.031 | 0.032 | 0.031 | 0.031 | 0.030 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 |
| 8.5 | 0.029 | 0.031 | 0.032 | 0.031 | 0.030 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.028 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 |
| 9.0 | 0.029 | 0.030 | 0.031 | 0.031 | 0.030 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 |
| 9.5 | 0.029 | 0.030 | 0.031 | 0.030 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.028 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 |
| 10.0 | 0.028 | 0.030 | 0.031 | 0.030 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 |
| 10.5 | 0.028 | 0.029 | 0.030 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 |
| 11.0 | 0.028 | 0.029 | 0.030 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 |
| 11.5 | 0.027 | 0.029 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 | 0.024 |
| 12.0 | 0.027 | 0.028 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.028 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 | 0.024 |
| 12.5 | 0.027 | 0.028 | 0.029 | 0.029 | 0.028 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.024 |
| 13.0 | 0.027 | 0.028 | 0.029 | 0.029 | 0.028 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 | 0.024 | 0.024 |
| 13.5 | 0.026 | 0.028 | 0.029 | 0.028 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 | 0.024 | 0.024 |
| 14.0 | 0.026 | 0.027 | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 | 0.024 | 0.024 | 0.024 |
| 14.5 | 0.026 | 0.027 | 0.028 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 | 0.024 | 0.024 | 0.024 |
| 15.0 | 0.026 | 0.027 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.024 | 0.024 | 0.024 |
| 15.5 | 0.025 | 0.027 | 0.028 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 | 0.024 | 0.024 | 0.024 | 0.024 |
| 16.0 | 0.025 | 0.027 | 0.028 | 0.027 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.024 | 0.024 | 0.024 | 0.024 |

NOTES:

1. Use of the Alternate Method of Modeling Box Culverts with Fish Baffles requires approval from the Bureau of Project Quality, Highway Delivery Division, Highway Design and Technology Section, Hydrology and Hydraulics Unit.
2. Manning's n values for standard baffle configuration in culvert on slope as per BD-632M. For other baffle configurations, see reference in Note 2.
3. n-values calculated based on methodology in Design Considerations and Calculations for Fishways through a Box Culvert by Fred F. M. Chang and Jerome M. Norman (Sept. 1976, FHWA).
4. Above n values assume full flow.
5. n-values are for the entire culvert, bottom, top, and sides.




**Cross Section**
**R C Frame Culvert**




**Cross Section**
**Plate Arch Culvert**

## FIGURE 10.11.3
## Open Bottom Culverts

## 10.12 ABANDONED WATER SUPPLY SOURCES

All abandoned water supply sources, such as wells and springs, located within the proposed right-of-way shall be filled, removed, sealed and/or altered to prevent access or accidental injury and to prevent pollution of the ground water.

Wells or springs shall not be used to dispose of liquid or solid waste materials under any circumstances.

The Assistant District Executive for Design shall be consulted in justifying decisions reached on the handling of abandoned water supply sources or when pulling the casing may be undesirable or unfeasible.

The location of all water supplies within the project right-of-way shall be shown on the Right-of-Way Plans.

**A. Standard Special Provisions.** The Department's Standard Special Provision (SSP), "Section 214 - Sealing Abandoned Water Wells and Springs," provides guidance in developing specifications for sealing abandoned water wells and springs. This SSP is found in ECMS's menu "Construction Projects" under "Resources", then "Special Provisions". Select "Advanced Search", and then choose the Section Related Index and Active Status. The Section Related Index addresses Section related issues that are no longer contained in Publication 408, *Specifications*. It describes the materials involved, construction of drilled or driven wells, dug wells, or springs, and the measurement and payment.

This SSP should only be considered as proper abandonment for dug wells (Section 214.3(b)) and springs (Section 214.3(c)). Proper considerations for drilled or driven wells (Section 214.3(a)) are discussed in Section 10.12.B below.

**B. Drilled or Driven Wells.** Drilled or driven water supply wells that are encountered during roadway construction or maintenance activities may occur in a variety of situations (e.g., cavernous rock, multiple aquifers, artesian wells, unconfined or semi-confined aquifers, flowing wells, etc.). PA DEP's publication, *Groundwater Monitoring Guidance Manual*, Chapter 7, Well Abandonment Procedures, should be referenced for the proper abandonment of water supply wells that are drilled or driven (Chapter 10, Appendix E, Reference 10). This chapter in the manual includes a summary of well abandonment procedures (i.e., the use of casing seals, aggregate, sealants, bridge seals or plugs, and/or the cutting of ell casings). A standard Well Abandonment Form shall be sent to the Pennsylvania Department of Conservation and Natural Resources' Bureau of Topographic and Geologic Survey (Survey) at least 10 days before any well is decommissioned by sealing and/or filling activities.

The *Groundwater Monitoring Guidance Manual*, Chapter 7 identifies materials that are used during well abandonment procedures for sealing wells that have been drilled or driven, including wells that have been completed in multiple groundwater aquifers. These materials include aggregate, sealants (e.g., neat cement grout, concrete grout with associated additives (i.e., bentonite, calcium chloride), high-solids sodium bentonite, or chip bentonite), and bridge seals.

**C. Dug Wells.** Abandoned dug wells shall be filled completely with concrete and finished flush with the surface.

**D. Springs.** Springs shall be enclosed with satisfactory spring boxes and with suitable overflow pipes to collect and direct the flow to inlets or parallel ditches.

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# CHAPTER 10, APPENDIX A

## PROCEDURES FOR COORDINATING HIGHWAY ENCROACHMENTS ON FLOODPLAINS WITH THE FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA)

# MEMORANDUM

'ocedures for Coordinating Highway
.ncroachments on Floodplains with the
Federal Emergency Management Agency
(FEMA)

JUN 25 1982

HNG-31

Associate Administrator for
Engineering and Operations
Washington, D.C. 20590

Regional Federal Highway
Administrators
Regions 1-10
Direct Federal Division Engineers

Attached are copies of the subject procedures and a letter from Mr. Richard W. Krimm of FEMA dated June 7, 1982. Mr. Krimm has endorsed the procedures and has distributed them to the field offices of FEMA. Please send copies of these procedures to the FHWA Divisions Offices and the States in your Region.

We believe these procedures provide excellent guidance in regard to meeting our responsibility to be consistent with the standards of the National Flood Insurance Program (NFIP) as set forth in the Federal-Aid Highway Program Manual (FHPM) 6-7-3-2, Location and Hydraulic Design of Encroachments ‑n Flood Plains. The procedures establish some flexibility for achieving st-effective encroachments on floodplains within communities that are in ‑ne NFIP. If an encroachment is proposed within an NFIP community, the economic consequences of alternatives can be assessed using the analysis procedures in Hydraulic Engineering Circular No. 17 (HEC 17), the Design of Encroachments on Floodplains Using Risk Analysis. This assessment/analysis can then be used, if needed, to support the community's application to FEMA for approval of an alternate floodway or a floodway revision. For all locations outside of NFIP communities or NFIP identified flood hazard areas, FHPM 6-7-3-2 shall be followed for encroachment design. This policy requires that encroachment designs be supported, as appropriate, by a risk assessment or risk analysis. Economic (risk) analysis, if appropriate, can be accomplished using the guidelines in HEC 17.

We encourage you to work with the States to implement these procedures as a part of Program Emphasis Area Number 2, Cost Effective Design and Construction. We are aware that some State environmental agencies have adopted strict requirements for encroachments on all floodplains, whether rural or urban in nature. These requirements allow the highway designer little discretion to achieve cost-effective designs. In such cases, this subject should be discussed with appropriate State personnel so that practicable State floodplain encroachment requirements can be developed. Implementation of these procedures, along with the economic (risk) assessment/analysis design process required by FHPM 6-7-3-2, has a high potential for achieving significant cost savings in the Federal-aid Highway Program.

/s/
R. D. Morgan

Attachments

# Federal Emergency Management Agency

Washington, D.C. 20472

7 JUN 1982

Mr. R. D. Morgan
Associate Administrator for Engineering
And Traffic Operations
Federal Highway Administration
Department of Transportation
Washingtin, D.C. 20590

Dear Mr. Morgan:

This is in response to your letter of May 3 1982, seeking our endorsement of the procedure paper entitled "procedures for Coordinating Highway Encroachments on Floodplains with FEMA." This paper expands upon my internal policy memorandum of December 29, 1981, concerning the Federal Emergency Management Agency's (FEMA's) handling of highway encroachments within regulatory floodways. Your expansion addresses highway agency responsibilities for coordination with FEMA under various situations in which FEMA has identified flood plains, floodways and base flood elevations.

We have reviewed your procedure paper and believe that it provides an excellent Guideline for coordination between highway agencies, communities participating in the National Flood Insurance Program (NFIP) and FEMA, when flood plain encroachments involving highway construction are proposed. In accordance with Executive Order 11988, the procedures require compliance with NFIP standards and regulations, where practicable, but also provide for responsible actions where no practicable alternative can be identified. These actions include appropriate compensation to affected property owners, assurance that the NFIP will not incur additional liability due to increased flood hazards, and the provision of appropriate technical data to FEMA so that flood insurance maps and studies can be revised as necessary.

We compliment you on your efforts to establish workable operating procedures which incorporate coordination with FEMA on site specific projects. We believe that this procedure paper will facilitate the attainment of our mutual objective of future flood loss reduction. We will provide copies of the paper, with our endorsement to our Regional Offices.

Sincerely,

/S/
Richard W. Krimm
Assistant Associate Director
Office of Natural and Technological
Hazards Programs

Procedures for Coordinating Highway Encroachments on Floodplains with Federal Emergency Management Agency (FEMA)

The local community with land use jurisdiction, whether it is a city, county, or State, has the responsibility for enforcing National Flood Insurance program (NFIP) regulations in that community if the community is participating in the NFIP. Most NFIP communities have established a permit requirement for all development within the base (100 year) floodplain. Consistency with NFIP standards is a requirement for Federal-aid highway actions involving regulatory floodways. The community, by necessity, is the one who must submit proposals to FEMA for amendments to NFIP ordinances and maps in that community should it be necessary. Determination of the status of a community's participation in the NFIP and review of applicable NFIP maps and ordinances are, therefore, essential first steps in conducting location hydraulic studies and preparing environmental documents.

Where NFIP maps are available, their use is mandatory in determining whether a highway location alternative will include an encroachment on the base floodplain. Three types of NFIP maps are published: (1) a Flood Hazard Boundary Map (FHBM), (2) a Flood Boundary and Floodway Map (FBFM), and a Flood Insurance Rate Map (FIRM). A FHBM is generally not based on a detailed hydraulic study and, therefore, the floodplain boundaries shown are approximate. A FBFM, on the other hand, is generally derived from a detailed hydraulic study and should provide reasonably accurate information. The hydraulic data from which the FBFM was derived is available through the regional office of FEMA. This is normally in the form of computer input data cards for calculating water surface profiles. The FIRM is generally produced at the same time using the same hydraulic model and has appropriate rate zones and base flood elevations added.

Communities in the regular program of the NFIP [illegible] have had detailed flood insurance studies performed. In these communities the NFIP map will be a FIRM and in the majority of cases, a regulatory floodway is in effect.

Communities in the emergency program of the NFIP usually have not had a detailed flood insurance study completed and, usually, only limited floodplain data is available. In this case the community NFIP map will be a FHBM and there will not be a regulatory floodway.

Other possibilities are: (1) the community is not in a FEMA identified flood hazard area and thus there is no NFIP map, (2) a FHBM, FIRM, or FBFM is available but the community is not participating in the NFIP, (3) a community is in the process of converting from the emergency program to the regular program and a detailed flood insurance study is underway, or (4) a community is participating in the regular program, the NFIP map is a FIRM, but no regulatory floodway has been established. Information on community participation in the NFIP is provided in the "National Flood Insurance Program Community Status Book" which is published bimonthly for each State and is available through the Headquarters of FEMA.

## Coordination With FEMA

It is intended that there should be highway agency coordination with FEMA in situations where administrative determinations are needed involving a regulatory floodway or where flood risks in NFIP communities are significantly impacted. The circumstances which would ordinarily require coordination with FEMA are:

1. a proposed crossing encroaches on a regulatory floodway and, as such, would require an amendment to the floodway map,

2. a proposed crossing encroaches on a floodplain where a detailed study has been performed but no floodway designated and the maximum 1 foot increase in the base flood elevation would be exceeded,

3. a local community is expected to enter into the regular program within a reasonable period and detailed floodplain studies are underway,

4. a local community is participating in the emergency program and base flood elevation in the vicinity of insurable buildings is increased by more than 1 foot. (Where insurable buildings are not affected, it is sufficient to notify FEMA of changes to base flood elevations as a result of highway construction.)

The draft EIS/EA should indicate the NFIP status of affected communities, the encroachments anticipated and the need for floodway or floodplain ordinance amendments. Coordination means furnishing to FEMA the draft EIS/EA and, upon selection of an alternative, furnishing to FEMA through the community a preliminary site plan and water surface elevation information and technical data in support of a floodway revision request as required. If a determination by FEMA would influence the selection of an alternative, a commitment from FEMA should be obtained prior to the FEIS or FONSI. Otherwise this later coordination may be postponed until the design phase.

For projects that will be processed with a categorical exclusion, coordination may be carried out during design. However, the outcome of the coordination at this time could change the class of environmental processing.

## Highway Encroachments Which Are Consistent With Regulatory Floodways In Effect

In many situations it is possible to design and construct highways in a cost-effective manner such that their components are excluded from the floodway. This is the simplest way to be consistent with the standards and should be the initial alternative evaluated. If a project element encroaches on the floodway but has a very minor effect on the floodway water surface elevation (such as piers in the floodway), the project may normally be considered as being consistent with the standards if hydraulic conditions can be improved so that no water surface elevation increase is reflected in the computer printout for the new conditions.

Revision of Regulatory Floodway So That Highway Encroachment Would Be Consistent

Where it is not cost-effective to design a highway crossing to avoid encroachment on an established floodway, a second alternative would be a modification of the floodway itself. Often, the community will be willing to accept an alternative floodway configuration to accommodate a proposed crossing provided NFIP limitations on increases in the base flood elevation are not exceeded. This approach is useful where the highway crossing does not cause more than a 1 foot rise in the base flood elevation. In some cases, it may be possible to enlarge the floodway or otherwise increase conveyance in the floodway above and below the crossing in order to allow greater encroachment. Such planning is best accomplished when the floodway is first established. However, where the community is willing to amend an established floodway to support this option, the floodway may be revised.

The responsibility for demonstrating that an alternative floodway configuration meets NFIP requirements rests with the community. However, this responsibility may be borne by the agency proposing to construct the highway crossing. Floodway revisions must be based on the hydraulic model which was used to develop the currently effective floodway but updated to reflect existing encroachment conditions. This will allow determination of the increase in the base flood elevation that has been caused by encroachments since the original floodway was established. Alternate floodway configurations may then be analyzed.

Base flood elevation increases are referenced to the profile obtained for existing conditions when the floodway was first established.

Data submitted to FEMA in support of a floodway revision request should include:

1. Copy of current regulatory Flood Boundary Floodway Map, showing existing conditions, proposed highway crossing and revised floodway limits.

2. Copy of computer printouts (input, computation, and output) for the current 100-year model and current 100-year floodway model.

3. Copy of computer printouts (input, computation, and output) for the revised 100-year floodway model. Any fill or development that has occurred in the existing flood fringe area must be incorporated into the revised 100-year floodway model.

4. Copy of engineering certification is required for work performed by private subcontractors.

The revised and current computer data required above should extend far enough upstream and downstream of the floodway revision area in order to tie back into the original floodway and profiles using sound hydraulic engineering practices. This distance will vary depending on the magnitude of the requested floodway revision and the hydraulic characteristics of the stream.

A floodway revision will not be acceptable if development that has occurred in the existing flood fringe area since the adoption of the community's floodway ordinance will now be located within the revised floodway area unless adversely affected adjacent property owners are compensated for the loss.

If the input data representing the original hydraulic model is unavailable, an approximation should be developed. A new model should be established using the original cross-section topographic information, where possible, and the discharges contained in the Flood Insurance Study which establish the original floodway. The model should then be run confining the effective flow area to the currently established floodway and calibrate to reproduce within 0.10 foot, the "With Floodway" elevations provided in the Floodway Data Table for the current floodway. Floodway revisions may then be evaluated using the procedures outlined above.

Floodway Encroachment Where Demonstrably Appropriate

When it would be demonstrably inappropriate to design a highway crossing to avoid encroachment on the floodway and where the floodway cannot be modifed such that the structure could be excluded, FEMA will approve an alternate floodway with backwater in excess of the 1 foot maximum only when the following conditions have been met:

1. A location hydraulic study has been performed in accordance with Federal-Aid Highway Program Manual (FHPM) 6-7-3-2 "Location and Hydraulic Design of Encroachments on Floodplains" (23 CFR 650, Subpart A) and FHWA finds the encroachment is the only practicable alternative.

2. The constructing agency has made appropriate arrangements with affected property owners and the community to obtain flooding easements or otherwise compensate them for future flood losses due to the effects of the structure.

3. The constructing agency has made appropriate arrangements to assure that the National Flood Insurance Program and Flood Insurance Fund do not incur any liability for additional future flood losses to existing structures which are insured under the Program and grandfathered in under the risk status existing prior to the construction of the structure.

4. Prior to initiating construction, the constructing agency provides FEMA with revised flood profiles, floodway and floodplain mapping, and background technical data necessary for FEMA to issue revised Flood Insurance Rate Maps and Flood Boundary and Floodway Maps for the affected area upon completion of the structure.

Highway Encroachment On A Floodplain With A Detailed Study (FIRM)

In communities where a detailed flood insurance study has been performed but no regulatory floodway designated, the highway crossing should be designed to allow no more than a 1 foot increase in the base flood elevation based on technical data from the flood insurance study. Technical data supporting the increased flood elevation should be submitted to the local community and FEMA for their files. Where it is demonstrably inappropriate to design the highway crossing and meet backwater limitations the procedures outlined under

Floodway Encroachment Where Demonstrably Appropriate should be followed in requesting a revision of base floodplain reference elevations.

Highway Encroachment On A Floodplain Indicated On An FHBM

In communities where detailed flood insurance studies have not been performed, the highway agency must generate its own technical data to determine the base floodplain elevation and design encroachments in accordance with FHPM 6-7-3-2. Base floodplain elevations should be furnished to the community, and coordination carried out with FEMA as outlined previously where the increase in base flood elevations in the vicinity of insurable buildings exceeds 1 foot.

Highway Encroachment On Unidentified Floodplains

Encroachments which are outside of NFIP communities or NFIP identified flood hazard areas should be designed in accordance with FHPM 6-7-3-2 of the Federal Highway Administration. The NFIP identified flood hazard areas are those delineated on an FHBM, FBFM or FIRM.

To Obtain FEMA Publications

1. National Flood Insurance Program Community Status Book

   Write to FEMA, 500 "C" Street, SW., Room 431, Insurance Operations, Washington, D.C. 20472 and request to be placed on the appropriate State mailing list.

2. Flood Insurance Study Report and/or FBFM

   Write to FEMA, 500 "C" Street, SW., State and Local Programs Room 418, Washington, D.C. 20472 request:

   (a) For future studies,

   To be placed on mailing list to receive all studies and maps as they are completed for a State.

   (b) For completed studies,

   (1) The study for a particular community (provide number).

   (2) All the studies for a particular State. You will received about 50 percent of the completed studies to date.

3. FHBM or FIRM for a particular community with ID number,

   (a) call NFIP contractor (800)638-6620, (800)492-6605(MD), 897-5900 in D.C., or

   (b) write NFIP, P.O. Box 34604, Bethesda, Maryland 20034

# CHAPTER 10, APPENDIX B

## FILL HEIGHT TABLES FOR PIPES AND PIPE ARCHES

### TABLE 10.B.1 (METRIC) TABLE OF CONTENTS - FILL HEIGHT TABLES INCLUDED IN BD-636M FOR REINFORCED CONCRETE PIPES AND ELLIPTICAL PIPES

| TYPE | DESIGN LIFE (years) | PIPE INSTALLATION PROCEDURE | PIPE SIZES (mm) | SHEET NO. IN BD-636M |
|---|---|---|---|---|
| A | 100 | Standard | 300 thru 3000 | 4 of 18 |
| B | 50 | Standard | 300 thru 1200 | 6 of 18 |
| A | 100 | Shoring/Trench Box | 300 thru 3000 | 7 of 18 |
| B | 50 | Shoring/Trench Box | 300 thru 1200 | 7 of 18 |
| A (Horiz Ellip Pipe) | 100 | Standard | 365 × 575 thru 2440 × 3840 | 8 of 18 |
| B (Horiz Ellip Pipe) | 50 | Standard | 365 × 575 thru 2440 × 3840 | 8 of 18 |
| A (Vert Ellip Pipe) | 100 | Shoring/Trench Box | 1150 × 730 thru 3840 × 2440 | 9 of 18 |
| A (Horiz Ellip Pipe) | 100 | Shoring/Trench Box | 365 × 575 thru 2440 × 3840 | 9 of 18 |
| B (Vert Ellip Pipe) | 50 | Shoring/Trench Box | 1150 × 730 thru 3840 × 2440 | 10 of 18 |
| B (Horiz Ellip Pipe) | 50 | Shoring/Trench Box | 365 × 575 thru 2440 × 3840 | 10 of 18 |

## TABLE 10.B.1 (ENGLISH)
## TABLE OF CONTENTS - FILL HEIGHT TABLES INCLUDED IN BD-636M FOR REINFORCED CONCRETE PIPES AND ELLIPTICAL PIPES

| TYPE | DESIGN LIFE (years) | PIPE INSTALLATION PROCEDURE | PIPE SIZES (in) | SHEET NO. IN BD-636M |
|---|---|---|---|---|
| A | 100 | Standard | 12 thru 120 | 12 of 18 |
| B | 50 | Standard | 12 thru 48 | 14 of 18 |
| A | 100 | Shoring/Trench Box | 12 thru 120 | 15 of 18 |
| B | 50 | Shoring/Trench Box | 12 thru 48 | 15 of 18 |
| A (Horiz Ellip Pipe) | 100 | Standard | 14 × 23 thru 97 × 151 | 16 of 18 |
| B (Horiz Ellip Pipe) | 50 | Standard | 14 × 23 thru 97 × 151 | 16 of 18 |
| A (Vert Ellip Pipe) | 100 | Shoring/Trench Box | 45 × 29 thru 97 × 151 | 17 of 18 |
| A (Horiz Ellip Pipe) | 100 | Shoring/Trench Box | 14 × 23 thru 151 × 97 | 17 of 18 |
| B (Vert Ellip Pipe) | 50 | Shoring/Trench Box | 45 × 29 thru 151 × 97 | 18 of 18 |
| B (Horiz Ellip Pipe) | 50 | Shoring/Trench Box | 14 × 23 thru 97 × 151 | 18 of 18 |

## TABLE 10.B.2 (METRIC)
## TABLE OF CONTENTS - ALLOWABLE FILL HEIGHTS FOR METAL PIPES AND PIPE ARCHES

| TYPE | CORRUGATIONS (mm) | TREATMENT | DESIGN LIFE | | |
|---|---|---|---|---|---|
| | | | 25 yr | 50 yr | 100 yr |
| Galvanized Steel Pipe | 68 × 13 | None | X | X | |
| Galvanized Steel Pipe | 75 × 25 | None | X | X | |
| Galvanized Steel Pipe | 125 × 25 | None | X | X | |
| Aluminized Steel Pipe | 68 × 13 | None | X | X | X |
| Aluminized Steel Pipe | 75 × 25 | None | X | X | X |
| Aluminized Steel Pipe | 125 × 25 | None | X | X | X |
| Galvanized Steel Pipe | 68 × 13 | Polymer Coating (≤ 1.5 m/s) | X | X | X |
| Galvanized Steel Pipe | 75 × 25 | Polymer Coating (≤ 1.5 m/s) | X | X | X |
| Galvanized Steel Pipe | 125 × 25 | Polymer Coating (≤ 1.5 m/s) | X | X | X |
| Galvanized Steel Pipe | 68 × 13 | Polymer Coating (> 1.5 m/s) | X | X | |
| Galvanized Steel Pipe | 75 × 25 | Polymer Coating (> 1.5 m/s) | X | X | |
| Galvanized Steel Pipe | 125 × 25 | Polymer Coating (> 1.5 m/s) | X | X | |
| Aluminum Pipe | 68 × 13 | None | X | X | X |
| Aluminum Pipe | 75 × 25 | None | X | X | X |
| Galvanized Steel Pipe Arch | 68 × 13 | None | X | X | |
| Galvanized Steel Pipe Arch | 75 × 25 | None | X | X | |
| Galvanized Steel Pipe Arch | 125 × 25 | None | X | X | |
| Aluminized Steel Pipe Arch | 68 × 13 | None | X | X | X |
| Aluminized Steel Pipe Arch | 75 × 25 | None | X | X | X |
| Aluminized Steel Pipe Arch | 125 × 25 | None | X | X | X |
| Galvanized Steel Pipe Arch | 68 × 13 | Polymer Coating (≤ 1.5 m/s) | X | X | |
| Galvanized Steel Pipe Arch | 75 × 25 | Polymer Coating (≤ 1.5 m/s) | X | X | |
| Galvanized Steel Pipe Arch | 125 × 25 | Polymer Coating (≤ 1.5 m/s) | X | X | |
| Galvanized Steel Pipe Arch | 68 × 13 | Polymer Coating (> 1.5 m/s) | X | X | |
| Galvanized Steel Pipe Arch | 75 × 25 | Polymer Coating (> 1.5 m/s) | X | X | |
| Galvanized Steel Pipe Arch | 125 × 25 | Polymer Coating (> 1.5 m/s) | X | X | |
| Aluminum Pipe Arch | 68 × 13 | None | X | X | X |
| Aluminum Pipe Arch | 75 × 25 | None | X | X | X |
| Aluminized Steel Pipe | 19 × 19 × 190 | None | X | X | X |
| Aluminum Pipe | 19 × 19 × 190 | None | X | X | X |
| Aluminized Steel Pipe Arch | 19 × 19 × 190 | None | X | X | X |
| Aluminum Pipe Arch | 19 × 19 × 190 | None | X | X | X |

## TABLE 10.B.2 (ENGLISH)
## TABLE OF CONTENTS - ALLOWABLE FILL HEIGHTS FOR METAL PIPES AND PIPE ARCHES

| TYPE | CORRUGATIONS (in) | TREATMENT | DESIGN LIFE | | |
|---|---|---|---|---|---|
| | | | 25 yr | 50 yr | 100 yr |
| Galvanized Steel Pipe | 2 2/3 × 1/2 | None | X | X | |
| Galvanized Steel Pipe | 3 × 1 | None | X | X | |
| Galvanized Steel Pipe | 5 × 1 | None | X | X | |
| Aluminized Steel Pipe | 2 2/3 × 1/2 | None | X | X | X |
| Aluminized Steel Pipe | 3 × 1 | None | X | X | X |
| Aluminized Steel Pipe | 5 × 1 | None | X | X | X |
| Galvanized Steel Pipe | 2 2/3 × 1/2 | Polymer Coating (≤ 5.0 ft/s) | X | X | X |
| Galvanized Steel Pipe | 3 × 1 | Polymer Coating (≤ 5.0 ft/s) | X | X | X |
| Galvanized Steel Pipe | 5 × 1 | Polymer Coating (≤ 5.0 ft/s) | X | X | X |
| Galvanized Steel Pipe | 2 2/3 × 1/2 | Polymer Coating (> 5.0 ft/s) | X | X | |
| Galvanized Steel Pipe | 3 × 1 | Polymer Coating (> 5.0 ft/s) | X | X | |
| Galvanized Steel Pipe | 5 × 1 | Polymer Coating (> 5.0 ft/s) | X | X | |
| Aluminum Pipe | 2 2/3 × 1/2 | None | X | X | X |
| Aluminum Pipe | 3 × 1 | None | X | X | X |
| Galvanized Steel Pipe Arch | 2 2/3 × 1/2 | None | X | X | |
| Galvanized Steel Pipe Arch | 3 × 1 | None | X | X | |
| Galvanized Steel Pipe Arch | 5 × 1 | None | X | X | |
| Aluminized Steel Pipe Arch | 2 2/3 × 1/2 | None | X | X | X |
| Aluminized Steel Pipe Arch | 3 × 1 | None | X | X | X |
| Aluminized Steel Pipe Arch | 5 × 1 | None | X | X | X |
| Galvanized Steel Pipe Arch | 2 2/3 × 1/2 | Polymer Coating (≤ 5.0 ft/s) | X | X | |
| Galvanized Steel Pipe Arch | 3 × 1 | Polymer Coating (≤ 5.0 ft/s) | X | X | |
| Galvanized Steel Pipe Arch | 5 × 1 | Polymer Coating (≤ 5.0 ft/s) | X | X | |
| Galvanized Steel Pipe Arch | 2 2/3 × 1/2 | Polymer Coating (> 5.0 ft/s) | X | X | |
| Galvanized Steel Pipe Arch | 3 × 1 | Polymer Coating (> 5.0 ft/s) | X | X | |
| Galvanized Steel Pipe Arch | 5 × 1 | Polymer Coating (> 5.0 ft/s) | X | X | |
| Aluminum Pipe Arch | 2 2/3 × 1/2 | None | X | X | X |
| Aluminum Pipe Arch | 3 × 1 | None | X | X | X |
| Aluminized Steel Pipe | 3/4 × 3/4 × 7 1/2 | None | X | X | X |
| Aluminum Pipe | 3/4 × 3/4 × 7 1/2 | None | X | X | X |
| Aluminized Steel Pipe Arch | 3/4 × 3/4 × 7 1/2 | None | X | X | X |
| Aluminum Pipe Arch | 3/4 × 3/4 × 7 1/2 | None | X | X | X |

# TABLE 10.B.3 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPES
# (68 mm × 13 mm CORRUGATIONS)

| DESIGN LIFE - 25 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | | | |
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | | 3.51 mm thickness | | 4.27 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 450 | 0.5 | 12.5 | 0.5 | 26.2 | — | — | — | — | — | — |
| 525 | 0.5 | 10.7 | 0.5 | 22.6 | 0.5 | 46.3 | — | — | — | — |
| 600 | 0.6 | 9.4 | 0.5 | 19.5 | 0.5 | 40.5 | — | — | — | — |
| 675 | 0.6 | 8.2 | 0.6 | 17.4 | 0.5 | 36.0 | — | — | — | — |
| 750 | 0.6 | 7.6 | 0.6 | 15.8 | 0.5 | 32.3 | — | — | — | — |
| 825 | 0.8 | 6.7 | 0.6 | 14.3 | 0.5 | 29.6 | — | — | — | — |
| 900 | 0.8 | 6.1 | 0.6 | 13.1 | 0.6 | 27.1 | 0.5 | 40.8 | — | — |
| 1050 | 0.8 | 5.5 | 0.8 | 11.3 | 0.6 | 23.2 | 0.6 | 35.1 | 0.5 | 43.9 |
| 1200 | 0.8 | 4.6 | 0.8 | 9.8 | 0.6 | 20.4 | 0.6 | 30.8 | 0.5 | 38.4 |
| 1350 | — | — | 0.8 | 8.8 | 0.8 | 18.0 | 0.6 | 27.4 | 0.6 | 34.1 |
| 1500 | — | — | — | — | 0.8 | 16.2 | 0.6 | 24.7 | 0.6 | 30.8 |
| 1650 | — | — | — | — | — | — | 0.8 | 22.3 | 0.6 | 28.0 |
| 1800 | — | — | — | — | — | — | 0.8 | 20.4 | 0.6 | 25.6 |
| 2100 | — | — | — | — | — | — | — | — | 0.8 | 19.8 |

| DESIGN LIFE - 50 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | | | |
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | | 3.51 mm thickness | | 4.27 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 525 | — | — | — | — | 0.5 | 7.0 | — | — | — | — |
| 600 | — | — | — | — | 0.5 | 6.1 | — | — | — | — |
| 675 | — | — | — | — | 0.5 | 5.5 | — | — | — | — |
| 750 | — | — | — | — | 0.5 | 4.9 | — | — | — | — |
| 825 | — | — | — | — | 0.5 | 4.6 | — | — | — | — |
| 900 | — | — | — | — | 0.6 | 4.3 | 0.5 | 17.7 | — | — |
| 1050 | — | — | — | — | 0.6 | 3.7 | 0.6 | 15.2 | 0.5 | 27.1 |
| 1200 | — | — | — | — | 0.8 | 3.0 | 0.6 | 13.4 | 0.5 | 23.8 |
| 1350 | — | — | — | — | 0.9 | 2.7 | 0.6 | 11.9 | 0.6 | 21.3 |
| 1500 | — | — | — | — | 1.1 | 2.4 | 0.6 | 10.7 | 0.6 | 19.2 |
| 1650 | — | — | — | — | — | — | 0.8 | 9.8 | 0.6 | 17.4 |
| 1800 | — | — | — | — | — | — | 0.8 | 8.8 | 0.6 | 15.8 |
| 2100 | — | — | — | — | — | — | — | — | 0.8 | 13.7 |

## TABLE 10.B.3 (ENGLISH)
## ALLOWABLE FILL HEIGHTS FOR
## CORRUGATED GALVANIZED STEEL PIPES
## (2 2/3 in × 1/2 in CORRUGATIONS)

| DESIGN LIFE - 25 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | | | |
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | | 8 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 18 | 1.5 | 41 | 1.5 | 86 | — | — | — | — | — | — |
| 21 | 1.5 | 35 | 1.5 | 74 | 1.5 | 152 | — | — | — | — |
| 24 | 2.0 | 31 | 1.5 | 64 | 1.5 | 133 | — | — | — | — |
| 27 | 2.0 | 27 | 2.0 | 57 | 1.5 | 118 | — | — | — | — |
| 30 | 2.0 | 25 | 2.0 | 52 | 1.5 | 106 | — | — | — | — |
| 33 | 2.5 | 22 | 2.0 | 47 | 1.5 | 97 | — | — | — | — |
| 36 | 2.5 | 20 | 2.0 | 43 | 2.0 | 89 | 1.5 | 134 | — | — |
| 42 | 2.5 | 18 | 2.5 | 37 | 2.0 | 76 | 2.0 | 115 | 1.5 | 144 |
| 48 | 2.5 | 15 | 2.5 | 32 | 2.0 | 67 | 2.0 | 101 | 1.5 | 126 |
| 54 | — | — | 2.5 | 29 | 2.5 | 59 | 2.0 | 90 | 2.0 | 112 |
| 60 | — | — | — | — | 2.5 | 53 | 2.0 | 81 | 2.0 | 101 |
| 66 | — | — | — | — | — | — | 2.5 | 73 | 2.0 | 92 |
| 72 | — | — | — | — | — | — | 2.5 | 67 | 2.0 | 84 |
| 84 | — | — | — | — | — | — | — | — | 2.5 | 65 |

| DESIGN LIFE - 50 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | | | |
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | | 8 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 21 | — | — | — | — | 1.5 | 23 | — | — | — | — |
| 24 | — | — | — | — | 1.5 | 20 | — | — | — | — |
| 27 | — | — | — | — | 1.5 | 18 | — | — | — | — |
| 30 | — | — | — | — | 1.5 | 16 | — | — | — | — |
| 33 | — | — | — | — | 1.5 | 15 | — | — | — | — |
| 36 | — | — | — | — | 2.0 | 14 | 1.5 | 58 | — | — |
| 42 | — | — | — | — | 2.0 | 12 | 2.0 | 50 | 1.5 | 89 |
| 48 | — | — | — | — | 2.5 | 10 | 2.0 | 44 | 1.5 | 78 |
| 54 | — | — | — | — | 3.0 | 9 | 2.0 | 39 | 2.0 | 70 |
| 60 | — | — | — | — | 3.5 | 8 | 2.0 | 35 | 2.0 | 63 |
| 66 | — | — | — | — | — | — | 2.5 | 32 | 2.0 | 57 |
| 72 | — | — | — | — | — | — | 2.5 | 29 | 2.0 | 52 |
| 84 | — | — | — | — | — | — | — | — | 2.5 | 45 |

# TABLE 10.B.4 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPES
# (75 mm × 25 mm CORRUGATIONS)

| DESIGN LIFE - 25 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | | | |
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | | 3.51 mm thickness | | 4.27 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 1350 | 0.8 | 4.9 | 0.6 | 10.1 | 0.6 | 20.7 | 0.5 | 31.4 | 0.5 | 39.3 |
| 1500 | 0.8 | 4.3 | 0.8 | 9.1 | 0.6 | 18.6 | 0.5 | 28.3 | 0.5 | 35.4 |
| 1650 | 0.8 | 4.0 | 0.8 | 8.2 | 0.6 | 17.1 | 0.6 | 25.6 | 0.5 | 32.3 |
| 1800 | 0.9 | 3.7 | 0.8 | 7.6 | 0.6 | 15.5 | 0.6 | 23.5 | 0.5 | 29.6 |
| 2100 | 0.9 | 3.0 | 0.8 | 6.4 | 0.8 | 13.4 | 0.6 | 20.1 | 0.6 | 25.3 |
| 2400 | — | — | 0.9 | 5.8 | 0.8 | 11.6 | 0.8 | 17.7 | 0.6 | 22.3 |

| DESIGN LIFE - 50 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | | | |
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | | 3.51 mm thickness | | 4.27 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 1350 | — | — | — | — | 0.8 | 3.0 | 0.5 | 13.7 | 0.5 | 24.4 |
| 1500 | — | — | — | — | 0.9 | 2.7 | 0.5 | 12.1 | 0.5 | 21.9 |
| 1650 | — | — | — | — | 0.9 | 2.1 | 0.6 | 11.0 | 0.5 | 20.1 |
| 1800 | — | — | — | — | 1.1 | 1.8 | 0.6 | 10.1 | 0.5 | 18.3 |
| 2100 | — | — | — | — | — | — | 0.6 | 8.8 | 0.6 | 15.8 |
| 2400 | — | — | — | — | — | — | 0.8 | 7.6 | 0.6 | 13.7 |

# TABLE 10.B.4 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPES
# (3 in × 1 in CORRUGATIONS)

| DESIGN LIFE - 25 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **PIPE DIAMETER (in)** | **HEIGHTS OF FILL (ft)** | | | | | | | | | |
| | **16 Gage** | | **14 Gage** | | **12 Gage** | | **10 Gage** | | **8 Gage** | |
| | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** |
| 54 | 2.5 | 16 | 2.0 | 33 | 2.0 | 68 | 1.5 | 103 | 1.5 | 129 |
| 60 | 2.5 | 14 | 2.5 | 30 | 2.0 | 61 | 1.5 | 93 | 1.5 | 116 |
| 66 | 2.5 | 13 | 2.5 | 27 | 2.0 | 56 | 2.0 | 84 | 1.5 | 106 |
| 72 | 3.0 | 12 | 2.5 | 25 | 2.0 | 51 | 2.0 | 77 | 1.5 | 97 |
| 84 | 3.0 | 10 | 2.5 | 21 | 2.5 | 44 | 2.0 | 66 | 2.0 | 83 |
| 96 | — | — | 3.0 | 19 | 2.5 | 38 | 2.5 | 58 | 2.0 | 73 |

| DESIGN LIFE - 50 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **PIPE DIAMETER (in)** | **HEIGHTS OF FILL (ft)** | | | | | | | | | |
| | **16 Gage** | | **14 Gage** | | **12 Gage** | | **10 Gage** | | **8 Gage** | |
| | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** |
| 54 | — | — | — | — | 2.5 | 10 | 1.5 | 45 | 1.5 | 80 |
| 60 | — | — | — | — | 3.0 | 9 | 1.5 | 40 | 1.5 | 72 |
| 66 | — | — | — | — | 3.0 | 7 | 2.0 | 36 | 1.5 | 66 |
| 72 | — | — | — | — | 3.5 | 6 | 2.0 | 33 | 1.5 | 60 |
| 84 | — | — | — | — | — | — | 2.0 | 29 | 2.0 | 52 |
| 96 | — | — | — | — | — | — | 2.5 | 25 | 2.0 | 45 |

# TABLE 10.B.5 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPES
# (125 mm × 25 mm CORRUGATIONS)

| DESIGN LIFE - 25 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | | | |
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | | 3.51 mm thickness | | 4.27 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 1350 | 0.8 | 4.3 | 0.6 | 8.8 | 0.6 | 18.6 | 0.5 | 28.0 | 0.5 | 35.1 |
| 1500 | 0.8 | 4.0 | 0.8 | 7.9 | 0.6 | 16.8 | 0.5 | 25.3 | 0.5 | 31.7 |
| 1650 | 0.8 | 3.4 | 0.8 | 7.3 | 0.6 | 15.2 | 0.6 | 22.9 | 0.5 | 28.7 |
| 1800 | 0.9 | 3.0 | 0.8 | 6.7 | 0.6 | 13.7 | 0.6 | 21.0 | 0.5 | 26.2 |
| 2100 | 0.9 | 2.7 | 0.8 | 5.8 | 0.8 | 11.9 | 0.6 | 18.0 | 0.6 | 22.6 |
| 2400 | — | — | 0.9 | 5.2 | 0.8 | 10.4 | 0.8 | 15.8 | 0.6 | 19.8 |

| DESIGN LIFE - 50 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | | | |
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | | 3.51 mm thickness | | 4.27 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 1350 | — | — | — | — | 0.9 | 2.7 | 0.5 | 12.2 | 0.5 | 21.6 |
| 1500 | — | — | — | — | 1.1 | 2.4 | 0.5 | 11.0 | 0.5 | 19.5 |
| 1650 | — | — | — | — | 1.2 | 1.5 | 0.6 | 9.8 | 0.5 | 17.7 |
| 1800 | — | — | — | — | — | — | 0.6 | 9.1 | 0.5 | 16.2 |
| 2100 | — | — | — | — | — | — | 0.6 | 7.9 | 0.6 | 14.0 |
| 2400 | — | — | — | — | — | — | 0.8 | 6.7 | 0.6 | 12.2 |

# TABLE 10.B.5 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPES
# (5 in × 1 in CORRUGATIONS)

| DESIGN LIFE - 25 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **PIPE DIAMETER (in)** | **HEIGHTS OF FILL (ft)** | | | | | | | | | |
| | **16 Gage** | | **14 Gage** | | **12 Gage** | | **10 Gage** | | **8 Gage** | |
| | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** |
| 54 | 2.5 | 14 | 2.0 | 29 | 2.0 | 61 | 1.5 | 92 | 1.5 | 115 |
| 60 | 2.5 | 13 | 2.5 | 26 | 2.0 | 55 | 1.5 | 83 | 1.5 | 104 |
| 66 | 2.5 | 11 | 2.5 | 24 | 2.0 | 50 | 2.0 | 75 | 1.5 | 94 |
| 72 | 3.0 | 10 | 2.5 | 22 | 2.0 | 45 | 2.0 | 69 | 1.5 | 86 |
| 84 | 3.0 | 9 | 2.5 | 19 | 2.5 | 39 | 2.0 | 59 | 2.0 | 74 |
| 96 | — | — | 3.0 | 17 | 2.5 | 34 | 2.5 | 52 | 2.0 | 65 |

| DESIGN LIFE - 50 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **PIPE DIAMETER (in)** | **HEIGHTS OF FILL (ft)** | | | | | | | | | |
| | **16 Gage** | | **14 Gage** | | **12 Gage** | | **10 Gage** | | **8 Gage** | |
| | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** |
| 54 | — | — | — | — | 3.0 | 9 | 1.5 | 40 | 1.5 | 71 |
| 60 | — | — | — | — | 3.5 | 8 | 1.5 | 36 | 1.5 | 64 |
| 66 | — | — | — | — | 4.0 | 5 | 2.0 | 32 | 1.5 | 58 |
| 72 | — | — | — | — | — | — | 2.0 | 30 | 1.5 | 53 |
| 84 | — | — | — | — | — | — | 2.0 | 26 | 2.0 | 46 |
| 96 | — | — | — | — | — | — | 2.5 | 22 | 2.0 | 40 |

# TABLE 10.B.6 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR CORRUGATED ALUMINIZED STEEL PIPES
# (68 mm × 13 mm CORRUGATIONS)

**DESIGN LIFE - 25 YR**

| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | | 3.51 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 450 | 0.5 | 34.7 | 0.5 | 46.6 | — | — | — | — |
| 525 | 0.5 | 29.9 | 0.5 | 39.9 | 0.5 | 56.1 | — | — |
| 600 | 0.6 | 26.2 | 0.5 | 35.1 | 0.5 | 49.1 | — | — |
| 750 | 0.6 | 21.0 | 0.6 | 28.0 | 0.5 | 39.3 | — | — |
| 900 | 0.8 | 17.4 | 0.6 | 23.2 | 0.6 | 32.6 | 0.5 | 42.1 |
| 1050 | 0.8 | 14.9 | 0.8 | 20.1 | 0.6 | 28.0 | 0.6 | 36.0 |
| 1200 | 0.8 | 13.1 | 0.8 | 17.4 | 0.6 | 24.4 | 0.6 | 31.4 |
| 1350 | — | — | 0.8 | 15.5 | 0.8 | 21.6 | 0.6 | 28.0 |
| 1500 | — | — | — | — | 0.8 | 19.5 | 0.6 | 25.3 |
| 1650 | — | — | — | — | — | — | 0.8 | 22.9 |
| 1800 | — | — | — | — | — | — | 0.8 | 21.0 |

**DESIGN LIFE - 50 YR**

| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | | 3.51 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 450 | 0.5 | 12.5 | 0.5 | 26.2 | — | — | — | — |
| 525 | 0.5 | 10.7 | 0.5 | 22.6 | 0.5 | 46.3 | — | — |
| 600 | 0.6 | 9.4 | 0.5 | 19.5 | 0.5 | 40.5 | — | — |
| 750 | 0.6 | 7.6 | 0.6 | 15.8 | 0.5 | 32.3 | — | — |
| 900 | 0.8 | 6.1 | 0.6 | 13.1 | 0.6 | 27.1 | 0.5 | 40.8 |
| 1050 | 0.8 | 5.5 | 0.8 | 11.3 | 0.6 | 23.2 | 0.6 | 35.1 |
| 1200 | 0.8 | 4.6 | 0.8 | 9.8 | 0.6 | 20.4 | 0.6 | 30.8 |
| 1350 | — | — | 0.8 | 8.8 | 0.8 | 18.0 | 0.6 | 27.4 |
| 1500 | — | — | — | — | 0.8 | 16.2 | 0.6 | 24.7 |
| 1650 | — | — | — | — | — | — | 0.8 | 22.3 |
| 1800 | — | — | — | — | — | — | 0.8 | 20.4 |

**DESIGN LIFE - 100 YR**

| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | | 3.51 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 525 | — | — | — | — | 0.5 | 7.0 | — | — |
| 600 | — | — | — | — | 0.5 | 6.1 | — | — |
| 750 | — | — | — | — | 0.5 | 4.9 | — | — |
| 900 | — | — | — | — | 0.6 | 4.3 | 0.5 | 17.7 |
| 1050 | — | — | — | — | 0.6 | 3.7 | 0.6 | 15.2 |
| 1200 | — | — | — | — | 0.8 | 3.0 | 0.6 | 13.4 |
| 1350 | — | — | — | — | 0.9 | 2.7 | 0.6 | 11.9 |
| 1500 | — | — | — | — | 1.1 | 2.4 | 0.6 | 10.7 |
| 1650 | — | — | — | — | — | — | 0.8 | 9.8 |
| 1800 | — | — | — | — | — | — | 0.8 | 8.8 |

# TABLE 10.B.6 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR CORRUGATED ALUMINIZED STEEL PIPES
# (2 2/3 in × 1/2 in CORRUGATIONS)

| DESIGN LIFE - 25 YR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | |
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 18 | 1.5 | 114 | 1.5 | 153 | — | — | — | — |
| 21 | 1.5 | 98 | 1.5 | 131 | 1.5 | 184 | — | — |
| 24 | 2.0 | 86 | 1.5 | 115 | 1.5 | 161 | — | — |
| 30 | 2.0 | 69 | 2.0 | 92 | 1.5 | 129 | — | — |
| 36 | 2.5 | 57 | 2.0 | 76 | 2.0 | 107 | 1.5 | 138 |
| 42 | 2.5 | 49 | 2.5 | 66 | 2.0 | 92 | 2.0 | 118 |
| 48 | 2.5 | 43 | 2.5 | 57 | 2.0 | 80 | 2.0 | 103 |
| 54 | — | — | 2.5 | 51 | 2.5 | 71 | 2.0 | 92 |
| 60 | — | — | — | — | 2.5 | 64 | 2.0 | 83 |
| 66 | — | — | — | — | — | — | 2.5 | 75 |
| 72 | — | — | — | — | — | — | 2.5 | 69 |

| DESIGN LIFE - 50 YR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | |
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 18 | 1.5 | 41 | 1.5 | 86 | — | — | — | — |
| 21 | 1.5 | 35 | 1.5 | 74 | 1.5 | 152 | — | — |
| 24 | 2.0 | 31 | 1.5 | 64 | 1.5 | 133 | — | — |
| 30 | 2.0 | 25 | 2.0 | 52 | 1.5 | 106 | — | — |
| 36 | 2.5 | 20 | 2.0 | 43 | 2.0 | 89 | 1.5 | 134 |
| 42 | 2.5 | 18 | 2.5 | 37 | 2.0 | 76 | 2.0 | 115 |
| 48 | 2.5 | 15 | 2.5 | 32 | 2.0 | 67 | 2.0 | 101 |
| 54 | — | — | 2.5 | 29 | 2.5 | 59 | 2.0 | 90 |
| 60 | — | — | — | — | 2.5 | 53 | 2.0 | 81 |
| 66 | — | — | — | — | — | — | 2.5 | 73 |
| 72 | — | — | — | — | — | — | 2.5 | 67 |

| DESIGN LIFE - 100 YR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | |
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 21 | — | — | — | — | 1.5 | 23 | — | — |
| 24 | — | — | — | — | 1.5 | 20 | — | — |
| 30 | — | — | — | — | 1.5 | 16 | — | — |
| 36 | — | — | — | — | 2.0 | 14 | 1.5 | 58 |
| 42 | — | — | — | — | 2.0 | 12 | 2.0 | 50 |
| 48 | — | — | — | — | 2.5 | 10 | 2.0 | 44 |
| 54 | — | — | — | — | 3.0 | 9 | 2.0 | 39 |
| 60 | — | — | — | — | 3.5 | 8 | 2.0 | 35 |
| 66 | — | — | — | — | — | — | 2.5 | 32 |
| 72 | — | — | — | — | — | — | 2.5 | 29 |

# TABLE 10.B.7 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED ALUMINIZED STEEL PIPES
# (75 mm × 25 mm CORRUGATIONS)

| DESIGN LIFE - 25 YR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | |
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | | 3.51 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 1350 | 0.8 | 13.4 | 0.6 | 18.0 | 0.6 | 25.0 | 0.5 | 32.3 |
| 1500 | 0.8 | 11.9 | 0.8 | 16.2 | 0.6 | 22.6 | 0.5 | 29.0 |
| 1650 | 0.8 | 11.0 | 0.8 | 14.6 | 0.6 | 20.4 | 0.6 | 26.2 |
| 1800 | 0.9 | 10.1 | 0.8 | 13.4 | 0.6 | 18.9 | 0.6 | 24.1 |
| 2100 | 0.9 | 8.5 | 0.8 | 11.6 | 0.8 | 16.2 | 0.6 | 20.7 |
| 2400 | — | — | 0.9 | 10.1 | 0.8 | 14.0 | 0.8 | 18.0 |

| DESIGN LIFE - 50 YR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | |
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | | 3.51 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 1350 | 0.8 | 4.9 | 0.6 | 10.1 | 0.6 | 20.7 | 0.5 | 31.4 |
| 1500 | 0.8 | 4.3 | 0.8 | 9.1 | 0.6 | 18.6 | 0.5 | 28.3 |
| 1650 | 0.8 | 4.0 | 0.8 | 8.2 | 0.6 | 17.1 | 0.6 | 25.6 |
| 1800 | 0.9 | 3.7 | 0.8 | 7.6 | 0.6 | 15.5 | 0.6 | 23.5 |
| 2100 | 0.9 | 3.0 | 0.8 | 6.4 | 0.8 | 13.4 | 0.6 | 20.1 |
| 2400 | — | — | 0.9 | 5.8 | 0.8 | 11.6 | 0.8 | 17.7 |

| DESIGN LIFE - 100 YR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | |
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | | 3.51 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 1350 | — | — | — | — | 0.8 | 3.0 | 0.5 | 13.7 |
| 1500 | — | — | — | — | 0.9 | 2.7 | 0.5 | 12.2 |
| 1650 | — | — | — | — | 0.9 | 2.1 | 0.6 | 11.0 |
| 1800 | — | — | — | — | 1.1 | 1.8 | 0.6 | 10.1 |
| 2100 | — | — | — | — | — | — | 0.6 | 8.8 |
| 2400 | — | — | — | — | — | — | 0.8 | 7.6 |

# TABLE 10.B.7 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR CORRUGATED ALUMINIZED STEEL PIPES (3 in × 1 in CORRUGATIONS)

| DESIGN LIFE - 25 YR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | |
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 54 | 2.5 | 44 | 2.0 | 59 | 2.0 | 82 | 1.5 | 106 |
| 60 | 2.5 | 39 | 2.5 | 53 | 2.0 | 74 | 1.5 | 95 |
| 66 | 2.5 | 36 | 2.5 | 48 | 2.0 | 67 | 2.0 | 86 |
| 72 | 3.0 | 33 | 2.5 | 44 | 2.0 | 62 | 2.0 | 79 |
| 84 | 3.0 | 28 | 2.5 | 38 | 2.5 | 53 | 2.0 | 68 |
| 96 | — | — | 3.0 | 33 | 2.5 | 46 | 2.5 | 59 |

| DESIGN LIFE - 50 YR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | |
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 54 | 2.5 | 16 | 2.0 | 33 | 2.0 | 68 | 1.5 | 103 |
| 60 | 2.5 | 14 | 2.5 | 30 | 2.0 | 61 | 1.5 | 93 |
| 66 | 2.5 | 13 | 2.5 | 27 | 2.0 | 56 | 2.0 | 84 |
| 72 | 3.0 | 12 | 2.5 | 25 | 2.0 | 51 | 2.0 | 77 |
| 84 | 3.0 | 10 | 2.5 | 21 | 2.5 | 44 | 2.0 | 66 |
| 96 | — | — | 3.0 | 19 | 2.5 | 38 | 2.5 | 58 |

| DESIGN LIFE - 100 YR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | |
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 54 | — | — | — | — | 2.5 | 10 | 1.5 | 45 |
| 60 | — | — | — | — | 3.0 | 9 | 1.5 | 40 |
| 66 | — | — | — | — | 3.0 | 7 | 2.0 | 36 |
| 72 | — | — | — | — | 3.5 | 6 | 2.0 | 33 |
| 84 | — | — | — | — | — | — | 2.0 | 29 |
| 96 | — | — | — | — | — | — | 2.5 | 25 |

# TABLE 10.B.8 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED ALUMINIZED STEEL PIPES
# (125 mm × 25 mm CORRUGATIONS)

| DESIGN LIFE - 25 YR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | |
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | | 3.51 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 1350 | 0.8 | 11.9 | 0.6 | 15.8 | 0.6 | 22.3 | 0.5 | 28.7 |
| 1500 | 0.8 | 10.7 | 0.8 | 14.3 | 0.6 | 20.1 | 0.5 | 25.9 |
| 1650 | 0.8 | 9.8 | 0.8 | 13.1 | 0.6 | 18.3 | 0.6 | 23.5 |
| 1800 | 0.9 | 8.8 | 0.8 | 11.9 | 0.6 | 16.8 | 0.6 | 21.6 |
| 2100 | — | — | 0.8 | 10.4 | 0.8 | 14.3 | 0.6 | 18.6 |
| 2400 | — | — | 0.9 | 8.8 | 0.8 | 12.5 | 0.8 | 16.2 |

| DESIGN LIFE - 50 YR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | |
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | | 3.51 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 1350 | 0.8 | 4.3 | 0.6 | 8.8 | 0.6 | 18.6 | 0.5 | 28.0 |
| 1500 | 0.8 | 4.0 | 0.8 | 7.9 | 0.6 | 16.8 | 0.5 | 25.3 |
| 1650 | 0.8 | 3.4 | 0.8 | 7.3 | 0.6 | 15.2 | 0.6 | 22.9 |
| 1800 | 0.9 | 3.0 | 0.8 | 6.7 | 0.6 | 13.7 | 0.6 | 21.0 |
| 2100 | — | — | 0.8 | 5.8 | 0.8 | 11.9 | 0.6 | 18.0 |
| 2400 | — | — | 0.9 | 5.2 | 0.8 | 10.4 | 0.8 | 15.8 |

| DESIGN LIFE - 100 YR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | |
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | | 3.51 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 1350 | — | — | — | — | 0.8 | 2.7 | 0.5 | 12.2 |
| 1500 | — | — | — | — | 0.9 | 2.4 | 0.5 | 11.0 |
| 1650 | — | — | — | — | 1.2 | 2.1 | 0.6 | 9.8 |
| 1800 | — | — | — | — | — | — | 0.6 | 9.1 |
| 2100 | — | — | — | — | — | — | 0.6 | 7.9 |
| 2400 | — | — | — | — | — | — | 0.8 | 6.7 |

# TABLE 10.B.8 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR CORRUGATED ALUMINIZED STEEL PIPES (5 in × 1 in CORRUGATIONS)

| DESIGN LIFE - 25 YR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | |
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 54 | 2.5 | 39 | 2.0 | 52 | 2.0 | 73 | 1.5 | 94 |
| 60 | 2.5 | 35 | 2.5 | 47 | 2.0 | 66 | 1.5 | 85 |
| 66 | 2.5 | 32 | 2.5 | 43 | 2.0 | 60 | 2.0 | 77 |
| 72 | 3.0 | 29 | 2.5 | 39 | 2.0 | 55 | 2.0 | 71 |
| 84 | — | — | 2.5 | 34 | 2.5 | 47 | 2.0 | 61 |
| 96 | — | — | 3.0 | 29 | 2.5 | 41 | 2.5 | 53 |

| DESIGN LIFE - 50 YR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | |
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 54 | 2.5 | 14 | 2.0 | 29 | 2.0 | 61 | 1.5 | 92 |
| 60 | 2.5 | 13 | 2.5 | 26 | 2.0 | 55 | 1.5 | 83 |
| 66 | 2.5 | 11 | 2.5 | 24 | 2.0 | 50 | 2.0 | 75 |
| 72 | 3.0 | 10 | 2.5 | 22 | 2.0 | 45 | 2.0 | 69 |
| 84 | — | — | 2.5 | 19 | 2.5 | 39 | 2.0 | 59 |
| 96 | — | — | 3.0 | 17 | 2.5 | 34 | 2.5 | 52 |

| DESIGN LIFE - 100 YR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | |
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 54 | — | — | — | — | 2.5 | 9 | 1.5 | 40 |
| 60 | — | — | — | — | 3.0 | 8 | 1.5 | 36 |
| 66 | — | — | — | — | 4.0 | 7 | 2.0 | 32 |
| 72 | — | — | — | — | — | — | 2.0 | 30 |
| 84 | — | — | — | — | — | — | 2.0 | 26 |
| 96 | — | — | — | — | — | — | 2.5 | 22 |

# TABLE 10.B.9 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPES
# (68 mm × 13 mm CORRUGATIONS)

POLYMER COATED (≤ 1.5 m/s)*

**DESIGN LIFE - 25 YR**

| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | | 3.51 mm thickness | | 4.27 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 450 | 0.5 | 37.2 | 0.5 | 46.6 | — | — | — | — | — | — |
| 525 | 0.5 | 32.0 | 0.5 | 39.9 | 0.5 | 56.1 | — | — | — | — |
| 600 | 0.6 | 28.0 | 0.5 | 35.1 | 0.5 | 49.1 | — | — | — | — |
| 675 | 0.6 | 25.0 | 0.6 | 31.1 | 0.5 | 43.6 | — | — | — | — |
| 750 | 0.6 | 22.3 | 0.6 | 28.0 | 0.5 | 39.3 | — | — | — | — |
| 825 | 0.8 | 20.4 | 0.6 | 25.3 | 0.5 | 35.7 | — | — | — | — |
| 900 | 0.8 | 18.6 | 0.6 | 23.2 | 0.6 | 32.6 | 0.5 | 42.1 | — | — |
| 1050 | 0.8 | 15.8 | 0.8 | 20.1 | 0.6 | 28.0 | 0.6 | 36.0 | 0.5 | 43.9 |
| 1200 | 0.8 | 14.0 | 0.8 | 17.4 | 0.6 | 24.4 | 0.6 | 31.4 | 0.5 | 38.4 |
| 1350 | — | — | 0.8 | 15.5 | 0.8 | 21.6 | 0.6 | 28.0 | 0.6 | 34.1 |
| 1500 | — | — | — | — | 0.8 | 19.5 | 0.6 | 25.3 | 0.6 | 30.8 |
| 1650 | — | — | — | — | — | — | 0.8 | 22.9 | 0.6 | 28.0 |
| 1800 | — | — | — | — | — | — | 0.8 | 21.0 | 0.6 | 25.6 |
| 2100 | — | — | — | — | — | — | — | — | 0.8 | 19.8 |

**DESIGN LIFE - 50 YR**

| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | | 3.51 mm thickness | | 4.27 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 450 | 0.6 | 3.7 | 0.5 | 17.1 | — | — | — | — | — | — |
| 525 | 0.8 | 3.0 | 0.5 | 14.6 | 0.5 | 38.4 | — | — | — | — |
| 600 | 0.9 | 2.7 | 0.5 | 12.8 | 0.5 | 33.8 | — | — | — | — |
| 675 | 1.1 | 1.8 | 0.6 | 11.6 | 0.5 | 29.9 | — | — | — | — |
| 750 | — | — | 0.6 | 10.4 | 0.5 | 26.8 | — | — | — | — |
| 825 | — | — | 0.6 | 9.4 | 0.5 | 24.4 | — | — | — | — |
| 900 | — | — | 0.6 | 8.5 | 0.6 | 22.6 | 0.5 | 36.3 | — | — |
| 1050 | — | — | 0.8 | 7.3 | 0.6 | 19.2 | 0.6 | 31.1 | 0.5 | 43.3 |
| 1200 | — | — | 0.8 | 6.4 | 0.6 | 16.8 | 0.6 | 27.1 | 0.5 | 37.8 |
| 1350 | — | — | 0.8 | 5.8 | 0.8 | 14.9 | 0.6 | 24.1 | 0.6 | 33.5 |
| 1500 | — | — | — | — | 0.8 | 13.4 | 0.6 | 21.6 | 0.6 | 30.2 |
| 1650 | — | — | — | — | — | — | 0.8 | 19.8 | 0.6 | 27.4 |
| 1800 | — | — | — | — | — | — | 0.8 | 18.3 | 0.6 | 25.3 |
| 2100 | — | — | — | — | — | — | — | — | 0.8 | 19.8 |

**DESIGN LIFE - 100 YR**

| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | | 3.51 mm thickness | | 4.27 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 1050 | — | — | — | — | — | — | — | — | 0.8 | 3.4 |
| 1200 | — | — | — | — | — | — | — | — | 0.9 | 2.7 |
| 1350 | — | — | — | — | — | — | — | — | 1.1 | 2.4 |

* Design Flow Velocity does not exceed 1.5 m/s, low abrasive (minimal bedload) environment.

# TABLE 10.B.9 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPES
# (2 2/3 in × 1/2 in CORRUGATIONS)

POLYMER COATED (≤ 5 ft/s)*

| DESIGN LIFE - 25 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | | | |
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | | 8 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 18 | 1.5 | 122 | 1.5 | 153 | — | — | — | — | — | — |
| 21 | 1.5 | 105 | 1.5 | 131 | 1.5 | 184 | — | — | — | — |
| 24 | 2.0 | 92 | 1.5 | 115 | 1.5 | 161 | — | — | — | — |
| 27 | 2.0 | 82 | 2.0 | 102 | 1.5 | 143 | — | — | — | — |
| 30 | 2.0 | 73 | 2.0 | 92 | 1.5 | 129 | — | — | — | — |
| 33 | 2.5 | 67 | 2.0 | 83 | 1.5 | 117 | — | — | — | — |
| 36 | 2.5 | 61 | 2.0 | 76 | 2.0 | 107 | 1.5 | 138 | — | — |
| 42 | 2.5 | 52 | 2.5 | 66 | 2.0 | 92 | 2.0 | 118 | 1.5 | 144 |
| 48 | 2.5 | 46 | 2.5 | 57 | 2.0 | 80 | 2.0 | 103 | 1.5 | 126 |
| 54 | — | — | 2.5 | 51 | 2.5 | 71 | 2.0 | 92 | 2.0 | 112 |
| 60 | — | — | — | — | 2.5 | 64 | 2.0 | 83 | 2.0 | 101 |
| 66 | — | — | — | — | — | — | 2.5 | 75 | 2.0 | 92 |
| 72 | — | — | — | — | — | — | 2.5 | 69 | 2.0 | 84 |
| 84 | — | — | — | — | — | — | — | — | 2.5 | 65 |

| DESIGN LIFE - 50 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | | | |
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | | 8 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 18 | 2.0 | 12 | 1.5 | 56 | — | — | — | — | — | — |
| 21 | 2.5 | 10 | 1.5 | 48 | 1.5 | 126 | — | — | — | — |
| 24 | 3.0 | 9 | 1.5 | 42 | 1.5 | 111 | — | — | — | — |
| 27 | 3.5 | 6 | 2.0 | 38 | 1.5 | 98 | — | — | — | — |
| 30 | — | — | 2.0 | 34 | 1.5 | 88 | — | — | — | — |
| 33 | — | — | 2.0 | 31 | 1.5 | 80 | — | — | — | — |
| 36 | — | — | 2.0 | 28 | 2.0 | 74 | 1.5 | 119 | — | — |
| 42 | — | — | 2.5 | 24 | 2.0 | 63 | 2.0 | 102 | 1.5 | 142 |
| 48 | — | — | 2.5 | 21 | 2.0 | 55 | 2.0 | 89 | 1.5 | 124 |
| 54 | — | — | 2.5 | 19 | 2.5 | 49 | 2.0 | 79 | 2.0 | 110 |
| 60 | — | — | — | — | 2.5 | 44 | 2.0 | 71 | 2.0 | 99 |
| 66 | — | — | — | — | — | — | 2.5 | 65 | 2.0 | 90 |
| 72 | — | — | — | — | — | — | 2.5 | 60 | 2.0 | 83 |
| 84 | — | — | — | — | — | — | — | — | 2.5 | 65 |

| DESIGN LIFE - 100 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | | | |
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | | 8 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 42 | — | — | — | — | — | — | — | — | 2.5 | 11 |
| 48 | — | — | — | — | — | — | — | — | 3.0 | 9 |
| 54 | — | — | — | — | — | — | — | — | 3.5 | 8 |

* Design Flow Velocity does not exceed 5 ft/s, low abrasive (minimal bedload) environment.

# TABLE 10.B.10 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPES
# (75 mm × 25 mm CORRUGATIONS)

POLYMER COATED (≤ 1.5 m/s)*

| DESIGN LIFE - 25 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | | | |
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | | 3.51 mm thickness | | 4.27 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 1350 | 0.8 | 14.3 | 0.6 | 18.0 | 0.6 | 25.0 | 0.5 | 32.3 | 0.5 | 39.3 |
| 1500 | 0.8 | 12.8 | 0.8 | 16.2 | 0.6 | 22.6 | 0.5 | 29.0 | 0.5 | 35.4 |
| 1650 | 0.8 | 11.6 | 0.8 | 14.6 | 0.6 | 20.4 | 0.6 | 26.2 | 0.5 | 32.3 |
| 1800 | 0.9 | 10.7 | 0.8 | 13.4 | 0.6 | 18.9 | 0.6 | 24.1 | 0.5 | 29.6 |
| 2100 | 0.9 | 9.1 | 0.8 | 11.6 | 0.8 | 16.2 | 0.6 | 20.7 | 0.6 | 25.3 |
| 2400 | — | — | 0.9 | 10.1 | 0.8 | 14.0 | 0.8 | 18.0 | 0.6 | 22.3 |

| DESIGN LIFE - 50 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | | | |
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | | 3.51 mm thickness | | 4.27 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 1350 | — | — | 0.6 | 6.7 | 0.6 | 17.4 | 0.5 | 27.7 | 0.5 | 38.7 |
| 1500 | — | — | 0.8 | 5.8 | 0.6 | 15.5 | 0.5 | 25.0 | 0.5 | 35.1 |
| 1650 | — | — | 0.8 | 5.5 | 0.6 | 14.0 | 0.6 | 22.9 | 0.5 | 31.7 |
| 1800 | — | — | 0.8 | 4.9 | 0.6 | 12.8 | 0.6 | 21.0 | 0.5 | 29.3 |
| 2100 | — | — | 0.8 | 4.3 | 0.8 | 11.0 | 0.6 | 18.0 | 0.6 | 25.0 |
| 2400 | — | — | 0.9 | 3.7 | 0.8 | 9.8 | 0.8 | 15.5 | 0.6 | 21.9 |

| DESIGN LIFE - 100 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | | | |
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | | 3.51 mm thickness | | 4.27 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 1350 | — | — | — | — | — | — | — | — | 0.6 | 2.7 |
| 1500 | — | — | — | — | — | — | — | — | 0.6 | 2.4 |
| 1650 | — | — | — | — | — | — | — | — | 1.2 | 1.8 |

* Design Flow Velocity does not exceed 1.5 m/s, low abrasive (minimal bedload) environment.

# TABLE 10.B.10 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR CORRUGATED GALVANIZED STEEL PIPES (3 in × 1 in CORRUGATIONS)

POLYMER COATED (≤ 5 ft/s)*

| DESIGN LIFE - 25 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | | | |
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | | 8 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 54 | 2.5 | 47 | 2.0 | 59 | 2.0 | 82 | 1.5 | 106 | 1.5 | 129 |
| 60 | 2.5 | 42 | 2.5 | 53 | 2.0 | 74 | 1.5 | 95 | 1.5 | 116 |
| 66 | 2.5 | 38 | 2.5 | 48 | 2.0 | 67 | 2.0 | 86 | 1.5 | 106 |
| 72 | 3.0 | 35 | 2.5 | 44 | 2.0 | 62 | 2.0 | 79 | 1.5 | 97 |
| 84 | 3.0 | 30 | 2.5 | 38 | 2.5 | 53 | 2.0 | 68 | 2.0 | 83 |
| 96 | — | — | 3.0 | 33 | 2.5 | 46 | 2.5 | 59 | 2.0 | 73 |

| DESIGN LIFE - 50 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | | | |
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | | 8 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 54 | — | — | 2.0 | 22 | 2.0 | 57 | 1.5 | 91 | 1.5 | 127 |
| 60 | — | — | 2.5 | 19 | 2.0 | 51 | 1.5 | 82 | 1.5 | 115 |
| 66 | — | — | 2.5 | 18 | 2.0 | 46 | 2.0 | 75 | 1.5 | 104 |
| 72 | — | — | 2.5 | 16 | 2.0 | 42 | 2.0 | 69 | 1.5 | 96 |
| 84 | — | — | 2.5 | 14 | 2.5 | 36 | 2.0 | 59 | 2.0 | 82 |
| 96 | — | — | 3.0 | 12 | 2.5 | 32 | 2.5 | 51 | 2.0 | 72 |

| DESIGN LIFE - 100 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | | | |
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | | 8 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 54 | — | — | — | — | — | — | — | — | 3.0 | 9 |
| 60 | — | — | — | — | — | — | — | — | 3.0 | 8 |
| 66 | — | — | — | — | — | — | — | — | 4.0 | 6 |

* Design Flow Velocity does not exceed 5 ft/s, low abrasive (minimal bedload) environment.

# TABLE 10.B.11 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPES
# (125 mm × 25 mm CORRUGATIONS)

POLYMER COATED (≤ 1.5 m/s)*

**DESIGN LIFE - 25 YR**

| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | | 3.51 mm thickness | | 4.27 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 1350 | 0.8 | 12.8 | 0.6 | 15.8 | 0.6 | 22.3 | 0.5 | 28.7 | 0.5 | 35.1 |
| 1500 | 0.8 | 11.6 | 0.8 | 14.3 | 0.6 | 20.1 | 0.5 | 25.9 | 0.5 | 31.7 |
| 1650 | 0.8 | 10.4 | 0.8 | 13.1 | 0.6 | 18.3 | 0.6 | 23.5 | 0.5 | 28.7 |
| 1800 | 0.9 | 9.4 | 0.8 | 11.9 | 0.6 | 17.8 | 0.6 | 21.6 | 0.5 | 26.2 |
| 2100 | 0.9 | 8.2 | 0.8 | 10.4 | 0.8 | 14.3 | 0.6 | 18.6 | 0.6 | 22.6 |
| 2400 | — | — | 0.9 | 8.8 | 0.8 | 12.5 | 0.8 | 16.2 | 0.6 | 19.8 |

**DESIGN LIFE - 50 YR**

| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | | 3.51 mm thickness | | 4.27 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 1350 | — | — | 0.6 | 5.8 | 0.6 | 15.2 | 0.5 | 24.7 | 0.5 | 34.4 |
| 1500 | — | — | 0.8 | 5.2 | 0.6 | 13.7 | 0.5 | 22.3 | 0.5 | 31.1 |
| 1650 | — | — | 0.8 | 4.9 | 0.6 | 12.5 | 0.6 | 20.4 | 0.5 | 28.3 |
| 1800 | — | — | 0.8 | 4.3 | 0.6 | 11.6 | 0.6 | 18.6 | 0.5 | 25.9 |
| 2100 | — | — | 0.8 | 3.7 | 0.8 | 9.8 | 0.6 | 15.8 | 0.6 | 22.3 |
| 2400 | — | — | 0.9 | 3.4 | 0.8 | 8.5 | 0.8 | 14.0 | 0.6 | 19.5 |

**DESIGN LIFE - 100 YR**

| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | | 3.51 mm thickness | | 4.27 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 1350 | — | — | — | — | — | — | — | — | 0.9 | 2.4 |
| 1500 | — | — | — | — | — | — | — | — | 1.2 | 1.5 |

* Design Flow Velocity does not exceed 1.5 m/s, low abrasive (minimal bedload) environment.

# TABLE 10.B.11 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPES
# (5 in × 1 in CORRUGATIONS)

POLYMER COATED (≤ 5 ft/s)*

**DESIGN LIFE - 25 YR**

| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | | 8 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 54 | 2.5 | 42 | 2.0 | 52 | 2.0 | 73 | 1.5 | 94 | 1.5 | 115 |
| 60 | 2.5 | 38 | 2.5 | 47 | 2.0 | 66 | 1.5 | 85 | 1.5 | 104 |
| 66 | 2.5 | 34 | 2.5 | 43 | 2.0 | 60 | 2.0 | 77 | 1.5 | 94 |
| 72 | 3.0 | 31 | 2.5 | 39 | 2.0 | 55 | 2.0 | 71 | 1.5 | 86 |
| 84 | 3.0 | 27 | 2.5 | 34 | 2.5 | 47 | 2.0 | 61 | 2.0 | 74 |
| 96 | — | — | 3.0 | 29 | 2.5 | 41 | 2.5 | 53 | 2.0 | 65 |

**DESIGN LIFE - 50 YR**

| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | | 8 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 54 | — | — | 2.0 | 19 | 2.0 | 50 | 1.5 | 81 | 1.5 | 113 |
| 60 | — | — | 2.5 | 17 | 2.0 | 45 | 1.5 | 73 | 1.5 | 102 |
| 66 | — | — | 2.5 | 16 | 2.0 | 41 | 2.0 | 67 | 1.5 | 93 |
| 72 | — | — | 2.5 | 14 | 2.0 | 38 | 2.0 | 61 | 1.5 | 85 |
| 84 | — | — | 2.5 | 12 | 2.5 | 32 | 2.0 | 52 | 2.0 | 73 |
| 96 | — | — | 3.0 | 11 | 2.5 | 28 | 2.5 | 46 | 2.0 | 64 |

**DESIGN LIFE - 100 YR**

| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | | 8 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 54 | — | — | — | — | — | — | — | — | 3.0 | 8 |
| 60 | — | — | — | — | — | — | — | — | 4.0 | 5 |

* Design Flow Velocity does not exceed 5 ft/s, low abrasive (minimal bedload) environment.

# TABLE 10.B.12 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPES
# (68 mm × 13 mm CORRUGATIONS)

POLYMER COATED (> 1.5 m/s)*

**DESIGN LIFE - 25 YR**

| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | | 3.51 mm thickness | | 4.27 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 450 | 0.5 | 30.5 | 0.5 | 44.2 | — | — | — | — | — | — |
| 525 | 0.5 | 25.9 | 0.5 | 37.8 | 0.5 | 56.1 | — | — | — | — |
| 600 | 0.6 | 22.9 | 0.5 | 33.2 | 0.5 | 49.1 | — | — | — | — |
| 675 | 0.6 | 20.1 | 0.6 | 29.6 | 0.5 | 43.6 | — | — | — | — |
| 750 | 0.6 | 18.3 | 0.6 | 26.5 | 0.5 | 39.3 | — | — | — | — |
| 825 | 0.8 | 16.5 | 0.6 | 24.1 | 0.5 | 35.7 | — | — | — | — |
| 900 | 0.8 | 15.2 | 0.6 | 22.3 | 0.6 | 32.6 | 0.5 | 42.1 | — | — |
| 1050 | 0.8 | 13.1 | 0.8 | 18.9 | 0.6 | 28.0 | 0.6 | 36.0 | 0.5 | 43.9 |
| 1200 | 0.8 | 11.3 | 0.8 | 16.5 | 0.6 | 24.4 | 0.6 | 31.4 | 0.5 | 38.4 |
| 1350 | — | — | 0.8 | 14.6 | 0.8 | 21.6 | 0.6 | 28.0 | 0.6 | 34.1 |
| 1500 | — | — | — | — | 0.8 | 19.5 | 0.6 | 25.3 | 0.6 | 30.8 |
| 1650 | — | — | — | — | — | — | 0.8 | 22.9 | 0.6 | 28.0 |
| 1800 | — | — | — | — | — | — | 0.8 | 21.0 | 0.6 | 25.6 |
| 2100 | — | — | — | — | — | — | — | — | 0.8 | 19.8 |

**DESIGN LIFE - 50 YR**

| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | | 3.51 mm thickness | | 4.27 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 525 | — | — | — | — | 0.5 | 22.9 | — | — | — | — |
| 600 | — | — | — | — | 0.5 | 19.8 | — | — | — | — |
| 675 | — | — | — | — | 0.5 | 17.7 | — | — | — | — |
| 750 | — | — | — | — | 0.5 | 15.8 | — | — | — | — |
| 825 | — | — | — | — | 0.5 | 14.6 | — | — | — | — |
| 900 | — | — | — | — | 0.6 | 13.4 | 0.5 | 27.1 | — | — |
| 1050 | — | — | — | — | 0.6 | 11.3 | 0.6 | 23.2 | 0.5 | 35.4 |
| 1200 | — | — | — | — | 0.6 | 10.1 | 0.6 | 20.1 | 0.5 | 30.8 |
| 1350 | — | — | — | — | 0.8 | 8.8 | 0.6 | 18.0 | 0.6 | 27.4 |
| 1500 | — | — | — | — | 0.8 | 7.9 | 0.6 | 16.2 | 0.6 | 24.7 |
| 1650 | — | — | — | — | — | — | 0.8 | 14.6 | 0.6 | 22.6 |
| 1800 | — | — | — | — | — | — | 0.8 | 13.4 | 0.6 | 20.7 |
| 2100 | — | — | — | — | — | — | — | — | 0.8 | 17.7 |

* Design Flow Velocity exceeds 1.5 m/s.

# TABLE 10.B.12 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPES
# (2 2/3 in × 1/2 in CORRUGATIONS)

POLYMER COATED (> 5 ft/s)*

**DESIGN LIFE - 25 YR**

| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | | 8 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 18 | 1.5 | 100 | 1.5 | 145 | — | — | — | — | — | — |
| 21 | 1.5 | 85 | 1.5 | 124 | 1.5 | 184 | — | — | — | — |
| 24 | 2.0 | 75 | 1.5 | 109 | 1.5 | 161 | — | — | — | — |
| 27 | 2.0 | 66 | 2.0 | 97 | 1.5 | 143 | — | — | — | — |
| 30 | 2.0 | 60 | 2.0 | 87 | 1.5 | 129 | — | — | — | — |
| 33 | 2.5 | 54 | 2.0 | 79 | 1.5 | 117 | — | — | — | — |
| 36 | 2.5 | 50 | 2.0 | 73 | 2.0 | 107 | 1.5 | 138 | — | — |
| 42 | 2.5 | 43 | 2.5 | 62 | 2.0 | 92 | 2.0 | 118 | 1.5 | 144 |
| 48 | 2.5 | 37 | 2.5 | 54 | 2.0 | 80 | 2.0 | 103 | 1.5 | 126 |
| 54 | — | — | 2.5 | 48 | 2.5 | 71 | 2.0 | 92 | 2.0 | 112 |
| 60 | — | — | — | — | 2.5 | 64 | 2.0 | 83 | 2.0 | 101 |
| 66 | — | — | — | — | — | — | 2.5 | 75 | 2.0 | 92 |
| 72 | — | — | — | — | — | — | 2.5 | 69 | 2.0 | 84 |
| 84 | — | — | — | — | — | — | — | — | 2.5 | 65 |

**DESIGN LIFE - 50 YR**

| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | | 8 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 21 | — | — | — | — | 1.5 | 75 | — | — | — | — |
| 24 | — | — | — | — | 1.5 | 65 | — | — | — | — |
| 27 | — | — | — | — | 1.5 | 58 | — | — | — | — |
| 30 | — | — | — | — | 1.5 | 52 | — | — | — | — |
| 33 | — | — | — | — | 1.5 | 48 | — | — | — | — |
| 36 | — | — | — | — | 2.0 | 44 | 1.5 | 89 | — | — |
| 42 | — | — | — | — | 2.0 | 37 | 2.0 | 76 | 1.5 | 116 |
| 48 | — | — | — | — | 2.0 | 33 | 2.0 | 66 | 1.5 | 101 |
| 54 | — | — | — | — | 2.5 | 29 | 2.0 | 59 | 2.0 | 90 |
| 60 | — | — | — | — | 2.5 | 26 | 2.0 | 53 | 2.0 | 81 |
| 66 | — | — | — | — | — | — | 2.5 | 48 | 2.0 | 74 |
| 72 | — | — | — | — | — | — | 2.5 | 44 | 2.0 | 68 |
| 84 | — | — | — | — | — | — | — | — | 2.5 | 58 |

* Design Flow Velocity exceeds 5 ft/s.

# TABLE 10.B.13 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPES
# (75 mm × 25 mm CORRUGATIONS)

POLYMER COATED (> 1.5 m/s)*

| DESIGN LIFE - 25 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **PIPE DIAMETER (mm)** | **HEIGHTS OF FILL (m)** | | | | | | | | | |
| | **1.63 mm thickness** | | **2.01 mm thickness** | | **2.77 mm thickness** | | **3.51 mm thickness** | | **4.27 mm thickness** | |
| | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** |
| 1350 | 0.8 | 11.6 | 0.6 | 17.1 | 0.6 | 25.0 | 0.5 | 32.4 | 0.5 | 39.3 |
| 1500 | 0.8 | 10.4 | 0.8 | 15.2 | 0.6 | 22.6 | 0.5 | 29.0 | 0.5 | 35.4 |
| 1650 | 0.8 | 9.4 | 0.8 | 14.0 | 0.6 | 20.4 | 0.6 | 26.2 | 0.5 | 32.3 |
| 1800 | 0.9 | 8.8 | 0.8 | 12.8 | 0.6 | 18.9 | 0.6 | 24.1 | 0.5 | 29.6 |
| 2100 | 0.9 | 7.3 | 0.8 | 11.0 | 0.8 | 16.2 | 0.6 | 20.7 | 0.6 | 25.3 |
| 2400 | — | — | 0.9 | 9.4 | 0.8 | 14.0 | 0.8 | 18.0 | 0.6 | 22.3 |

| DESIGN LIFE - 50 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **PIPE DIAMETER (mm)** | **HEIGHTS OF FILL (m)** | | | | | | | | | |
| | **1.63 mm thickness** | | **2.01 mm thickness** | | **2.77 mm thickness** | | **3.51 mm thickness** | | **4.27 mm thickness** | |
| | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** |
| 1350 | — | — | — | — | 0.6 | 10.1 | 0.5 | 20.7 | 0.5 | 31.7 |
| 1500 | — | — | — | — | 0.6 | 9.1 | 0.5 | 16.6 | 0.5 | 28.3 |
| 1650 | — | — | — | — | 0.6 | 8.2 | 0.6 | 17.1 | 0.5 | 25.9 |
| 1800 | — | — | — | — | 0.6 | 7.6 | 0.6 | 15.5 | 0.5 | 23.8 |
| 2100 | — | — | — | — | 0.8 | 6.7 | 0.6 | 13.4 | 0.6 | 20.4 |
| 2400 | — | — | — | — | 0.8 | 5.8 | 0.8 | 11.6 | 0.6 | 17.7 |

* Design Flow Velocity exceeds 1.5 m/s.

# TABLE 10.B.13 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPES
# (3 in × 1 in CORRUGATIONS)

POLYMER COATED (> 5 ft/s)*

| DESIGN LIFE - 25 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **PIPE DIAMETER (in)** | **HEIGHTS OF FILL (ft)** | | | | | | | | | |
| | **16 Gage** | | **14 Gage** | | **12 Gage** | | **10 Gage** | | **8 Gage** | |
| | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** |
| 54 | 2.5 | 38 | 2.0 | 56 | 2.0 | 82 | 1.5 | 106 | 1.5 | 129 |
| 60 | 2.5 | 34 | 2.5 | 50 | 2.0 | 74 | 1.5 | 95 | 1.5 | 116 |
| 66 | 2.5 | 31 | 2.5 | 46 | 2.0 | 67 | 2.0 | 86 | 1.5 | 106 |
| 72 | 3.0 | 29 | 2.5 | 42 | 2.0 | 62 | 2.0 | 79 | 1.5 | 97 |
| 84 | 3.0 | 24 | 2.5 | 36 | 2.5 | 53 | 2.0 | 68 | 2.0 | 83 |
| 96 | — | — | 3.0 | 31 | 2.5 | 46 | 2.5 | 59 | 2.0 | 73 |

| DESIGN LIFE - 50 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **PIPE DIAMETER (in)** | **HEIGHTS OF FILL (ft)** | | | | | | | | | |
| | **16 Gage** | | **14 Gage** | | **12 Gage** | | **10 Gage** | | **8 Gage** | |
| | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** |
| 54 | — | — | — | — | 2.0 | 33 | 1.5 | 68 | 1.5 | 104 |
| 60 | — | — | — | — | 2.0 | 30 | 1.5 | 61 | 1.5 | 93 |
| 66 | — | — | — | — | 2.0 | 27 | 2.0 | 56 | 1.5 | 85 |
| 72 | — | — | — | — | 2.0 | 25 | 2.0 | 51 | 1.5 | 78 |
| 84 | — | — | — | — | 2.5 | 22 | 2.0 | 44 | 2.0 | 67 |
| 96 | — | — | — | — | 2.5 | 19 | 2.5 | 38 | 2.0 | 58 |

* Design Flow Velocity exceeds 5 ft/s.

# TABLE 10.B.14 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPES
# (125 mm × 25 mm CORRUGATIONS)

POLYMER COATED (> 1.5 m/s)*

| DESIGN LIFE - 25 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **PIPE DIAMETER (mm)** | **HEIGHTS OF FILL (m)** | | | | | | | | | |
| | **1.63 mm thickness** | | **2.01 mm thickness** | | **2.77 mm thickness** | | **3.51 mm thickness** | | **4.27 mm thickness** | |
| | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** |
| 1350 | 0.8 | 10.4 | 0.6 | 15.2 | 0.6 | 22.3 | 0.5 | 28.6 | 0.5 | 35.1 |
| 1500 | 0.8 | 9.4 | 0.8 | 13.7 | 0.6 | 20.1 | 0.5 | 25.9 | 0.5 | 31.7 |
| 1650 | 0.8 | 8.5 | 0.8 | 12.5 | 0.6 | 18.3 | 0.6 | 23.5 | 0.5 | 28.7 |
| 1800 | 0.9 | 7.6 | 0.8 | 11.3 | 0.6 | 16.8 | 0.6 | 21.6 | 0.5 | 26.2 |
| 2100 | 0.9 | 6.7 | 0.8 | 9.8 | 0.8 | 14.3 | 0.6 | 18.6 | 0.6 | 22.6 |
| 2400 | — | — | 0.9 | 8.5 | 0.8 | 12.5 | 0.8 | 16.2 | 0.6 | 19.8 |

| DESIGN LIFE - 50 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **PIPE DIAMETER (mm)** | **HEIGHTS OF FILL (m)** | | | | | | | | | |
| | **1.63 mm thickness** | | **2.01 mm thickness** | | **2.77 mm thickness** | | **3.51 mm thickness** | | **4.27 mm thickness** | |
| | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** | **MIN** | **MAX** |
| 1350 | — | — | — | — | 0.6 | 9.1 | 0.5 | 18.6 | 0.5 | 28.0 |
| 1500 | — | — | — | — | 0.6 | 8.2 | 0.5 | 16.8 | 0.5 | 25.3 |
| 1650 | — | — | — | — | 0.6 | 7.3 | 0.6 | 15.2 | 0.5 | 22.9 |
| 1800 | — | — | — | — | 0.6 | 6.7 | 0.6 | 13.7 | 0.5 | 21.0 |
| 2100 | — | — | — | — | 0.8 | 5.8 | 0.6 | 11.9 | 0.6 | 18.0 |
| 2400 | — | — | — | — | 0.8 | 5.2 | 0.8 | 10.4 | 0.6 | 15.8 |

* Design Flow Velocity exceeds 1.5 m/s.

# TABLE 10.B.14 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPES
# (5 in × 1 in CORRUGATIONS)

POLYMER COATED (> 5 ft/s)*

| DESIGN LIFE - 25 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | | | |
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | | 8 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 54 | 2.5 | 34 | 2.0 | 50 | 2.0 | 73 | 1.5 | 94 | 1.5 | 115 |
| 60 | 2.5 | 31 | 2.5 | 45 | 2.0 | 66 | 1.5 | 85 | 1.5 | 104 |
| 66 | 2.5 | 28 | 2.5 | 41 | 2.0 | 60 | 2.0 | 77 | 1.5 | 94 |
| 72 | 3.0 | 25 | 2.5 | 37 | 2.0 | 55 | 2.0 | 71 | 1.5 | 86 |
| 84 | 3.0 | 22 | 2.5 | 32 | 2.5 | 47 | 2.0 | 61 | 2.0 | 74 |
| 96 | — | — | 3.0 | 28 | 2.5 | 41 | 2.5 | 53 | 2.0 | 65 |

| DESIGN LIFE - 50 YR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | | | |
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | | 8 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 54 | — | — | — | — | 2.0 | 30 | 1.5 | 61 | 1.5 | 92 |
| 60 | — | — | — | — | 2.0 | 27 | 1.5 | 55 | 1.5 | 83 |
| 66 | — | — | — | — | 2.0 | 24 | 2.0 | 50 | 1.5 | 75 |
| 72 | — | — | — | — | 2.0 | 22 | 2.0 | 45 | 1.5 | 69 |
| 84 | — | — | — | — | 2.5 | 19 | 2.0 | 39 | 2.0 | 59 |
| 96 | — | — | — | — | 2.5 | 17 | 2.5 | 34 | 2.0 | 52 |

* Design Flow Velocity exceeds 5 ft/s.

# TABLE 10.B.15 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED ALUMINUM ALLOY PIPES
# (68 mm × 13 mm CORRUGATIONS)

**DESIGN LIFE - 25 YR**

| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1.52 mm thickness | | 1.91 mm thickness | | 2.67 mm thickness | | 3.43 mm thickness | | 4.17 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 450 | 0.8 | 24.1 | 0.6 | 33.8 | — | — | — | — | — | — |
| 525 | 0.8 | 20.7 | 0.8 | 29.0 | — | — | — | — | — | — |
| 600 | 0.9 | 18.3 | 0.8 | 25.3 | 0.6 | 35.7 | — | — | — | — |
| 750 | — | — | 0.9 | 20.4 | 0.6 | 28.1 | — | — | — | — |
| 900 | — | — | 0.9 | 17.1 | 0.8 | 23.8 | 0.6 | 30.5 | — | — |
| 1050 | — | — | — | — | 0.8 | 20.4 | 0.6 | 26.2 | — | — |
| 1200 | — | — | — | — | 0.9 | 17.7 | 0.6 | 22.9 | 0.6 | 28.0 |
| 1350 | — | — | — | — | 0.9 | 14.3 | 0.8 | 18.6 | 0.6 | 23.2 |
| 1500 | — | — | — | — | — | — | 0.8 | 15.2 | 0.8 | 18.9 |
| 1650 | — | — | — | — | — | — | — | — | 0.8 | 15.2 |
| 1800 | — | — | — | — | — | — | — | — | 0.8 | 11.9 |

**DESIGN LIFE - 50 YR**

| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1.52 mm thickness | | 1.91 mm thickness | | 2.67 mm thickness | | 3.43 mm thickness | | 4.17 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 450 | 0.8 | 7.0 | 0.6 | 17.4 | — | — | — | — | — | — |
| 525 | 0.8 | 5.8 | 0.8 | 14.9 | — | — | — | — | — | — |
| 600 | 0.9 | 5.2 | 0.8 | 13.1 | 0.6 | 28.7 | — | — | — | — |
| 750 | — | — | 0.9 | 10.4 | 0.6 | 22.9 | — | — | — | — |
| 900 | — | — | 0.9 | 8.5 | 0.8 | 18.9 | 0.6 | 29.6 | — | — |
| 1050 | — | — | — | — | 0.8 | 16.5 | 0.6 | 25.3 | — | — |
| 1200 | — | — | — | — | 0.9 | 14.3 | 0.6 | 22.0 | 0.6 | 28.0 |
| 1350 | — | — | — | — | 0.9 | 12.8 | 0.8 | 18.6 | 0.6 | 23.2 |
| 1500 | — | — | — | — | — | — | 0.9 | 15.2 | 0.8 | 18.9 |
| 1650 | — | — | — | — | — | — | — | — | 0.8 | 15.2 |
| 1800 | — | — | — | — | — | — | — | — | 0.8 | 11.9 |

**DESIGN LIFE - 100 YR**

| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1.52 mm thickness | | 1.91 mm thickness | | 2.67 mm thickness | | 3.43 mm thickness | | 4.17 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 600 | — | — | — | — | 0.6 | 2.7 | — | — | — | — |
| 750 | — | — | — | — | — | — | — | — | — | — |
| 900 | — | — | — | — | — | — | 0.6 | 12.2 | — | — |
| 1050 | — | — | — | — | — | — | 0.6 | 10.4 | — | — |
| 1200 | — | — | — | — | — | — | 0.6 | 9.1 | 0.6 | 16.8 |
| 1350 | — | — | — | — | — | — | 0.8 | 8.2 | 0.6 | 14.9 |
| 1500 | — | — | — | — | — | — | 0.8 | 7.3 | 0.8 | 13.4 |
| 1650 | — | — | — | — | — | — | — | — | 0.8 | 12.2 |
| 1800 | — | — | — | — | — | — | — | — | 0.8 | 11.3 |

## TABLE 10.B.15 (ENGLISH)
## ALLOWABLE FILL HEIGHTS FOR
## CORRUGATED ALUMINUM ALLOY PIPES
## (2 2/3 in × 1/2 in CORRUGATIONS)

**DESIGN LIFE - 25 YR**

| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | | 8 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 18 | 2.5 | 79 | 2.0 | 111 | — | — | — | — | — | — |
| 21 | 2.5 | 68 | 2.5 | 95 | — | — | — | — | — | — |
| 24 | 3.0 | 60 | 2.5 | 83 | 2.0 | 117 | — | — | — | — |
| 30 | — | — | 3.0 | 67 | 2.0 | 93 | — | — | — | — |
| 36 | — | — | 3.0 | 56 | 2.5 | 78 | 2.0 | 100 | — | — |
| 42 | — | — | — | — | 2.5 | 67 | 2.0 | 86 | — | — |
| 48 | — | — | — | — | 3.0 | 58 | 2.0 | 75 | 2.0 | 92 |
| 54 | — | — | — | — | 3.0 | 47 | 2.5 | 61 | 2.0 | 76 |
| 60 | — | — | — | — | — | — | 2.5 | 50 | 2.5 | 62 |
| 66 | — | — | — | — | — | — | — | — | 2.5 | 50 |
| 72 | — | — | — | — | — | — | — | — | 2.5 | 39 |

**DESIGN LIFE - 50 YR**

| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | | 8 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 18 | 2.5 | 23 | 2.0 | 57 | — | — | — | — | — | — |
| 21 | 2.5 | 19 | 2.5 | 49 | — | — | — | — | — | — |
| 24 | 3.0 | 17 | 2.5 | 43 | 2.0 | 94 | — | — | — | — |
| 30 | — | — | 3.0 | 34 | 2.0 | 75 | — | — | — | — |
| 36 | — | — | 3.0 | 28 | 2.5 | 62 | 2.0 | 97 | — | — |
| 42 | — | — | — | — | 2.5 | 54 | 2.0 | 83 | — | — |
| 48 | — | — | — | — | 3.0 | 47 | 2.0 | 72 | 2.0 | 92 |
| 54 | — | — | — | — | 3.0 | 42 | 2.5 | 61 | 2.0 | 76 |
| 60 | — | — | — | — | — | — | 2.5 | 50 | 2.5 | 62 |
| 66 | — | — | — | — | — | — | — | — | 2.5 | 50 |
| 72 | — | — | — | — | — | — | — | — | 2.5 | 39 |

**DESIGN LIFE - 100 YR**

| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | | 8 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 24 | — | — | — | — | 2.0 | 9 | — | — | — | — |
| 30 | — | — | — | — | — | — | — | — | — | — |
| 36 | — | — | — | — | — | — | 2.0 | 40 | — | — |
| 42 | — | — | — | — | — | — | 2.0 | 34 | — | — |
| 48 | — | — | — | — | — | — | 2.0 | 30 | 2.0 | 55 |
| 54 | — | — | — | — | — | — | 2.5 | 27 | 2.0 | 49 |
| 60 | — | — | — | — | — | — | 2.5 | 24 | 2.5 | 44 |
| 66 | — | — | — | — | — | — | — | — | 2.5 | 40 |
| 72 | — | — | — | — | — | — | — | — | 2.5 | 37 |

# TABLE 10.B.16 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR CORRUGATED ALUMINUM ALLOY PIPES (75 mm × 25 mm CORRUGATIONS)

**DESIGN LIFE - 25 YR**

| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) 1.52 mm thickness MIN | 1.52 mm thickness MAX | 1.91 mm thickness MIN | 1.91 mm thickness MAX | 2.67 mm thickness MIN | 2.67 mm thickness MAX | 3.43 mm thickness MIN | 3.43 mm thickness MAX | 4.17 mm thickness MIN | 4.17 mm thickness MAX |
|---|---|---|---|---|---|---|---|---|---|---|
| 750 | 0.6 | 16.8 | 0.6 | 23.5 | 0.5 | 32.9 | 0.5 | 43.9 | — | — |
| 900 | 0.8 | 14.0 | 0.8 | 19.5 | 0.6 | 27.4 | 0.5 | 36.6 | — | — |
| 1050 | 0.8 | 11.9 | 0.8 | 16.8 | 0.6 | 23.5 | 0.6 | 31.4 | — | — |
| 1200 | 0.9 | 10.4 | 0.8 | 14.6 | 0.8 | 20.4 | 0.6 | 27.4 | 0.6 | 32.3 |
| 1350 | 0.9 | 9.1 | 0.9 | 13.1 | 0.8 | 18.3 | 0.6 | 24.4 | 0.6 | 28.6 |
| 1500 | 1.1 | 8.2 | 0.9 | 11.9 | 0.8 | 16.5 | 0.8 | 21.9 | 0.6 | 25.9 |
| 1650 | 1.1 | 7.6 | 0.9 | 10.7 | 0.9 | 14.9 | 0.8 | 19.8 | 0.8 | 23.5 |
| 1800 | 1.1 | 7.0 | 1.1 | 9.8 | 0.9 | 13.7 | 0.8 | 18.3 | 0.8 | 21.6 |
| 2100 | — | — | — | — | 0.9 | 11.6 | 0.9 | 15.5 | 0.8 | 18.6 |

**DESIGN LIFE - 50 YR**

| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) 1.52 mm thickness MIN | 1.52 mm thickness MAX | 1.91 mm thickness MIN | 1.91 mm thickness MAX | 2.67 mm thickness MIN | 2.67 mm thickness MAX | 3.43 mm thickness MIN | 3.43 mm thickness MAX | 4.17 mm thickness MIN | 4.17 mm thickness MAX |
|---|---|---|---|---|---|---|---|---|---|---|
| 750 | 0.6 | 4.9 | 0.6 | 11.9 | 0.5 | 26.2 | 0.5 | 42.4 | — | — |
| 900 | 0.8 | 4.0 | 0.8 | 10.1 | 0.6 | 21.9 | 0.5 | 35.4 | — | — |
| 1050 | 0.8 | 3.4 | 0.8 | 8.5 | 0.6 | 18.9 | 0.6 | 30.2 | — | — |
| 1200 | 0.9 | 3.0 | 0.8 | 7.6 | 0.8 | 16.5 | 0.6 | 26.5 | 0.6 | 32.3 |
| 1350 | 0.9 | 2.7 | 0.9 | 6.7 | 0.8 | 14.6 | 0.6 | 23.5 | 0.6 | 28.6 |
| 1500 | 1.1 | 1.8 | 0.9 | 6.1 | 0.8 | 13.1 | 0.8 | 21.0 | 0.6 | 25.9 |
| 1650 | — | — | 0.9 | 5.5 | 0.9 | 11.9 | 0.8 | 19.2 | 0.8 | 23.5 |
| 1800 | — | — | 1.1 | 4.9 | 0.9 | 11.0 | 0.8 | 17.7 | 0.8 | 21.6 |
| 2100 | — | — | — | — | 0.9 | 9.4 | 0.9 | 15.2 | 0.8 | 18.6 |

**DESIGN LIFE - 100 YR**

| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) 1.52 mm thickness MIN | 1.52 mm thickness MAX | 1.91 mm thickness MIN | 1.91 mm thickness MAX | 2.67 mm thickness MIN | 2.67 mm thickness MAX | 3.43 mm thickness MIN | 3.43 mm thickness MAX | 4.17 mm thickness MIN | 4.17 mm thickness MAX |
|---|---|---|---|---|---|---|---|---|---|---|
| 750 | — | — | — | — | — | — | 0.5 | 17.4 | — | — |
| 900 | — | — | — | — | — | — | 0.5 | 14.6 | — | — |
| 1050 | — | — | — | — | — | — | 0.6 | 12.5 | — | — |
| 1200 | — | — | — | — | — | — | 0.6 | 11.0 | 0.6 | 19.2 |
| 1350 | — | — | — | — | — | — | 0.6 | 9.8 | 0.6 | 17.1 |
| 1500 | — | — | — | — | — | — | 0.8 | 8.8 | 0.6 | 15.5 |
| 1650 | — | — | — | — | — | — | 0.8 | 7.9 | 0.8 | 14.0 |
| 1800 | — | — | — | — | — | — | 0.8 | 7.3 | 0.8 | 12.8 |
| 2100 | — | — | — | — | — | — | 0.9 | 6.1 | 0.8 | 11.0 |

# TABLE 10.B.16 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR CORRUGATED ALUMINUM ALLOY PIPES (3 in × 1 in CORRUGATIONS)

**DESIGN LIFE - 25 YR**

| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | | 8 Gage | |
|---|---|---|---|---|---|---|---|---|---|---|
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 30 | 2.0 | 55 | 2.0 | 77 | 1.5 | 108 | 1.5 | 144 | — | — |
| 36 | 2.5 | 46 | 2.5 | 64 | 2.0 | 90 | 1.5 | 120 | — | — |
| 42 | 2.5 | 39 | 2.5 | 55 | 2.0 | 77 | 2.0 | 103 | — | — |
| 48 | 3.0 | 34 | 2.5 | 48 | 2.5 | 67 | 2.0 | 90 | 2.0 | 106 |
| 54 | 3.0 | 30 | 3.0 | 43 | 2.5 | 60 | 2.0 | 80 | 2.0 | 94 |
| 60 | 3.5 | 27 | 3.0 | 39 | 2.5 | 54 | 2.5 | 72 | 2.0 | 85 |
| 66 | 3.5 | 25 | 3.0 | 35 | 3.0 | 49 | 2.5 | 65 | 2.5 | 77 |
| 72 | 3.5 | 23 | 3.5 | 32 | 3.0 | 45 | 2.5 | 60 | 2.5 | 71 |
| 84 | — | — | — | — | 3.0 | 38 | 3.0 | 51 | 2.5 | 61 |

**DESIGN LIFE - 50 YR**

| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | | 8 Gage | |
|---|---|---|---|---|---|---|---|---|---|---|
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 30 | 2.0 | 16 | 2.0 | 39 | 1.5 | 86 | 1.5 | 139 | — | — |
| 36 | 2.5 | 13 | 2.5 | 33 | 2.0 | 72 | 1.5 | 116 | — | — |
| 42 | 2.5 | 11 | 2.5 | 28 | 2.0 | 62 | 2.0 | 99 | — | — |
| 48 | 3.0 | 10 | 2.5 | 25 | 2.5 | 54 | 2.0 | 87 | 2.0 | 106 |
| 54 | 3.0 | 9 | 3.0 | 22 | 2.5 | 48 | 2.0 | 77 | 2.0 | 94 |
| 60 | 3.5 | 6 | 3.0 | 20 | 2.5 | 43 | 2.5 | 69 | 2.0 | 85 |
| 66 | — | — | 3.0 | 18 | 3.0 | 39 | 2.5 | 63 | 2.5 | 77 |
| 72 | — | — | 3.5 | 16 | 3.0 | 36 | 2.5 | 58 | 2.5 | 71 |
| 84 | — | — | — | — | 3.0 | 31 | 3.0 | 50 | 2.5 | 61 |

**DESIGN LIFE - 100 YR**

| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | | 8 Gage | |
|---|---|---|---|---|---|---|---|---|---|---|
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX |
| 30 | — | — | — | — | — | — | 1.5 | 57 | — | — |
| 36 | — | — | — | — | — | — | 1.5 | 48 | — | — |
| 42 | — | — | — | — | — | — | 2.0 | 41 | — | — |
| 48 | — | — | — | — | — | — | 2.0 | 36 | 2.0 | 63 |
| 54 | — | — | — | — | — | — | 2.0 | 32 | 2.0 | 56 |
| 60 | — | — | — | — | — | — | 2.5 | 29 | 2.0 | 51 |
| 66 | — | — | — | — | — | — | 2.5 | 26 | 2.5 | 46 |
| 72 | — | — | — | — | — | — | 2.5 | 24 | 2.5 | 42 |
| 84 | — | — | — | — | — | — | 3.0 | 20 | 2.5 | 36 |

# TABLE 10.B.17 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPE ARCHES
# (68 mm × 13 mm CORRUGATIONS)

**DESIGN LIFE - 25 YR**

| SPAN × RISE (mm) | MINIMUM FILL FOR 20 tonne/m² (m) | THICKNESS (mm) | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m² (m) | |
|---|---|---|---|---|
| | | | **20 tonne** | **30 tonne** |
| 530 × 380 | 0.5 | 1.63 | 3.1 | 5.0 |
| 610 × 460 | 0.5 | 1.63 | 3.1 | 5.0 |
| 710 × 510 | 0.5 | 1.63 | 3.1 | 5.0 |
| 885 × 610 | 0.5 | 1.63 | 3.1 | 5.0 |
| 1060 × 740 | 0.5 | 1.63 | 3.1 | 5.0 |
| 1240 × 840 | 0.5 | 2.01 | 3.1 | 5.0 |
| 1440 × 970 | 0.5 | 2.77 | 3.1 | 5.0 |
| 1620 × 1100 | 0.5 | 2.77 | 3.1 | 5.0 |
| 1800 × 1200 | 0.5 | 3.51 | 3.1 | 5.0 |
| 1950 × 1320 | 0.5 | 4.27 | 3.1 | 5.0 |
| 2100 × 1450 | 0.5 | 4.27 | 3.1 | 5.0 |

**DESIGN LIFE - 50 YR**

| SPAN × RISE (mm) | MINIMUM FILL FOR 20 tonne/m² (m) | THICKNESS (mm) | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m² (m) | |
|---|---|---|---|---|
| | | | **20 tonne** | **30 tonne** |
| 1440 × 970 | 0.9 | 2.77 | 2.2 | 2.2 |
| 1620 × 1100 | 1.2 | 2.77 | 1.7 | 1.7 |
| 1800 × 1200 | 0.5 | 3.51 | 3.1 | 5.0 |
| 1950 × 1320 | 0.5 | 4.27 | 3.1 | 5.0 |
| 2100 × 1450 | 0.5 | 4.27 | 3.1 | 5.0 |

# TABLE 10.B.17 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPE ARCHES
# (2 2/3 in × 1/2 in CORRUGATIONS)

| DESIGN LIFE - 25 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (in)** | **MINIMUM FILL FOR 2 tons/ft$^2$ (ft)** | **GAGE** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft)** | |
| | | | **2 tons** | **3 tons** |
| 21 × 15 | 1.5 | 16 | 10 | 16 |
| 24 × 18 | 1.5 | 16 | 10 | 16 |
| 28 × 20 | 1.5 | 16 | 10 | 16 |
| 35 × 24 | 1.5 | 16 | 10 | 16 |
| 42 × 29 | 1.5 | 16 | 10 | 16 |
| 49 × 33 | 1.5 | 14 | 10 | 16 |
| 57 × 38 | 1.5 | 12 | 10 | 16 |
| 64 × 43 | 1.5 | 12 | 10 | 16 |
| 71 × 47 | 1.5 | 10 | 10 | 16 |
| 77 × 52 | 1.5 | 8 | 10 | 16 |
| 83 × 57 | 1.5 | 8 | 10 | 16 |

| DESIGN LIFE - 50 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (in)** | **MINIMUM FILL FOR 2 tons/ft$^2$ (ft)** | **GAGE** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft)** | |
| | | | **2 tons** | **3 tons** |
| 57 × 38 | 3 | 12 | 7 | 7 |
| 64 × 43 | 4 | 12 | 5.5 | 5.5 |
| 71 × 47 | 1 | 10 | 10 | 16 |
| 77 × 52 | 1 | 8 | 10 | 16 |
| 83 × 57 | 1 | 8 | 10 | 16 |

# TABLE 10.B.18 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPE ARCHES
# (75 mm × 25 mm CORRUGATIONS)

**DESIGN LIFE - 25 YR**

| SPAN × RISE (mm) | MINIMUM FILL FOR 20 tonne/m² (m) | THICKNESS (mm) | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m² (m) | |
|---|---|---|---|---|
| | | | 20 tonne | 30 tonne |
| 1340 × 1050 | 0.5 | 2.01 | 3.1 | 4.6 |
| 1520 × 1170 | 0.5 | 2.01 | 5.5 | 8.2 |
| 1670 × 1300 | 0.5 | 2.01 | 5.5 | 8.2 |
| 1850 × 1400 | 0.5 | 2.01 | 5.2 | 7.3 |
| 2050 × 1500 | 0.5 | 2.01 | 4.6 | 6.7 |
| 2200 × 1620 | 0.5 | 2.01 | 4.3 | 6.1 |
| 2400 × 1720 | 0.5 | 2.01 | 4.3 | 5.8 |
| 2600 × 1820 | 0.5 | 2.01 | 4.3 | 5.2 |
| 2840 × 1920 | 0.5 | 2.01 | 4.3 | 4.9 |
| 2970 × 2020 | 0.5 | 2.77 | 4.3 | 6.4 |
| 3240 × 2120 | 0.5 | 2.77 | 4.3 | 6.4 |
| 3470 × 2220 | 0.5 | 2.77 | 4.0 | 6.1 |
| 3600 × 2320 | 0.5 | 3.51 | 4.0 | 6.1 |

**DESIGN LIFE - 50 YR**

| SPAN × RISE (mm) | MINIMUM FILL FOR 20 tonne/m² (m) | THICKNESS (mm) | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m² (m) | |
|---|---|---|---|---|
| | | | 20 tonne | 30 tonne |
| 3600 × 2320 | 0.5 | 3.51 | 4.0 | 5.2 |

# TABLE 10.B.18 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPE ARCHES
# (3 in × 1 in CORRUGATIONS)

| DESIGN LIFE - 25 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (in)** | **MINIMUM FILL FOR 2 tons/ft$^2$ (ft)** | **GAGE** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft)** | |
| | | | **2 tons** | **3 tons** |
| 53 × 41 | 1.5 | 14 | 10 | 15 |
| 60 × 46 | 1.5 | 14 | 18 | 27 |
| 66 × 51 | 1.5 | 14 | 18 | 27 |
| 73 × 55 | 1.5 | 14 | 17 | 24 |
| 81 × 59 | 1.5 | 14 | 15 | 22 |
| 87 × 63 | 1.5 | 14 | 14 | 20 |
| 95 × 67 | 1.5 | 14 | 14 | 19 |
| 103 × 71 | 1.5 | 14 | 14 | 17 |
| 112 × 75 | 1.5 | 14 | 14 | 16 |
| 117 × 79 | 1.5 | 12 | 14 | 21 |
| 128 × 83 | 1.5 | 12 | 14 | 21 |
| 137 × 87 | 1.5 | 12 | 13 | 20 |
| 142 × 91 | 1.5 | 10 | 13 | 20 |

| DESIGN LIFE - 50 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (in)** | **MINIMUM FILL FOR 2 tons/ft$^2$ (ft)** | **GAGE** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft)** | |
| | | | **2 tons** | **3 tons** |
| 142 × 91 | 1.5 | 10 | 13 | 17 |

# TABLE 10.B.19 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPE ARCHES
# (125 mm × 25 mm CORRUGATIONS)

**DESIGN LIFE - 25 YR**

| SPAN × RISE (mm) | MINIMUM FILL FOR 20 tonne/m$^2$ (m) | THICKNESS (mm) | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m$^2$ (m) | |
|---|---|---|---|---|
| | | | 20 tonne | 30 tonne |
| 1340 × 1050 | 0.5 | 2.77 | 3.1 | 4.6 |
| 1520 × 1170 | 0.5 | 2.77 | 5.5 | 8.2 |
| 1670 × 1300 | 0.5 | 2.77 | 5.5 | 8.2 |
| 1850 × 1400 | 0.5 | 2.77 | 5.2 | 7.9 |
| 2050 × 1500 | 0.5 | 2.77 | 4.6 | 6.7 |
| 2200 × 1620 | 0.5 | 2.77 | 4.3 | 6.7 |
| 2400 × 1720 | 0.5 | 2.77 | 4.3 | 6.7 |
| 2600 × 1820 | 0.5 | 2.77 | 4.3 | 6.4 |
| 2840 × 1920 | 0.5 | 2.77 | 4.3 | 6.4 |
| 2970 × 2020 | 0.5 | 2.77 | 4.3 | 6.4 |
| 3240 × 2120 | 0.5 | 2.77 | 4.3 | 6.4 |
| 3470 × 2220 | 0.5 | 2.77 | 4.0 | 6.1 |
| 3600 × 2320 | 0.5 | 3.51 | 4.0 | 6.1 |

**DESIGN LIFE - 50 YR**

| SPAN × RISE (mm) | MINIMUM FILL FOR 20 tonne/m$^2$ (m) | THICKNESS (mm) | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m$^2$ (m) | |
|---|---|---|---|---|
| | | | 20 tonne | 30 tonne |
| 1340 × 1050 | 0.9 | 2.77 | 2.7 | 2.7 |
| 1520 × 1170 | 1.1 | 2.77 | 2.1 | 2.1 |
| 1670 × 1300 | 1.4 | 2.77 | 1.7 | 1.7 |
| 3600 × 2320 | 0.5 | 3.51 | 4.0 | 4.6 |

# TABLE 10.B.19 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR CORRUGATED GALVANIZED STEEL PIPE ARCHES (5 in × 1 in CORRUGATIONS)

**DESIGN LIFE - 25 YR**

| SPAN × RISE (in) | MINIMUM FILL FOR 2 tons/ft² (ft) | GAGE | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft² (ft) | |
|---|---|---|---|---|
| | | | 2 tons | 3 tons |
| 53 × 41 | 1.5 | 12 | 10 | 15 |
| 60 × 46 | 1.5 | 12 | 18 | 27 |
| 66 × 51 | 1.5 | 12 | 18 | 27 |
| 73 × 55 | 1.5 | 12 | 17 | 26 |
| 81 × 59 | 1.5 | 12 | 15 | 22 |
| 87 × 63 | 1.5 | 12 | 14 | 22 |
| 95 × 67 | 1.5 | 12 | 14 | 22 |
| 103 × 71 | 1.5 | 12 | 14 | 21 |
| 112 × 75 | 1.5 | 12 | 14 | 21 |
| 117 × 79 | 1.5 | 12 | 14 | 21 |
| 128 × 83 | 1.5 | 12 | 14 | 21 |
| 137 × 87 | 1.5 | 12 | 13 | 20 |
| 142 × 91 | 1.5 | 10 | 13 | 20 |

**DESIGN LIFE - 50 YR**

| SPAN × RISE (in) | MINIMUM FILL FOR 2 tons/ft² (ft) | GAGE | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft² (ft) | |
|---|---|---|---|---|
| | | | 2 tons | 3 tons |
| 53 × 41 | 3 | 12 | 9 | 9 |
| 60 × 46 | 3.5 | 12 | 7 | 7 |
| 66 × 51 | 4.5 | 12 | 5.5 | 5.5 |
| 142 × 91 | 1.5 | 10 | 13 | 15 |

# TABLE 10.B.20 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED ALUMINIZED STEEL PIPE ARCHES
# (68 mm × 13 mm CORRUGATIONS)

**DESIGN LIFE - 25 YR**

| SPAN × RISE (mm) | MINIMUM FILL FOR 20 tonne/m² (m) | THICKNESS (mm) | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m² (m) | |
|---|---|---|---|---|
| | | | 20 tonne | 30 tonne |
| 530 × 380 | 0.5 | 2.01 - 1.63 | 3.1 | 5.0 |
| 610 × 460 | 0.5 | 2.77 - 2.01<br>1.63 | 3.1 | 5.0 |
| 710 × 510 | 0.5 | 2.77 - 2.01<br>1.63 | 3.1 | 5.0 |
| 885 × 610 | 0.5 | 2.77 - 2.01<br>1.63 | 3.1 | 5.0 |
| 1060 × 740 | 0.5 | 3.51 - 2.77<br>2.01 - 1.63 | 3.1 | 5.0 |
| 1240 × 840 | 0.5 | 3.51 - 2.77<br>2.01 - 1.63 | 3.1 | 5.0 |
| 1440 × 970 | 0.5 | 3.51 - 2.77<br>2.01 | 3.1 | 5.0 |
| 1620 × 1100 | 0.5 | 3.51 - 2.77<br>2.01 | 3.1 | 5.0 |
| 1800 × 1200 | 0.5 | 3.51 - 2.77 | 3.1 | 5.0 |
| 1950 × 1320 | 0.5 | 3.51 - 2.77 | 3.1 | 5.0 |
| 2100 × 1450 | 0.5 | 3.51 | 3.1 | 5.0 |

**DESIGN LIFE - 50 YR**

| SPAN × RISE (mm) | MINIMUM FILL FOR 20 tonne/m² (m) | THICKNESS (mm) | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m² (m) | |
|---|---|---|---|---|
| | | | 20 tonne | 30 tonne |
| 530 × 380 | 0.5 | 2.01 - 1.63 | 3.1 | 5.0 |
| 610 × 460 | 0.5 | 2.77 - 2.01<br>1.63 | 3.1 | 5.0 |
| 710 × 510 | 0.5 | 2.77 - 2.01<br>1.63 | 3.1 | 5.0 |
| 885 × 610 | 0.5 | 2.77 - 2.01<br>1.63 | 3.1 | 5.0 |
| 1060 × 740 | 0.6 | 1.63 | 3.1 | 5.0 |
| | 0.5 | 3.51 - 2.77<br>2.01 | 3.1 | 5.0 |
| 1240 × 840 | 0.8 | 1.63 | 3.1 | 5.0 |
| | 0.5 | 3.51 - 2.77<br>2.01 | 3.1 | 5.0 |
| 1440 × 970 | 0.5 | 3.51 - 2.77<br>2.01 | 3.1 | 5.0 |
| 1620 × 1100 | 0.5 | 3.51 - 2.77<br>2.01 | 3.1 | 5.0 |
| 1800 × 1200 | 0.5 | 3.51 - 2.77 | 3.1 | 5.0 |
| 1950 × 1320 | 0.5 | 3.51 - 2.77 | 3.1 | 5.0 |
| 2100 × 1450 | 0.5 | 3.51 | 3.1 | 5.0 |

# TABLE 10.B.20 (METRIC) (CONTINUED)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED ALUMINIZED STEEL PIPE ARCHES
# (68 mm × 13 mm CORRUGATIONS)

| DESIGN LIFE - 100 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (mm)** | **MINIMUM FILL FOR 20 tonne/m$^2$ (m)** | **THICKNESS (mm)** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m$^2$ (m)** | |
| | | | **20 tonne** | **30 tonne** |
| 610 × 460 | 0.8 | 2.77 | 3.1 | 3.1 |
| 710 × 510 | 0.9 | 2.77 | 2.4 | 2.4 |
| 885 × 610 | 1.4 | 2.77 | 1.5 | 1.5 |
| 1060 × 740 | 0.5 | 3.51 | 3.1 | 5.0 |
| 1240 × 840 | 0.5 | 3.51 | 3.1 | 5.0 |
| 1440 × 970 | 0.5 | 3.51 | 3.1 | 5.0 |
| 1620 × 1100 | 0.5 | 3.51 | 3.1 | 5.0 |
| 1800 × 1200 | 0.5 | 3.51 | 3.1 | 5.0 |
| 1950 × 1320 | 0.5 | 3.51 | 3.1 | 5.0 |
| 2100 × 1450 | 0.5 | 3.51 | 3.1 | 5.0 |

# TABLE 10.B.20 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED ALUMINIZED STEEL PIPE ARCHES
# (2 2/3 in × 1/2 in CORRUGATIONS)

| DESIGN LIFE - 25 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (in)** | **MINIMUM FILL FOR 2 tons/ft$^2$ (ft)** | **GAGE** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft)** | |
| | | | **2 tons** | **3 tons** |
| 21 × 15 | 1.5 | 12-14-16 | 10 | 16 |
| 24 × 18 | 1.5 | 12-14-16 | 10 | 16 |
| 28 × 20 | 1.5 | 12-14-16 | 10 | 16 |
| 35 × 24 | 1.5 | 12-14-16 | 10 | 16 |
| 42 × 29 | 1.5 | 10-12-14-16 | 10 | 16 |
| 49 × 33 | 1.5 | 10-12-14-16 | 10 | 16 |
| 57 × 38 | 1.5 | 10-12-14 | 10 | 16 |
| 64 × 43 | 1.5 | 10-12-14 | 10 | 16 |
| 71 × 47 | 1.5 | 10-12 | 10 | 16 |
| 77 × 52 | 1.5 | 10-12 | 10 | 16 |
| 83 × 57 | 1.5 | 10 | 10 | 16 |

| DESIGN LIFE - 50 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (in)** | **MINIMUM FILL FOR 2 tons/ft$^2$ (ft)** | **GAGE** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft)** | |
| | | | **2 tons** | **3 tons** |
| 21 × 15 | 1.5 | 14 - 16 | 10 | 16 |
| 24 × 18 | 1.5 | 12 - 14 - 16 | 10 | 16 |
| 28 × 20 | 1.5 | 12 - 14 - 16 | 10 | 16 |
| 35 × 24 | 1.5 | 12 - 14 - 16 | 10 | 16 |
| 42 × 29 | 2 | 16 | 10 | 16 |
| | 1.5 | 10 - 12 - 14 | 10 | 16 |
| 49 × 33 | 2.5 | 16 | 10 | 16 |
| | 1.5 | 10 - 12 - 14 | 10 | 16 |
| 57 × 38 | 1.5 | 10 - 12 - 14 | 10 | 16 |
| 64 × 43 | 1.5 | 10 - 12 - 14 | 10 | 16 |
| 71 × 47 | 1.5 | 10 - 12 | 10 | 16 |
| 77 × 52 | 1.5 | 10 - 12 | 10 | 16 |
| 83 × 57 | 1.5 | 10 | 10 | 16 |

| DESIGN LIFE - 100 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (in)** | **MINIMUM FILL FOR 2 tons/ft$^2$ (ft)** | **GAGE** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft)** | |
| | | | **2 tons** | **3 tons** |
| 24 × 18 | 2.5 | 12 | 10 | 10 |
| 28 × 20 | 3 | 12 | 8 | 8 |
| 35 × 24 | 4.5 | 12 | 5 | 5 |
| 42 × 29 | 1.5 | 10 | 10 | 16 |
| 49 × 33 | 1.5 | 10 | 10 | 16 |
| 57 × 38 | 1.5 | 10 | 10 | 16 |
| 64 × 43 | 1.5 | 10 | 10 | 16 |
| 71 × 47 | 1.5 | 10 | 10 | 16 |
| 77 × 52 | 1.5 | 10 | 10 | 16 |
| 83 × 57 | 1.5 | 10 | 10 | 16 |

# TABLE 10.B.21 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR CORRUGATED ALUMINIZED STEEL PIPE ARCHES (75 mm × 25 mm CORRUGATIONS)

**DESIGN LIFE - 25 YR**

| SPAN × RISE (mm) | MINIMUM FILL FOR 20 tonne/m$^2$ (m) | THICKNESS (mm) | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m$^2$ (m) | |
|---|---|---|---|---|
| | | | 20 tonne | 30 tonne |
| 1340 × 1050 | 0.5 | 3.51 - 2.77<br>2.01 | 3.1 | 4.6 |
| 1520 × 1170 | 0.5 | 3.51 - 2.77<br>2.01 | 5.2 | 8.2 |
| 1670 × 1300 | 0.5 | 3.51 - 2.77<br>2.01 | 5.2 | 8.2 |
| 1850 × 1400 | 0.5 | 3.51 - 2.77<br>2.01 | 5.2 | 7.9 |
| 2050 × 1500 | 0.5 | 3.51 - 2.77<br>2.01 | 4.3 | 6.7 |
| 2200 × 1620 | 0.5 | 3.51 - 2.77<br>2.01 | 4.3 | 6.7 |
| 2400 × 1720 | 0.5 | 3.51 - 2.77<br>2.01 | 4.3 | 6.7 |
| 2600 × 1820 | 0.5 | 3.51 - 2.77<br>2.01 | 4.3 | 6.4 |
| 2840 × 1920 | 0.5 | 3.51 - 2.77<br>2.01 | 4.3 | 6.4 |
| 2970 × 2020 | 0.5 | 3.51 - 2.77 | 4.3 | 6.4 |
| 3240 × 2120 | 0.5 | 3.51 - 2.77 | 4.0 | 6.4 |
| 3470 × 2220 | 0.5 | 3.51 - 2.77 | 4.0 | 6.1 |
| 3600 × 2320 | 0.5 | 3.51 | 4.0 | 6.1 |

**DESIGN LIFE - 50 YR**

| SPAN × RISE (mm) | MINIMUM FILL FOR 20 tonne/m$^2$ (m) | THICKNESS (mm) | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m$^2$ (m) | |
|---|---|---|---|---|
| | | | 20 tonne | 30 tonne |
| 1340 × 1050 | 0.5 | 3.51 - 2.77<br>2.01 | 3.0 | 4.6 |
| 1520 × 1170 | 0.5 | 3.51 - 2.77<br>2.01 | 5.2 | 8.2 |
| 1670 × 1300 | 0.5 | 3.51 - 2.77<br>2.01 | 5.2 | 8.2 |
| 1850 × 1400 | 0.5 | 3.51 - 2.77<br>2.01 | 5.2 | 7.9 |
| 2050 × 1500 | 0.5 | 3.51 - 2.77<br>2.01 | 4.3 | 6.7 |
| 2200 × 1620 | 0.5 | 3.51 - 2.77<br>2.01 | 4.3 | 6.7 |
| 2400 × 1720 | 0.5 | 3.51 - 2.77<br>2.01 | 4.3 | 6.7 |
| 2600 × 1820 | 0.5 | 3.51 - 2.77<br>2.01 | 4.3 | 6.4 |
| 2840 × 1920 | 0.6 | 2.01 | 4.3 | 6.4 |
| | 0.5 | 3.51 - 2.77 | 4.3 | 6.4 |
| 2970 × 2020 | 0.5 | 3.51 - 2.77 | 4.3 | 6.4 |
| 3240 × 2120 | 0.5 | 3.51 - 2.77 | 4.0 | 6.4 |
| 3470 × 2220 | 0.5 | 3.51 - 2.77 | 4.0 | 6.1 |
| 3600 × 2320 | 0.5 | 3.51 | 4.0 | 6.1 |

# TABLE 10.B.21 (METRIC) (CONTINUED)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED ALUMINIZED STEEL PIPE ARCHES
# (75 mm × 25 mm CORRUGATIONS)

| DESIGN LIFE - 100 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (mm)** | **MINIMUM FILL FOR 20 tonne/m$^2$ (m)** | **THICKNESS (mm)** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m$^2$ (m)** | |
| | | | **20 tonne** | **30 tonne** |
| 1340 × 1050 | 0.5 | 3.51 | 3.0 | 4.6 |
| 1520 × 1170 | 0.5 | 3.51 | 5.2 | 8.2 |
| 1670 × 1300 | 0.5 | 3.51 | 5.2 | 8.2 |
| 1850 × 1400 | 0.5 | 3.51 | 5.2 | 7.9 |
| 2050 × 1500 | 0.5 | 3.51 | 4.3 | 6.7 |
| 2200 × 1620 | 0.5 | 3.51 | 4.3 | 6.7 |
| 2400 × 1720 | 0.5 | 3.51 | 4.3 | 6.7 |
| 2600 × 1820 | 0.5 | 3.51 | 4.3 | 6.4 |
| 2840 × 1920 | 0.5 | 3.51 | 4.3 | 6.4 |
| 2970 × 2020 | 0.5 | 3.51 | 4.3 | 6.4 |
| 3240 × 2120 | 0.5 | 3.51 | 4.0 | 6.4 |
| 3470 × 2220 | 0.5 | 3.51 | 4.0 | 6.1 |
| 3600 × 2320 | 0.5 | 3.51 | 4.0 | 6.1 |

# TABLE 10.B.21 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED ALUMINIZED STEEL PIPE ARCHES
# (3 in × 1 in CORRUGATIONS)

**DESIGN LIFE - 25 YR**

| SPAN × RISE (in) | MINIMUM FILL FOR 2 tons/ft$^2$ (ft) | GAGE | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft) | |
|---|---|---|---|---|
| | | | 2 tons | 3 tons |
| 53 × 41 | 1.5 | 10 - 12 - 14 | 10 | 15 |
| 60 × 46 | 1.5 | 10 - 12 - 14 | 17 | 27 |
| 66 × 51 | 1.5 | 10 - 12 - 14 | 17 | 27 |
| 73 × 55 | 1.5 | 10 - 12 - 14 | 17 | 26 |
| 81 × 59 | 1.5 | 10 - 12 - 14 | 14 | 22 |
| 87 × 63 | 1.5 | 10 - 12 - 14 | 14 | 22 |
| 95 × 67 | 1.5 | 10 - 12 - 14 | 14 | 22 |
| 103 × 71 | 1.5 | 10 - 12 - 14 | 14 | 21 |
| 112 × 75 | 1.5 | 10 - 12 - 14 | 14 | 21 |
| 117 × 79 | 1.5 | 10 - 12 | 14 | 21 |
| 128 × 83 | 1.5 | 10 - 12 | 13 | 21 |
| 137 × 87 | 1.5 | 10 - 12 | 13 | 20 |
| 142 × 91 | 1.5 | 10 | 13 | 20 |

**DESIGN LIFE - 50 YR**

| SPAN × RISE (in) | MINIMUM FILL FOR 2 tons/ft$^2$ (ft) | GAGE | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft) | |
|---|---|---|---|---|
| | | | 2 tons | 3 tons |
| 53 × 41 | 1.5 | 10 - 12 - 14 | 10 | 15 |
| 60 × 46 | 1.5 | 10 - 12 - 14 | 17 | 27 |
| 66 × 51 | 1.5 | 10 - 12 - 14 | 17 | 27 |
| 73 × 55 | 1.5 | 10 - 12 - 14 | 17 | 26 |
| 81 × 59 | 1.5 | 10 - 12 - 14 | 14 | 22 |
| 87 × 63 | 1.5 | 10 - 12 - 14 | 14 | 22 |
| 95 × 67 | 1.5 | 10 - 12 - 14 | 14 | 22 |
| 103 × 71 | 1.5 | 10 - 12 - 14 | 14 | 21 |
| 112 × 75 | 2 | 14 | 14 | 21 |
| | 1.5 | 10 - 12 | 14 | 21 |
| 117 × 79 | 1.5 | 10 - 12 | 14 | 21 |
| 128 × 83 | 1.5 | 10 - 12 | 13 | 21 |
| 137 × 87 | 1.5 | 10 - 12 | 13 | 20 |
| 142 × 91 | 1.5 | 10 | 13 | 20 |

**DESIGN LIFE - 100 YR**

| SPAN × RISE (in) | MINIMUM FILL FOR 2 tons/ft$^2$ (ft) | GAGE | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft) | |
|---|---|---|---|---|
| | | | 2 tons | 3 tons |
| 53 × 41 | 1.5 | 10 | 10 | 15 |
| 60 × 46 | 1.5 | 10 | 17 | 27 |
| 66 × 51 | 1.5 | 10 | 17 | 27 |
| 73 × 55 | 1.5 | 10 | 17 | 26 |
| 81 × 59 | 1.5 | 10 | 14 | 22 |
| 87 × 63 | 1.5 | 10 | 14 | 22 |
| 95 × 67 | 1.5 | 10 | 14 | 22 |
| 103 × 71 | 1.5 | 10 | 14 | 21 |
| 112 × 75 | 1.5 | 10 | 14 | 21 |
| 117 × 79 | 1.5 | 10 | 14 | 21 |
| 128 × 83 | 1.5 | 10 | 13 | 21 |
| 137 × 87 | 1.5 | 10 | 13 | 20 |
| 142 × 91 | 1.5 | 10 | 13 | 20 |

# TABLE 10.B.22 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED ALUMINIZED STEEL PIPE ARCHES
# (125 mm × 25 mm CORRUGATIONS)

**DESIGN LIFE - 25 YR**

| SPAN × RISE (mm) | MINIMUM FILL FOR 20 tonne/m² (m) | THICKNESS (mm) | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m² (m) | |
|---|---|---|---|---|
| | | | 20 tonne | 30 tonne |
| 2050 × 1500 | 0.5 | 3.51 - 2.77 | 4.3 | 6.7 |
| 2200 × 1620 | 0.5 | 3.51 - 2.77 | 4.3 | 6.7 |
| 2400 × 1720 | 0.5 | 3.51 - 2.77 | 4.3 | 6.7 |
| 2600 × 1820 | 0.5 | 3.51 - 2.77 | 4.3 | 6.4 |
| 2840 × 1920 | 0.5 | 3.51 - 2.77 | 4.3 | 6.4 |
| 2970 × 2020 | 0.5 | 3.51 - 2.77 | 4.3 | 6.4 |
| 3240 × 2120 | 0.5 | 3.51 - 2.77 | 4.0 | 6.4 |
| 3470 × 2220 | 0.5 | 3.51 - 2.77 | 4.0 | 6.1 |
| 3600 × 2320 | 0.5 | 3.51 | 4.0 | 6.1 |

**DESIGN LIFE - 50 YR**

| SPAN × RISE (mm) | MINIMUM FILL FOR 20 tonne/m² (m) | THICKNESS (mm) | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m² (m) | |
|---|---|---|---|---|
| | | | 20 tonne | 30 tonne |
| 2050 × 1500 | 0.5 | 3.51 - 2.77 | 4.3 | 6.7 |
| 2200 × 1620 | 0.5 | 3.51 - 2.77 | 4.3 | 6.7 |
| 2400 × 1720 | 0.5 | 3.51 - 2.77 | 4.3 | 6.7 |
| 2600 × 1820 | 0.5 | 3.51 - 2.77 | 4.3 | 6.4 |
| 2840 × 1920 | 0.5 | 3.51 - 2.77 | 4.3 | 6.4 |
| 2970 × 2020 | 0.5 | 3.51 - 2.77 | 4.3 | 6.4 |
| 3240 × 2120 | 0.5 | 3.51 - 2.77 | 4.0 | 6.4 |
| 3470 × 2220 | 0.5 | 3.51 - 2.77 | 4.0 | 6.1 |
| 3600 × 2320 | 0.5 | 3.51 | 4.0 | 6.1 |

**DESIGN LIFE - 100 YR**

| SPAN × RISE (mm) | MINIMUM FILL FOR 20 tonne/m² (m) | THICKNESS (mm) | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m² (m) | |
|---|---|---|---|---|
| | | | 20 tonne | 30 tonne |
| 2050 × 1500 | 0.5 | 3.51 | 4.3 | 6.7 |
| 2200 × 1620 | 0.5 | 3.51 | 4.3 | 6.7 |
| 2400 × 1720 | 0.5 | 3.51 | 4.3 | 6.7 |
| 2600 × 1820 | 0.5 | 3.51 | 4.3 | 6.4 |
| 2840 × 1920 | 0.5 | 3.51 | 4.3 | 5.8 |
| 2970 × 2020 | 0.5 | 3.51 | 4.3 | 5.5 |
| 3240 × 2120 | 0.5 | 3.51 | 4.0 | 4.9 |
| 3470 × 2220 | 0.6 | 3.51 | 4.0 | 4.6 |
| 3600 × 2320 | 0.6 | 3.51 | 4.0 | 4.6 |

# TABLE 10.B.22 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED ALUMINIZED STEEL PIPE ARCHES
# (5 in × 1 in CORRUGATIONS)

| DESIGN LIFE - 25 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (in)** | **MINIMUM FILL FOR 2 tons/ft$^2$ (ft)** | **GAGE** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft)** | |
| | | | **2 tons** | **3 tons** |
| 81 × 59 | 1.5 | 10 - 12 | 14 | 22 |
| 87 × 63 | 1.5 | 10 - 12 | 14 | 22 |
| 95 × 67 | 1.5 | 10 - 12 | 14 | 22 |
| 103 × 71 | 1.5 | 10 - 12 | 14 | 21 |
| 112 × 75 | 1.5 | 10 - 12 | 14 | 21 |
| 117 × 79 | 1.5 | 10 - 12 | 14 | 21 |
| 128 × 83 | 1.5 | 10 - 12 | 13 | 21 |
| 137 × 87 | 1.5 | 10 - 12 | 13 | 20 |
| 142 × 91 | 1.5 | 10 | 13 | 20 |

| DESIGN LIFE - 50 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (in)** | **MINIMUM FILL FOR 2 tons/ft$^2$ (ft)** | **GAGE** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft)** | |
| | | | **2 tons** | **3 tons** |
| 81 × 59 | 1.5 | 10 - 12 | 14 | 22 |
| 87 × 63 | 1.5 | 10 - 12 | 14 | 22 |
| 95 × 67 | 1.5 | 10 - 12 | 14 | 22 |
| 103 × 71 | 1.5 | 10 - 12 | 14 | 21 |
| 112 × 75 | 1.5 | 10 - 12 | 14 | 21 |
| 117 × 79 | 1.5 | 10 - 12 | 14 | 21 |
| 128 × 83 | 1.5 | 10 - 12 | 13 | 21 |
| 137 × 87 | 1.5 | 10 - 12 | 13 | 20 |
| 142 × 91 | 1.5 | 10 | 13 | 20 |

| DESIGN LIFE - 100 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (in)** | **MINIMUM FILL FOR 2 tons/ft$^2$ (ft)** | **GAGE** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft)** | |
| | | | **2 tons** | **3 tons** |
| 81 × 59 | 1.5 | 10 | 14 | 22 |
| 87 × 63 | 1.5 | 10 | 14 | 22 |
| 95 × 67 | 1.5 | 10 | 14 | 22 |
| 103 × 71 | 1.5 | 10 | 14 | 21 |
| 112 × 75 | 1.5 | 10 | 14 | 19 |
| 117 × 79 | 1.5 | 10 | 14 | 18 |
| 128 × 83 | 1.5 | 10 | 13 | 16 |
| 137 × 87 | 2 | 10 | 13 | 15 |
| 142 × 91 | 2 | 10 | 13 | 15 |

# TABLE 10.B.23 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPE ARCHES
# (68 mm × 13 mm CORRUGATIONS)

POLYMER COATED (≤ 1.5 m/s)*

| DESIGN LIFE - 25 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (mm)** | **MINIMUM FILL FOR 20 tonne/m² (m)** | **THICKNESS (mm)** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m² (m)** | |
| | | | **20 tonne** | **30 tonne** |
| 530 × 380 | 0.5 | 1.63 | 3.1 | 5.0 |
| 610 × 460 | 0.5 | 1.63 | 3.1 | 5.0 |
| 710 × 510 | 0.5 | 1.63 | 3.1 | 5.0 |
| 885 × 610 | 0.5 | 1.63 | 3.1 | 5.0 |
| 1060 × 740 | 0.5 | 1.63 | 3.1 | 5.0 |
| 1240 × 840 | 0.5 | 2.01 | 3.1 | 5.0 |
| 1440 × 970 | 0.5 | 2.77 | 3.1 | 5.0 |
| 1620 × 1100 | 0.5 | 2.77 | 3.1 | 5.0 |
| 1800 × 1200 | 0.5 | 3.51 | 3.1 | 5.0 |
| 1950 × 1320 | 0.5 | 4.27 | 3.1 | 5.0 |
| 2100 × 1450 | 0.5 | 4.27 | 3.1 | 5.0 |

| DESIGN LIFE - 50 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (mm)** | **MINIMUM FILL FOR 20 tonne/m² (m)** | **THICKNESS (mm)** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m² (m)** | |
| | | | **20 tonne** | **30 tonne** |
| 530 × 380 | 0.8 | 1.63 | 3.1 | 3.1 |
| 610 × 460 | 0.9 | 1.63 | 2.4 | 2.4 |
| 710 × 510 | 1.2 | 1.63 | 1.7 | 1.7 |
| 1240 × 840 | 0.5 | 2.01 | 3.1 | 5.0 |
| 1440 × 970 | 0.5 | 2.77 | 3.1 | 5.0 |
| 1620 × 1100 | 0.5 | 2.77 | 3.1 | 5.0 |
| 1800 × 1200 | 0.5 | 3.51 | 3.1 | 5.0 |
| 1950 × 1320 | 0.5 | 4.27 | 3.1 | 5.0 |
| 2100 × 1450 | 0.5 | 4.27 | 3.1 | 5.0 |

* Design Flow Velocity does not exceed 1.5 m/s, low abrasive (minimal bedload) environment.

# TABLE 10.B.23 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPE ARCHES
# (2 2/3 in × 1/2 in CORRUGATIONS)

POLYMER COATED (≤ 5 ft/s)*

| DESIGN LIFE - 25 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (in)** | **MINIMUM FILL FOR 2 tons/ft$^2$ (ft)** | **GAGE** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft)** | |
| | | | **2 tons** | **3 tons** |
| 21 × 15 | 1.5 | 16 | 10 | 16 |
| 24 × 18 | 1.5 | 16 | 10 | 16 |
| 28 × 20 | 1.5 | 16 | 10 | 16 |
| 35 × 24 | 1.5 | 16 | 10 | 16 |
| 42 × 29 | 1.5 | 16 | 10 | 16 |
| 49 × 33 | 1.5 | 14 | 10 | 16 |
| 57 × 38 | 1.5 | 12 | 10 | 16 |
| 64 × 43 | 1.5 | 12 | 10 | 16 |
| 71 × 47 | 1.5 | 10 | 10 | 16 |
| 77 × 52 | 1.5 | 8 | 10 | 16 |
| 83 × 57 | 1.5 | 8 | 10 | 16 |

| DESIGN LIFE - 50 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (in)** | **MINIMUM FILL FOR 2 tons/ft$^2$ (ft)** | **GAGE** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft)** | |
| | | | **2 tons** | **3 tons** |
| 21 × 15 | 2.5 | 16 | 10 | 10 |
| 24 × 18 | 3 | 16 | 8 | 8 |
| 28 × 20 | 4 | 16 | 5.5 | 5.5 |
| 49 × 33 | 1.5 | 14 | 10 | 16 |
| 57 × 38 | 1.5 | 12 | 10 | 16 |
| 64 × 43 | 1.5 | 12 | 10 | 16 |
| 71 × 47 | 1.5 | 10 | 10 | 16 |
| 77 × 52 | 1.5 | 8 | 10 | 16 |
| 83 × 57 | 1.5 | 8 | 10 | 16 |

* Design Flow Velocity does not exceed 5 ft/s, low abrasive (minimal bedload) environment.

# TABLE 10.B.24 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPE ARCHES
# (75 mm × 25 mm CORRUGATIONS)

POLYMER COATED (≤ 1.5 m/s)*

| DESIGN LIFE - 25 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (mm)** | **MINIMUM FILL FOR 20 tonne/m² (m)** | **THICKNESS (mm)** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m² (m)** | |
| | | | **20 tonne** | **30 tonne** |
| 1340 × 1050 | 0.5 | 2.01 | 3.1 | 4.6 |
| 1520 × 1170 | 0.5 | 2.01 | 5.5 | 8.2 |
| 1670 × 1300 | 0.5 | 2.01 | 5.5 | 8.2 |
| 1850 × 1400 | 0.5 | 2.01 | 5.2 | 7.9 |
| 2050 × 1500 | 0.5 | 2.01 | 4.6 | 6.7 |
| 2200 × 1620 | 0.5 | 2.01 | 4.3 | 6.7 |
| 2400 × 1720 | 0.5 | 2.01 | 4.3 | 6.7 |
| 2600 × 1820 | 0.5 | 2.01 | 4.3 | 6.4 |
| 2840 × 1920 | 0.5 | 2.01 | 4.3 | 6.4 |
| 2970 × 2020 | 0.5 | 2.77 | 4.3 | 6.4 |
| 3240 × 2120 | 0.5 | 2.77 | 4.3 | 6.4 |
| 3470 × 2220 | 0.5 | 2.77 | 4.0 | 6.1 |
| 3600 × 2320 | 0.5 | 3.51 | 4.0 | 6.1 |

| DESIGN LIFE - 50 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (mm)** | **MINIMUM FILL FOR 20 tonne/m² (m)** | **THICKNESS (mm)** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m² (m)** | |
| | | | **20 tonne** | **30 tonne** |
| 1340 × 1050 | 0.5 | 2.01 | 3.1 | 4.6 |
| 1520 × 1170 | 0.5 | 2.01 | 5.5 | 5.8 |
| 1670 × 1300 | 0.5 | 2.01 | 5.5 | 5.5 |
| 1850 × 1400 | 0.5 | 2.01 | 5.0 | 5.0 |
| 2050 × 1500 | 0.5 | 2.01 | 4.3 | 4.3 |
| 2200 × 1620 | 0.6 | 2.01 | 4.0 | 4.0 |
| 2400 × 1720 | 0.6 | 2.01 | 3.7 | 3.7 |
| 2600 × 1820 | 0.8 | 2.01 | 3.4 | 3.4 |
| 2840 × 1920 | 0.8 | 2.01 | 3.1 | 3.1 |
| 2970 × 2020 | 0.5 | 2.77 | 4.3 | 6.4 |
| 3240 × 2120 | 0.5 | 2.77 | 4.3 | 6.4 |
| 3470 × 2220 | 0.5 | 2.77 | 4.0 | 6.1 |
| 3600 × 2320 | 0.5 | 3.51 | 4.0 | 6.1 |

* Design Flow Velocity does not exceed 1.5 m/s, low abrasive (minimal bedload) environment.

# TABLE 10.B.24 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPE ARCHES
# (3 in × 1 in CORRUGATIONS)

POLYMER COATED (≤ 5 ft/s)*

**DESIGN LIFE - 25 YR**

| SPAN × RISE (in) | MINIMUM FILL FOR 2 tons/ft$^2$ (ft) | GAGE | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft) | |
|---|---|---|---|---|
| | | | 2 tons | 3 tons |
| 53 × 41 | 1.5 | 14 | 10 | 15 |
| 60 × 46 | 1.5 | 14 | 18 | 27 |
| 66 × 51 | 1.5 | 14 | 18 | 27 |
| 73 × 55 | 1.5 | 14 | 17 | 26 |
| 81 × 59 | 1.5 | 14 | 15 | 22 |
| 87 × 63 | 1.5 | 14 | 14 | 22 |
| 95 × 67 | 1.5 | 14 | 14 | 22 |
| 103 × 71 | 1.5 | 14 | 14 | 21 |
| 112 × 75 | 1.5 | 14 | 14 | 21 |
| 117 × 79 | 1.5 | 12 | 14 | 21 |
| 128 × 83 | 1.5 | 12 | 14 | 21 |
| 137 × 87 | 1.5 | 12 | 13 | 20 |
| 142 × 91 | 1.5 | 10 | 13 | 20 |

**DESIGN LIFE - 50 YR**

| SPAN × RISE (in) | MINIMUM FILL FOR 2 tons/ft$^2$ (ft) | GAGE | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft) | |
|---|---|---|---|---|
| | | | 2 tons | 3 tons |
| 53 × 41 | 1.5 | 14 | 10 | 15 |
| 60 × 46 | 1.5 | 14 | 18 | 19 |
| 66 × 51 | 1.5 | 14 | 18 | 18 |
| 73 × 55 | 1.5 | 14 | 16 | 16 |
| 81 × 59 | 1.5 | 14 | 14 | 14 |
| 87 × 63 | 2 | 14 | 13 | 13 |
| 95 × 67 | 2 | 14 | 12 | 12 |
| 103 × 71 | 2.5 | 14 | 11 | 11 |
| 112 × 75 | 2.5 | 14 | 10 | 10 |
| 117 × 79 | 1.5 | 12 | 14 | 21 |
| 128 × 83 | 1.5 | 12 | 14 | 21 |
| 137 × 87 | 1.5 | 12 | 13 | 20 |
| 142 × 91 | 1.5 | 10 | 13 | 20 |

* Design Flow Velocity does not exceed 5 ft/s, low abrasive (minimal bedload) environment.

# TABLE 10.B.25 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPE ARCHES
# (125 mm × 25 mm CORRUGATIONS)

POLYMER COATED (≤ 1.5 m/s)*

| DESIGN LIFE - 25 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (mm)** | **MINIMUM FILL FOR 20 tonne/m$^2$ (m)** | **THICKNESS (mm)** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m$^2$ (m)** | |
| | | | **20 tonne** | **30 tonne** |
| 1340 × 1050 | 0.5 | 2.77 | 3.1 | 4.6 |
| 1520 × 1170 | 0.5 | 2.77 | 5.5 | 8.2 |
| 1670 × 1300 | 0.5 | 2.77 | 5.5 | 8.2 |
| 1850 × 1400 | 0.5 | 2.77 | 5.2 | 7.9 |
| 2050 × 1500 | 0.5 | 2.77 | 4.6 | 6.7 |
| 2200 × 1620 | 0.5 | 2.77 | 4.3 | 6.7 |
| 2400 × 1720 | 0.5 | 2.77 | 4.3 | 6.7 |
| 2600 × 1820 | 0.5 | 2.77 | 4.3 | 6.4 |
| 2840 × 1920 | 0.5 | 2.77 | 4.3 | 6.4 |
| 2970 × 2020 | 0.5 | 2.77 | 4.3 | 6.4 |
| 3240 × 2120 | 0.5 | 2.77 | 4.3 | 6.4 |
| 3470 × 2220 | 0.5 | 2.77 | 4.0 | 6.1 |
| 3600 × 2320 | 0.5 | 3.51 | 4.0 | 6.1 |

| DESIGN LIFE - 50 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (mm)** | **MINIMUM FILL FOR 20 tonne/m$^2$ (m)** | **THICKNESS (mm)** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m$^2$ (m)** | |
| | | | **20 tonne** | **30 tonne** |
| 1340 × 1050 | 0.5 | 2.77 | 3.1 | 4.6 |
| 1520 × 1170 | 0.5 | 2.77 | 5.5 | 8.2 |
| 1670 × 1300 | 0.5 | 2.77 | 5.5 | 8.2 |
| 1850 × 1400 | 0.5 | 2.77 | 5.2 | 7.9 |
| 2050 × 1500 | 0.5 | 2.77 | 4.6 | 6.7 |
| 2200 × 1620 | 0.5 | 2.77 | 4.3 | 6.7 |
| 2400 × 1720 | 0.5 | 2.77 | 4.3 | 6.7 |
| 2600 × 1820 | 0.5 | 2.77 | 4.3 | 6.4 |
| 2840 × 1920 | 0.5 | 2.77 | 4.3 | 6.4 |
| 2970 × 2020 | 0.5 | 2.77 | 4.3 | 6.4 |
| 3240 × 2120 | 0.5 | 2.77 | 4.3 | 6.4 |
| 3470 × 2220 | 0.5 | 2.77 | 4.0 | 5.8 |
| 3600 × 2320 | 0.5 | 3.51 | 4.0 | 6.1 |

* Design Flow Velocity does not exceed 1.5 m/s, low abrasive (minimal bedload) environment.

# TABLE 10.B.25 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPE ARCHES
# (5 in × 1 in CORRUGATIONS)

POLYMER COATED (≤ 5 ft/s)*

| DESIGN LIFE - 25 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (in)** | **MINIMUM FILL FOR 2 tons/ft$^2$ (ft)** | **GAGE** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft)** | |
| | | | **2 tons** | **3 tons** |
| 53 × 41 | 1.5 | 12 | 10 | 15 |
| 60 × 46 | 1.5 | 12 | 18 | 27 |
| 66 × 51 | 1.5 | 12 | 18 | 27 |
| 73 × 55 | 1.5 | 12 | 17 | 26 |
| 81 × 59 | 1.5 | 12 | 15 | 22 |
| 87 × 63 | 1.5 | 12 | 14 | 22 |
| 95 × 67 | 1.5 | 12 | 14 | 22 |
| 103 × 71 | 1.5 | 12 | 14 | 21 |
| 112 × 75 | 1.5 | 12 | 14 | 21 |
| 117 × 79 | 1.5 | 12 | 14 | 21 |
| 128 × 83 | 1.5 | 12 | 14 | 21 |
| 137 × 87 | 1.5 | 12 | 13 | 20 |
| 142 × 91 | 1.5 | 10 | 13 | 20 |

| DESIGN LIFE - 50 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (in)** | **MINIMUM FILL FOR 2 tons/ft$^2$ (ft)** | **GAGE** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft)** | |
| | | | **2 tons** | **3 tons** |
| 53 × 41 | 1.5 | 12 | 10 | 15 |
| 60 × 46 | 1.5 | 12 | 18 | 27 |
| 66 × 51 | 1.5 | 12 | 18 | 27 |
| 73 × 55 | 1.5 | 12 | 17 | 26 |
| 81 × 59 | 1.5 | 12 | 15 | 22 |
| 87 × 63 | 1.5 | 12 | 14 | 22 |
| 95 × 67 | 1.5 | 12 | 14 | 22 |
| 103 × 71 | 1.5 | 12 | 14 | 21 |
| 112 × 75 | 1.5 | 12 | 14 | 21 |
| 117 × 79 | 1.5 | 12 | 14 | 21 |
| 128 × 83 | 1.5 | 12 | 14 | 21 |
| 137 × 87 | 1.5 | 12 | 13 | 19 |
| 142 × 91 | 1.5 | 10 | 13 | 20 |

* Design Flow Velocity does not exceed 5 ft/s, low abrasive (minimal bedload) environment.

# TABLE 10.B.26 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPE ARCHES
# (68 mm × 13 mm CORRUGATIONS)

POLYMER COATED (> 1.5 m/s)*

| DESIGN LIFE - 25 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (mm)** | **MINIMUM FILL FOR 20 tonne/m$^2$ (m)** | **THICKNESS (mm)** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m$^2$ (m)** | |
| | | | **20 tonne** | **30 tonne** |
| 530 × 380 | 0.5 | 1.63 | 3.1 | 5.0 |
| 610 × 460 | 0.5 | 1.63 | 3.1 | 5.0 |
| 710 × 510 | 0.5 | 1.63 | 3.1 | 5.0 |
| 885 × 610 | 0.5 | 1.63 | 3.1 | 5.0 |
| 1060 × 740 | 0.5 | 1.63 | 3.1 | 5.0 |
| 1240 × 840 | 0.5 | 2.01 | 3.1 | 5.0 |
| 1440 × 970 | 0.5 | 2.77 | 3.1 | 5.0 |
| 1620 × 1100 | 0.5 | 2.77 | 3.1 | 5.0 |
| 1800 × 1200 | 0.5 | 3.51 | 3.1 | 5.0 |
| 1950 × 1320 | 0.5 | 4.27 | 3.1 | 5.0 |
| 2100 × 1450 | 0.5 | 4.27 | 3.1 | 5.0 |

| DESIGN LIFE - 50 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (mm)** | **MINIMUM FILL FOR 20 tonne/m$^2$ (m)** | **THICKNESS (mm)** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m$^2$ (m)** | |
| | | | **20 tonne** | **30 tonne** |
| 1440 × 970 | 0.5 | 2.77 | 3.1 | 5.0 |
| 1620 × 1100 | 0.5 | 2.77 | 3.1 | 5.0 |
| 1800 × 1200 | 0.5 | 3.51 | 3.1 | 5.0 |
| 1950 × 1320 | 0.5 | 4.27 | 3.1 | 5.0 |
| 2100 × 1450 | 0.5 | 4.27 | 3.1 | 5.0 |

* Design Flow Velocity exceeds 1.5 m/s.

# TABLE 10.B.26 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPE ARCHES
# (2 2/3 in × 1/2 in CORRUGATIONS)

POLYMER COATED (> 5 ft/s)*

| DESIGN LIFE - 25 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (in)** | **MINIMUM FILL FOR 2 tons/ft$^2$ (ft)** | **GAGE** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft)** | |
| | | | **2 tons** | **3 tons** |
| 21 × 15 | 1.5 | 16 | 10 | 16 |
| 24 × 18 | 1.5 | 16 | 10 | 16 |
| 28 × 20 | 1.5 | 16 | 10 | 16 |
| 35 × 24 | 1.5 | 16 | 10 | 16 |
| 42 × 29 | 1.5 | 16 | 10 | 16 |
| 49 × 33 | 1.5 | 14 | 10 | 16 |
| 57 × 38 | 1.5 | 12 | 10 | 16 |
| 64 × 43 | 1.5 | 12 | 10 | 16 |
| 71 × 47 | 1.5 | 10 | 10 | 16 |
| 77 × 52 | 1.5 | 8 | 10 | 16 |
| 83 × 57 | 1.5 | 8 | 10 | 16 |

| DESIGN LIFE - 50 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (in)** | **MINIMUM FILL FOR 2 tons/ft$^2$ (ft)** | **GAGE** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft)** | |
| | | | **2 tons** | **3 tons** |
| 57 × 38 | 1.5 | 12 | 10 | 16 |
| 64 × 43 | 1.5 | 12 | 10 | 16 |
| 71 × 47 | 1.5 | 10 | 10 | 16 |
| 77 × 52 | 1.5 | 8 | 10 | 16 |
| 83 × 57 | 1.5 | 8 | 10 | 16 |

*	Design Flow Velocity exceeds 5 ft/s.

# TABLE 10.B.27 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPE ARCHES
# (75 mm × 25 mm CORRUGATIONS)

POLYMER COATED (> 1.5 m/s)*

| DESIGN LIFE - 25 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (mm)** | **MINIMUM FILL FOR 20 tonne/m$^2$ (m)** | **THICKNESS (mm)** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m$^2$ (m)** | |
| | | | **20 tonne** | **30 tonne** |
| 1340 × 1050 | 0.5 | 2.01 | 3.1 | 4.6 |
| 1520 × 1170 | 0.5 | 2.01 | 5.5 | 8.2 |
| 1670 × 1300 | 0.5 | 2.01 | 5.5 | 8.2 |
| 1850 × 1400 | 0.5 | 2.01 | 5.2 | 7.9 |
| 2050 × 1500 | 0.5 | 2.01 | 4.6 | 6.7 |
| 2200 × 1620 | 0.5 | 2.01 | 4.3 | 6.7 |
| 2400 × 1720 | 0.5 | 2.01 | 4.3 | 6.7 |
| 2600 × 1820 | 0.5 | 2.01 | 4.3 | 6.4 |
| 2840 × 1920 | 0.5 | 2.01 | 4.3 | 6.4 |
| 2970 × 2020 | 0.5 | 2.77 | 4.3 | 6.4 |
| 3240 × 2120 | 0.5 | 2.77 | 4.3 | 6.4 |
| 3470 × 2220 | 0.5 | 2.77 | 4.0 | 6.1 |
| 3600 × 2320 | 0.5 | 3.51 | 4.0 | 6.1 |

| DESIGN LIFE - 50 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (mm)** | **MINIMUM FILL FOR 20 tonne/m$^2$ (m)** | **THICKNESS (mm)** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m$^2$ (m)** | |
| | | | **20 tonne** | **30 tonne** |
| 2970 × 2020 | 0.5 | 2.77 | 4.3 | 4.6 |
| 3240 × 2120 | 0.5 | 2.77 | 4.3 | 4.3 |
| 3470 × 2220 | 0.5 | 2.77 | 4.0 | 4.0 |
| 3600 × 2320 | 0.5 | 3.51 | 4.0 | 6.1 |

* Design Flow Velocity exceeds 1.5 m/s.

# TABLE 10.B.27 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPE ARCHES
# (3 in × 1 in CORRUGATIONS)

POLYMER COATED (> 5 ft/s)*

| DESIGN LIFE - 25 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (in)** | **MINIMUM FILL FOR 2 tons/ft$^2$ (ft)** | **GAGE** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft)** | |
| | | | **2 tons** | **3 tons** |
| 53 × 41 | 1.5 | 14 | 10 | 15 |
| 60 × 46 | 1.5 | 14 | 18 | 27 |
| 66 × 51 | 1.5 | 14 | 18 | 27 |
| 73 × 55 | 1.5 | 14 | 17 | 26 |
| 81 × 59 | 1.5 | 14 | 15 | 22 |
| 87 × 63 | 1.5 | 14 | 14 | 22 |
| 95 × 67 | 1.5 | 14 | 14 | 22 |
| 103 × 71 | 1.5 | 14 | 14 | 21 |
| 112 × 75 | 1.5 | 14 | 14 | 21 |
| 117 × 79 | 1.5 | 12 | 14 | 21 |
| 128 × 83 | 1.5 | 12 | 14 | 21 |
| 137 × 87 | 1.5 | 12 | 13 | 20 |
| 142 × 91 | 1.5 | 10 | 13 | 20 |

| DESIGN LIFE - 50 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (in)** | **MINIMUM FILL FOR 2 tons/ft$^2$ (ft)** | **GAGE** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft)** | |
| | | | **2 tons** | **3 tons** |
| 117 × 79 | 1.5 | 12 | 14 | 15 |
| 128 × 83 | 1.5 | 12 | 14 | 14 |
| 137 × 87 | 2 | 12 | 13 | 13 |
| 142 × 91 | 1.5 | 10 | 13 | 20 |

* Design Flow Velocity exceeds 5 ft/s.

# TABLE 10.B.28 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPE ARCHES
# (125 mm × 25 mm CORRUGATIONS)

POLYMER COATED (> 1.5 m/s)*

**DESIGN LIFE - 25 YR**

| SPAN × RISE (mm) | MINIMUM FILL FOR 20 tonne/m$^2$ (m) | THICKNESS (mm) | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m$^2$ (m) | |
|---|---|---|---|---|
| | | | 20 tonne | 30 tonne |
| 1340 × 1050 | 0.5 | 2.77 | 3.1 | 4.6 |
| 1520 × 1170 | 0.5 | 2.77 | 5.5 | 8.2 |
| 1670 × 1300 | 0.5 | 2.77 | 5.5 | 8.2 |
| 1850 × 1400 | 0.5 | 2.77 | 5.2 | 7.9 |
| 2050 × 1500 | 0.5 | 2.77 | 4.6 | 6.7 |
| 2200 × 1620 | 0.5 | 2.77 | 4.3 | 6.7 |
| 2400 × 1720 | 0.5 | 2.77 | 4.3 | 6.7 |
| 2600 × 1820 | 0.5 | 2.77 | 4.3 | 6.4 |
| 2840 × 1920 | 0.5 | 2.77 | 4.3 | 6.4 |
| 2970 × 2020 | 0.5 | 2.77 | 4.3 | 6.4 |
| 3240 × 2120 | 0.5 | 2.77 | 4.3 | 6.4 |
| 3470 × 2220 | 0.5 | 2.77 | 4.0 | 6.1 |
| 3600 × 2320 | 0.5 | 3.51 | 4.0 | 6.1 |

**DESIGN LIFE - 50 YR**

| SPAN × RISE (mm) | MINIMUM FILL FOR 20 tonne/m$^2$ (m) | THICKNESS (mm) | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m$^2$ (m) | |
|---|---|---|---|---|
| | | | 20 tonne | 30 tonne |
| 1340 × 1050 | 0.5 | 2.77 | 3.1 | 4.6 |
| 1520 × 1170 | 0.5 | 2.77 | 5.5 | 7.9 |
| 1670 × 1300 | 0.5 | 2.77 | 5.5 | 7.3 |
| 1850 × 1400 | 0.5 | 2.77 | 5.2 | 6.7 |
| 2050 × 1500 | 0.5 | 2.77 | 4.6 | 5.8 |
| 2200 × 1620 | 0.5 | 2.77 | 4.3 | 5.5 |
| 2400 × 1720 | 0.5 | 2.77 | 4.3 | 5.0 |
| 2600 × 1820 | 0.5 | 2.77 | 4.3 | 4.6 |
| 2840 × 1920 | 0.5 | 2.77 | 4.3 | 4.3 |
| 2970 × 2020 | 0.6 | 2.77 | 4.0 | 4.0 |
| 3240 × 2120 | 0.6 | 2.77 | 3.7 | 3.7 |
| 3470 × 2220 | 0.6 | 2.77 | 3.4 | 3.4 |
| 3600 × 2320 | 0.5 | 3.51 | 4.0 | 6.1 |

* Design Flow Velocity exceeds 1.5 m/s.

# TABLE 10.B.28 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED GALVANIZED STEEL PIPE ARCHES
# (5 in × 1 in CORRUGATIONS)

POLYMER COATED (> 5 ft/s)*

| DESIGN LIFE - 25 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (in)** | **MINIMUM FILL FOR 2 tons/ft$^2$ (ft)** | **GAGE** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft)** | |
| | | | **2 tons** | **3 tons** |
| 53 × 41 | 1.5 | 12 | 10 | 15 |
| 60 × 46 | 1.5 | 12 | 18 | 27 |
| 66 × 51 | 1.5 | 12 | 18 | 27 |
| 73 × 55 | 1.5 | 12 | 17 | 26 |
| 81 × 59 | 1.5 | 12 | 15 | 22 |
| 87 × 63 | 1.5 | 12 | 14 | 22 |
| 95 × 67 | 1.5 | 12 | 14 | 22 |
| 103 × 71 | 1.5 | 12 | 14 | 21 |
| 112 × 75 | 1.5 | 12 | 14 | 21 |
| 117 × 79 | 1.5 | 12 | 14 | 21 |
| 128 × 83 | 1.5 | 12 | 14 | 21 |
| 137 × 87 | 1.5 | 12 | 13 | 20 |
| 142 × 91 | 1.5 | 10 | 13 | 20 |

| DESIGN LIFE - 50 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (in)** | **MINIMUM FILL FOR 2 tons/ft$^2$ (ft)** | **GAGE** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft)** | |
| | | | **2 tons** | **3 tons** |
| 53 × 41 | 1.5 | 12 | 10 | 15 |
| 60 × 46 | 1.5 | 12 | 18 | 26 |
| 66 × 51 | 1.5 | 12 | 18 | 24 |
| 73 × 55 | 1.5 | 12 | 17 | 22 |
| 81 × 59 | 1.5 | 12 | 15 | 19 |
| 87 × 63 | 1.5 | 12 | 14 | 18 |
| 95 × 67 | 1.5 | 12 | 14 | 16 |
| 103 × 71 | 1.5 | 12 | 14 | 15 |
| 112 × 75 | 1.5 | 12 | 14 | 14 |
| 117 × 79 | 2 | 12 | 13 | 13 |
| 128 × 83 | 2 | 12 | 12 | 12 |
| 137 × 87 | 2 | 12 | 11 | 11 |
| 142 × 91 | 1.5 | 10 | 13 | 20 |

* Design Flow Velocity exceeds 5 ft/s.

# TABLE 10.B.29 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED ALUMINUM ALLOY PIPE ARCHES
# (68 mm × 13 mm CORRUGATIONS)

**DESIGN LIFE - 25 YR**

| SPAN × RISE (mm) | MINIMUM FILL FOR 20 tonne/m$^2$ (m) | THICKNESS (mm) | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m$^2$ (m) | |
|---|---|---|---|---|
| | | | 20 tonne | 30 tonne |
| 530 × 380 | 0.6 | 1.52 - 1.91 | 3.1 | 5.0 |
| 610 × 460 | 0.6 | 1.52 - 1.91 | 3.1 | 5.0 |
| 710 × 510 | 0.6 | 1.91 - 2.67 | 3.1 | 5.0 |
| 885 × 610 | 0.6 | 1.91 - 2.67 | 3.1 | 5.0 |
| 1060 × 740 | 0.6 | 2.67 - 3.43 | 3.1 | 5.0 |
| 1240 × 840 | 0.6 | 2.67 - 3.43 | 3.1 | 5.0 |
| 1440 × 970 | 0.6 | 3.43 - 4.17 | 3.1 | 5.0 |
| 1620 × 1100 | 0.6 | 3.43 - 4.17 | 3.1 | 5.0 |
| 1800 × 1200 | 0.6 | 4.17 | 3.1 | 5.0 |

**DESIGN LIFE - 50 YR**

| SPAN × RISE (mm) | MINIMUM FILL FOR 20 tonne/m$^2$ (m) | THICKNESS (mm) | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m$^2$ (m) | |
|---|---|---|---|---|
| | | | 20 tonne | 30 tonne |
| 530 × 380 | 0.6 | 1.52 - 1.91 | 3.1 | 5.0 |
| 610 × 460 | 0.6 | 1.52 - 1.91 | 3.1 | 5.0 |
| 710 × 510 | 0.6 | 1.91 - 2.67 | 3.1 | 5.0 |
| 885 × 610 | 0.6 | 1.91 - 2.67 | 3.1 | 5.0 |
| 1060 × 740 | 0.6 | 2.67 - 3.43 | 3.1 | 5.0 |
| 1240 × 840 | 0.6 | 2.67 - 3.43 | 3.1 | 5.0 |
| 1440 × 970 | 0.6 | 3.43 - 4.17 | 3.1 | 5.0 |
| 1620 × 1100 | 0.6 | 3.43 - 4.17 | 3.1 | 5.0 |
| 1800 × 1200 | 0.6 | 4.17 | 3.1 | 5.0 |

**DESIGN LIFE - 100 YR**

| SPAN × RISE (mm) | MINIMUM FILL FOR 20 tonne/m$^2$ (m) | THICKNESS (mm) | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m$^2$ (m) | |
|---|---|---|---|---|
| | | | 20 tonne | 30 tonne |
| 1060 × 740 | 0.6 | 3.43 | 3.1 | 5.0 |
| 1240 × 840 | 0.6 | 3.43 | 3.1 | 5.0 |
| 1440 × 970 | 0.6 | 3.43 - 4.17 | 3.1 | 5.0 |
| 1620 × 1100 | 0.6 | 3.43 - 4.17 | 3.1 | 5.0 |
| 1800 × 1200 | 0.6 | 4.17 | 3.1 | 5.0 |

# TABLE 10.B.29 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED ALUMINUM ALLOY PIPE ARCHES
# (2 2/3 in × 1/2 in CORRUGATIONS)

| DESIGN LIFE - 25 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (in)** | **MINIMUM FILL FOR 2 tons/ft² (ft)** | **GAGE** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft² (ft)** | |
| | | | **2 tons** | **3 tons** |
| 21 × 15 | 2 | 14 - 16 | 10 | 16 |
| 24 × 18 | 2 | 14 - 16 | 10 | 16 |
| 28 × 20 | 2 | 12 - 14 | 10 | 16 |
| 35 × 24 | 2 | 12 - 14 | 10 | 16 |
| 42 × 29 | 2 | 10 - 12 | 10 | 16 |
| 49 × 33 | 2 | 10 - 12 | 10 | 16 |
| 57 × 38 | 2 | 8 - 10 | 10 | 16 |
| 64 × 43 | 2 | 8 - 10 | 10 | 16 |
| 71 × 47 | 2 | 8 | 10 | 16 |

| DESIGN LIFE - 50 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (in)** | **MINIMUM FILL FOR 2 tons/ft² (ft)** | **GAGE** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft² (ft)** | |
| | | | **2 tons** | **3 tons** |
| 21 × 15 | 2 | 14 - 16 | 10 | 16 |
| 24 × 18 | 2 | 14 - 16 | 10 | 16 |
| 28 × 20 | 2 | 12 - 14 | 10 | 16 |
| 35 × 24 | 2 | 12 - 14 | 10 | 16 |
| 42 × 29 | 2 | 10 - 12 | 10 | 16 |
| 49 × 33 | 2 | 10 - 12 | 10 | 16 |
| 57 × 38 | 2 | 8 - 10 | 10 | 16 |
| 64 × 43 | 2 | 8 - 10 | 10 | 16 |
| 71 × 47 | 2 | 8 | 10 | 16 |

| DESIGN LIFE - 100 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (in)** | **MINIMUM FILL FOR 2 tons/ft² (ft)** | **GAGE** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft² (ft)** | |
| | | | **2 tons** | **3 tons** |
| 42 × 29 | 2 | 10 | 10 | 16 |
| 49 × 33 | 2 | 10 | 10 | 16 |
| 57 × 38 | 2 | 8 - 10 | 10 | 16 |
| 64 × 43 | 2 | 8 - 10 | 10 | 16 |
| 71 × 47 | 2 | 8 | 10 | 16 |

# TABLE 10.B.30 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# CORRUGATED ALUMINUM ALLOY PIPE ARCHES
# (75 mm × 25 mm CORRUGATIONS)

**DESIGN LIFE - 25 YR**

| SPAN × RISE (mm) | MINIMUM FILL FOR 20 tonne/m² (m) | THICKNESS (mm) | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m² (m) | |
|---|---|---|---|---|
| | | | 20 tonne | 30 tonne |
| 1520 × 1170 | 0.5 | 4.17 - 3.43<br>2.67 - 1.91 | 5.2 | 8.2 |
| 1670 × 1300 | 0.5 | 4.17 - 3.43<br>2.67 - 1.91 | 5.2 | 8.2 |
| 1850 × 1400 | 0.5 | 4.17 - 3.43<br>2.67 - 1.91 | 5.2 | 7.9 |
| 2050 × 1500 | 0.5 | 4.17 - 3.43<br>2.67 | 4.3 | 6.7 |
| 2200 × 1620 | 0.5 | 4.17 - 3.43<br>2.67 | 4.3 | 6.7 |
| 2400 × 1720 | 0.5 | 4.17 - 3.43<br>2.67 | 4.3 | 6.7 |
| 2600 × 1820 | 0.5 | 4.17 - 3.43 | 4.3 | 6.4 |
| 2840 × 1920 | 0.5 | 4.17 | 4.3 | 6.4 |

**DESIGN LIFE - 50 YR**

| SPAN × RISE (mm) | MINIMUM FILL FOR 20 tonne/m² (m) | THICKNESS (mm) | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m² (m) | |
|---|---|---|---|---|
| | | | 20 tonne | 30 tonne |
| 1520 × 1170 | 0.5 | 1.91 | 5.2 | 5.8 |
| | 0.5 | 4.17 - 3.43<br>2.67 | 5.2 | 8.2 |
| 1670 × 1300 | 0.5 | 1.91 | 5.2 | 5.2 |
| | 0.5 | 4.17 - 3.43<br>2.67 | 5.2 | 8.2 |
| 1850 × 1400 | 0.5 | 1.91 | 4.6 | 4.6 |
| | 0.5 | 4.17 - 3.43<br>2.67 | 5.2 | 7.9 |
| 2050 × 1500 | 0.5 | 4.17 - 3.43<br>2.67 | 4.3 | 6.7 |
| 2200 × 1620 | 0.5 | 4.17 - 3.43<br>2.67 | 4.3 | 6.7 |
| 2400 × 1720 | 0.5 | 4.17 - 3.43<br>2.67 | 4.3 | 6.7 |
| 2600 × 1820 | 0.5 | 4.17 - 3.43 | 4.3 | 6.4 |
| 2840 × 1920 | 0.5 | 4.17 | 4.3 | 6.4 |

# TABLE 10.B.30 (METRIC) (CONTINUED) ALLOWABLE FILL HEIGHTS FOR CORRUGATED ALUMINUM ALLOY PIPE ARCHES (75 mm × 25 mm CORRUGATIONS)

| DESIGN LIFE - 100 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (mm)** | **MINIMUM FILL FOR 20 tonne/m² (m)** | **THICKNESS (mm)** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m² (m)** | |
| | | | **20 tonne** | **30 tonne** |
| 1520 × 1170 | 0.5 | 4.17 - 3.43 | 5.2 | 8.2 |
| 1670 × 1300 | 0.5 | 3.43 | 5.2 | 7.6 |
| | 0.5 | 4.17 | 5.2 | 8.2 |
| 1850 × 1400 | 0.5 | 3.43 | 5.2 | 7.0 |
| | 0.5 | 4.17 | 5.2 | 7.9 |
| 2050 × 1500 | 0.5 | 3.43 | 4.3 | 6.4 |
| | 0.5 | 4.17 | 4.3 | 6.7 |
| 2200 × 1620 | 0.5 | 3.43 | 4.3 | 5.8 |
| | 0.5 | 4.17 | 4.3 | 6.7 |
| 2400 × 1720 | 0.5 | 3.43 | 4.3 | 5.5 |
| | 0.5 | 4.17 | 4.3 | 6.7 |
| 2600 × 1820 | 0.5 | 3.43 | 4.3 | 4.9 |
| | 0.5 | 4.17 | 4.3 | 6.4 |
| 2840 × 1920 | 0.5 | 4.17 | 4.3 | 6.4 |

# TABLE 10.B.30 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR CORRUGATED ALUMINUM ALLOY PIPE ARCHES
# (3 in × 1 in CORRUGATIONS)

**DESIGN LIFE - 25 YR**

| SPAN × RISE (in) | MINIMUM FILL FOR 2 tons/ft$^2$ (ft) | GAGE | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft) | |
|---|---|---|---|---|
| | | | 2 tons | 3 tons |
| 60 × 46 | 1.5 | 8 - 10 - 12 - 14 | 17 | 27 |
| 66 × 51 | 1.5 | 8 - 10 - 12 - 14 | 17 | 27 |
| 73 × 55 | 1.5 | 8 - 10 - 12 - 14 | 17 | 26 |
| 81 × 59 | 1.5 | 8 - 10 - 12 | 14 | 22 |
| 87 × 63 | 1.5 | 8 - 10 - 12 | 14 | 22 |
| 95 × 67 | 1.5 | 8 - 10 - 12 | 14 | 22 |
| 103 × 71 | 1.5 | 8 - 10 | 14 | 21 |
| 112 × 75 | 1.5 | 8 | 14 | 21 |

**DESIGN LIFE - 50 YR**

| SPAN × RISE (in) | MINIMUM FILL FOR 2 tons/ft$^2$ (ft) | GAGE | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft) | |
|---|---|---|---|---|
| | | | 2 tons | 3 tons |
| 60 × 46 | 1.5 | 14 | 17 | 19 |
| | 1.5 | 8 - 10 - 12 | 17 | 27 |
| 66 × 51 | 1.5 | 14 | 17 | 17 |
| | 1.5 | 8 - 10 - 12 | 17 | 27 |
| 73 × 55 | 1.5 | 14 | 15 | 15 |
| | 1.5 | 8 - 10 - 12 | 17 | 26 |
| 81 × 59 | 1.5 | 8 - 10 - 12 | 14 | 22 |
| 87 × 63 | 1.5 | 8 - 10 - 12 | 14 | 22 |
| 95 × 67 | 1.5 | 8 - 10 - 12 | 14 | 22 |
| 103 × 71 | 1.5 | 8 - 10 | 14 | 21 |
| 112 × 75 | 1.5 | 8 | 14 | 21 |

**DESIGN LIFE - 100 YR**

| SPAN × RISE (in) | MINIMUM FILL FOR 2 tons/ft$^2$ (ft) | GAGE | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft) | |
|---|---|---|---|---|
| | | | 2 tons | 3 tons |
| 60 × 46 | 1.5 | 8 - 10 | 17 | 27 |
| 66 × 51 | 1.5 | 10 | 17 | 25 |
| | 1.5 | 8 | 17 | 27 |
| 73 × 55 | 1.5 | 10 | 17 | 23 |
| | 1.5 | 8 | 17 | 26 |
| 81 × 59 | 1.5 | 10 | 14 | 21 |
| | 1.5 | 8 | 14 | 22 |
| 87 × 63 | 1.5 | 10 | 14 | 19 |
| | 1.5 | 8 | 14 | 22 |
| 95 × 67 | 1.5 | 10 | 14 | 18 |
| | 1.5 | 8 | 14 | 22 |
| 103 × 71 | 1.5 | 10 | 14 | 16 |
| | 1.5 | 8 | 14 | 21 |
| 112 × 75 | 1.5 | 8 | 14 | 21 |

# TABLE 10.B.31 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# SPIRAL RIB ALUMINIZED STEEL PIPES
# (19 mm x 19 mm x 190 mm CORRUGATIONS)

**DESIGN LIFE - 25 YR**

| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | |
|---|---|---|---|---|---|---|
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX |
| 450 | 0.5 | 20.1 | 0.5 | 31.7 | — | — |
| 525 | 0.5 | 17.4 | 0.5 | 27.1 | 0.5 | 49.1 |
| 600 | 0.5 | 14.9 | 0.5 | 23.8 | 0.5 | 43.0 |
| 750 | 0.5 | 11.9 | 0.5 | 18.9 | 0.5 | 34.1 |
| 900 | 0.5 | 10.1 | 0.5 | 15.8 | 0.5 | 28.7 |
| 1050 | 0.5 | 8.5 | 0.5 | 13.4 | 0.5 | 24.4 |
| 1200 | 0.5 | 7.3 | 0.5 | 11.9 | 0.5 | 21.3 |
| 1350 | — | — | 0.5 | 10.4 | 0.5 | 18.9 |
| 1500 | — | — | 0.5 | 9.4 | 0.5 | 17.1 |
| 1650 | — | — | — | — | 0.5 | 15.5 |
| 1800 | — | — | — | — | 0.5 | 14.3 |
| 1950 | — | — | — | — | 0.6 | 13.1 |

**DESIGN LIFE - 50 YR**

| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | |
|---|---|---|---|---|---|---|
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX |
| 450 | 0.5 | 9.4 | 0.5 | 16.8 | — | — |
| 525 | 0.5 | 7.9 | 0.5 | 14.3 | 0.5 | 33.5 |
| 600 | 0.5 | 7.0 | 0.5 | 12.5 | 0.5 | 29.3 |
| 750 | 0.5 | 5.5 | 0.5 | 10.1 | 0.5 | 23.5 |
| 900 | 0.5 | 4.6 | 0.5 | 8.2 | 0.5 | 19.5 |
| 1050 | 0.6 | 4.0 | 0.5 | 7.0 | 0.5 | 16.8 |
| 1200 | 0.6 | 3.4 | 0.5 | 6.1 | 0.5 | 14.6 |
| 1350 | — | — | 0.5 | 5.5 | 0.5 | 12.8 |
| 1500 | — | — | 0.5 | 4.9 | 0.5 | 11.6 |
| 1650 | — | — | — | — | 0.5 | 10.7 |
| 1800 | — | — | — | — | 0.5 | 9.8 |
| 1950 | — | — | — | — | 0.6 | 8.8 |

**DESIGN LIFE - 100 YR**

| PIPE DIAMETER (mm) | HEIGHTS OF FILL (m) | | | | | |
|---|---|---|---|---|---|---|
| | 1.63 mm thickness | | 2.01 mm thickness | | 2.77 mm thickness | |
| | MIN | MAX | MIN | MAX | MIN | MAX |
| 525 | — | — | — | — | 0.5 | 11.3 |
| 600 | — | — | — | — | 0.5 | 10.1 |
| 750 | — | — | — | — | 0.5 | 7.9 |
| 900 | — | — | — | — | 0.5 | 6.4 |
| 1050 | — | — | — | — | 0.5 | 5.5 |
| 1200 | — | — | — | — | 0.5 | 4.9 |
| 1350 | — | — | — | — | 0.5 | 4.3 |
| 1500 | — | — | — | — | 0.6 | 3.7 |
| 1650 | — | — | — | — | 0.6 | 3.4 |
| 1800 | — | — | — | — | 0.8 | 3.0 |
| 1950 | — | — | — | — | 0.8 | 2.7 |

# TABLE 10.B.31 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR
# SPIRAL RIB ALUMINIZED STEEL PIPES
# (3/4 in x 3/4 in x 7 1/2 in CORRUGATIONS)

| DESIGN LIFE - 25 YR | | | | | | |
|---|---|---|---|---|---|---|
| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | |
| | 16 Gage | | 14 Gage | | 12 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX |
| 18 | 1.5 | 66 | 1.5 | 104 | — | — |
| 21 | 1.5 | 57 | 1.5 | 89 | 1.5 | 161 |
| 24 | 1.5 | 49 | 1.5 | 78 | 1.5 | 141 |
| 30 | 1.5 | 39 | 1.5 | 62 | 1.5 | 112 |
| 36 | 1.5 | 33 | 1.5 | 52 | 1.5 | 94 |
| 42 | 1.5 | 28 | 1.5 | 44 | 1.5 | 80 |
| 48 | 1.5 | 24 | 1.5 | 39 | 1.5 | 70 |
| 54 | — | — | 1.5 | 34 | 1.5 | 62 |
| 60 | — | — | 1.5 | 31 | 1.5 | 56 |
| 66 | — | — | — | — | 1.5 | 51 |
| 72 | — | — | — | — | 1.5 | 47 |
| 78 | — | — | — | — | 2 | 43 |

| DESIGN LIFE - 50 YR | | | | | | |
|---|---|---|---|---|---|---|
| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | |
| | 16 Gage | | 14 Gage | | 12 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX |
| 18 | 1.5 | 31 | 1.5 | 55 | — | — |
| 21 | 1.5 | 26 | 1.5 | 47 | 1.5 | 110 |
| 24 | 1.5 | 23 | 1.5 | 41 | 1.5 | 96 |
| 30 | 1.5 | 18 | 1.5 | 33 | 1.5 | 77 |
| 36 | 1.5 | 15 | 1.5 | 27 | 1.5 | 64 |
| 42 | 2 | 13 | 1.5 | 23 | 1.5 | 55 |
| 48 | 2 | 11 | 1.5 | 20 | 1.5 | 48 |
| 54 | — | — | 1.5 | 18 | 1.5 | 42 |
| 60 | — | — | 1.5 | 16 | 1.5 | 38 |
| 66 | — | — | — | — | 1.5 | 35 |
| 72 | — | — | — | — | 1.5 | 32 |
| 78 | — | — | — | — | 2 | 29 |

| DESIGN LIFE - 100 YR | | | | | | |
|---|---|---|---|---|---|---|
| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | |
| | 16 Gage | | 14 Gage | | 12 Gage | |
| | MIN | MAX | MIN | MAX | MIN | MAX |
| 21 | — | — | — | — | 1.5 | 37 |
| 24 | — | — | — | — | 1.5 | 33 |
| 30 | — | — | — | — | 1.5 | 26 |
| 36 | — | — | — | — | 1.5 | 21 |
| 42 | — | — | — | — | 1.5 | 18 |
| 48 | — | — | — | — | 1.5 | 16 |
| 54 | — | — | — | — | 1.5 | 14 |
| 60 | — | — | — | — | 2 | 12 |
| 66 | — | — | — | — | 2 | 11 |
| 72 | — | — | — | — | 2.5 | 10 |
| 78 | — | — | — | — | 2.5 | 9 |

# TABLE 10.B.32 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# SPIRAL RIB ALUMINUM ALLOY PIPES
# (19 mm x 19 mm x 190 mm CORRUGATIONS)

| DESIGN LIFE - 25 YR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **PIPE DIAMETER (mm)** | **HEIGHTS OF FILL (m)** | | | | | | | |
| | **1.52 mm thickness** | | **1.91 mm thickness** | | **2.67 mm thickness** | | **3.43 mm thickness** | |
| | **MIN** | **MAX** | **MIN** | **MAX** | **MIIN** | **MAX** | **MIN** | **MAX** |
| 450 | 0.5 | 13.1 | 0.5 | 19.8 | — | — | — | — |
| 525 | 0.5 | 11.0 | 0.5 | 17.1 | 0.5 | 28.0 | — | — |
| 600 | 0.5 | 9.8 | 0.5 | 14.9 | 0.5 | 24.7 | — | — |
| 750 | 0.5 | 7.6 | 0.5 | 11.9 | 0.5 | 19.5 | — | — |
| 900 | — | — | 0.5 | 9.8 | 0.5 | 16.5 | 0.5 | 23.2 |
| 1050 | — | — | — | — | 0.6 | 14.0 | 0.6 | 19.8 |
| 1200 | — | — | — | — | 0.6 | 12.2 | 0.6 | 17.4 |
| 1350 | — | — | — | — | 0.6 | 10.7 | 0.6 | 15.2 |
| 1500 | — | — | — | — | — | — | 0.6 | 13.7 |
| 1650 | — | — | — | — | — | — | 0.6 | 12.5 |

| DESIGN LIFE - 50 YR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **PIPE DIAMETER (mm)** | **HEIGHTS OF FILL (m)** | | | | | | | |
| | **1.52 mm thickness** | | **1.91 mm thickness** | | **2.67 mm thickness** | | **3.43 mm thickness** | |
| | **MIN** | **MAX** | **MIN** | **MAX** | **MIIN** | **MAX** | **MIN** | **MAX** |
| 450 | 0.5 | 6.7 | 0.5 | 11.3 | — | — | — | — |
| 525 | 0.5 | 5.8 | 0.5 | 9.8 | 0.5 | 21.3 | — | — |
| 600 | 0.5 | 4.9 | 0.5 | 8.5 | 0.5 | 18.6 | — | — |
| 750 | 0.6 | 4.0 | 0.5 | 6.7 | 0.5 | 14.9 | — | — |
| 900 | — | — | 0.5 | 5.5 | 0.5 | 12.2 | 0.5 | 21.3 |
| 1050 | — | — | — | — | 0.6 | 10.7 | 0.6 | 18.3 |
| 1200 | — | — | — | — | 0.6 | 9.1 | 0.6 | 16.2 |
| 1350 | — | — | — | — | 0.6 | 8.2 | 0.6 | 14.3 |
| 1500 | — | — | — | — | — | — | 0.6 | 12.8 |
| 1650 | — | — | — | — | — | — | 0.6 | 11.6 |

| DESIGN LIFE - 100 YR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **PIPE DIAMETER (mm)** | **HEIGHTS OF FILL (m)** | | | | | | | |
| | **1.52 mm thickness** | | **1.91 mm thickness** | | **2.67 mm thickness** | | **3.43 mm thickness** | |
| | **MIN** | **MAX** | **MIN** | **MAX** | **MIIN** | **MAX** | **MIN** | **MAX** |
| 900 | — | — | — | — | — | — | 0.5 | 9.8 |
| 1050 | — | — | — | — | — | — | 0.6 | 8.2 |
| 1200 | — | — | — | — | — | — | 0.6 | 7.3 |
| 1350 | — | — | — | — | — | — | 0.6 | 6.4 |
| 1500 | — | — | — | — | — | — | 0.6 | 5.8 |
| 1650 | — | — | — | — | — | — | 0.6 | 5.2 |

# TABLE 10.B.32 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR
# SPRIAL RIB ALUMINUM ALLOY PIPES
# (3/4 in x 3/4 in x 7 1/2 in CORRUGATIONS)

| DESIGN LIFE - 25 YR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | |
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | |
| | MIN | MAX | MIN | MAX | MIIN | MAX | MIN | MAX |
| 18 | 1.5 | 43 | 1.5 | 65 | — | — | — | — |
| 21 | 1.5 | 36 | 1.5 | 56 | 1.5 | 92 | — | — |
| 24 | 1.5 | 32 | 1.5 | 49 | 1.5 | 81 | — | — |
| 30 | 1.5 | 25 | 1.5 | 39 | 1.5 | 64 | — | — |
| 36 | — | — | 1.5 | 32 | 1.5 | 54 | 1.5 | 76 |
| 42 | — | — | — | — | 2 | 46 | 2 | 65 |
| 48 | — | — | — | — | 2 | 40 | 2 | 57 |
| 54 | — | — | — | — | 2 | 35 | 2 | 50 |
| 60 | — | — | — | — | — | — | 2 | 45 |
| 66 | — | — | — | — | — | — | 2 | 41 |

| DESIGN LIFE - 50 YR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | |
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | |
| | MIN | MAX | MIN | MAX | MIIN | MAX | MIN | MAX |
| 18 | 1.5 | 22 | 1.5 | 37 | — | — | — | — |
| 21 | 1.5 | 19 | 1.5 | 32 | 1.5 | 70 | — | — |
| 24 | 1.5 | 16 | 1.5 | 28 | 1.5 | 61 | — | — |
| 30 | 2 | 13 | 1.5 | 22 | 1.5 | 49 | — | — |
| 36 | — | — | 1.5 | 18 | 1.5 | 40 | 1.5 | 70 |
| 42 | — | — | — | — | 2 | 35 | 2 | 60 |
| 48 | — | — | — | — | 2 | 30 | 2 | 53 |
| 54 | — | — | — | — | 2 | 27 | 2 | 47 |
| 60 | — | — | — | — | — | — | 2 | 42 |
| 66 | — | — | — | — | — | — | 2 | 38 |

| DESIGN LIFE - 100 YR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PIPE DIAMETER (in) | HEIGHTS OF FILL (ft) | | | | | | | |
| | 16 Gage | | 14 Gage | | 12 Gage | | 10 Gage | |
| | MIN | MAX | MIN | MAX | MIIN | MAX | MIN | MAX |
| 900 | — | — | — | — | — | — | 1.5 | 32 |
| 1050 | — | — | — | — | — | — | 2 | 27 |
| 1200 | — | — | — | — | — | — | 2 | 24 |
| 1350 | — | — | — | — | — | — | 2 | 21 |
| 1500 | — | — | — | — | — | — | 2 | 19 |
| 1650 | — | — | — | — | — | — | 2 | 17 |

# TABLE 10.B.33 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# SPIRAL RIB ALUMINIZED STEEL PIPE ARCHES
# (19 mm x 19 mm x 190 mm CORRUGATIONS)

**DESIGN LIFE - 25 YR**

| SPAN × RISE (mm) | MINIMUM FILL FOR 20 tonne/m² (m) | THICKNESS (mm) | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m² (m) | |
|---|---|---|---|---|
| | | | 20 tonne | 30 tonne |
| 500 × 400 | 0.5 | 1.63 - 2.01 | 4.3 | 6.1 |
| 575 × 475 | 0.5 | 1.63 - 2.01 - 2.77 | 4.0 | 5.8 |
| 675 × 525 | 0.5 | 1.63 - 2.01 - 2.77 | 3.7 | 5.2 |
| 825 × 650 | 0.5 | 1.63 - 2.01 - 2.77 | 3.7 | 5.2 |
| 1000 × 775 | 0.5 | 1.63 - 2.01 - 2.77 | 3.4 | 5.2 |
| 1150 × 900 | 0.5 | 2.77 | 3.4 | 5.2 |
| 1325 × 1025 | 0.5 | 2.77 | 3.4 | 5.2 |
| 1500 × 1150 | 0.5 | 2.77 | 5.2 | 8.2 |
| 1650 × 1275 | 0.5 | 2.77 | 5.2 | 8.2 |

**DESIGN LIFE - 50 YR**

| SPAN × RISE (mm) | MINIMUM FILL FOR 20 tonne/m² (m) | THICKNESS (mm) | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m² (m) | |
|---|---|---|---|---|
| | | | 20 tonne | 30 tonne |
| 500 × 400 | 0.5 | 1.63 - 2.01 | 4.3 | 6.1 |
| 575 × 475 | 0.5 | 1.63 - 2.01 - 2.77 | 4.0 | 5.8 |
| 675 × 525 | 0.5 | 1.63 - 2.01 - 2.77 | 3.7 | 5.2 |
| 825 × 650 | 0.5 | 1.63 - 2.01 - 2.77 | 3.7 | 5.2 |
| 1000 × 775 | 0.6 | 1.63 | 3.4 | 4.3 |
| | 0.5 | 2.01 - 2.77 | 3.4 | 5.2 |
| 1150 × 900 | 0.5 | 2.77 | 3.4 | 5.2 |
| 1325 × 1025 | 0.5 | 2.77 | 3.4 | 5.2 |
| 1500 × 1150 | 0.5 | 2.77 | 5.2 | 8.2 |
| 1650 × 1275 | 0.5 | 2.77 | 5.2 | 8.2 |

**DESIGN LIFE - 100 YR**

| SPAN × RISE (mm) | MINIMUM FILL FOR 20 tonne/m² (m) | THICKNESS (mm) | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m² (m) | |
|---|---|---|---|---|
| | | | 20 tonne | 30 tonne |
| 575 × 475 | 0.5 | 2.77 | 4.0 | 5.8 |
| 675 × 525 | 0.5 | 2.77 | 3.7 | 5.2 |
| 825 × 650 | 0.5 | 2.77 | 3.7 | 5.2 |
| 1000 × 775 | 0.5 | 2.77 | 3.4 | 5.2 |
| 1150 × 900 | 0.5 | 2.77 | 3.4 | 5.2 |
| 1325 × 1025 | 0.5 | 2.77 | 3.4 | 4.6 |
| 1500 × 1150 | 0.6 | 2.77 | 3.4 | 3.7 |
| 1650 × 1275 | 0.6 | 2.77 | 3.4 | 3.4 |

# TABLE 10.B.33 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR
# SPIRAL RIB ALUMINIZED STEEL PIPE ARCHES
# (3/4 in x 3/4 in x 7 1/2 in CORRUGATIONS)

| DESIGN LIFE - 25 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (in)** | **MINIMUM FILL FOR 2 tons/ft$^2$ (ft)** | **GAGE** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft)** | |
| | | | **2 tons** | **3 tons** |
| 20 × 16 | 1.5 | 16 - 14 | 14 | 20 |
| 23 × 19 | 1.5 | 16 - 14 - 12 | 13 | 19 |
| 27 × 21 | 1.5 | 16 - 14 - 12 | 12 | 17 |
| 33 × 26 | 1.5 | 16 - 14 - 12 | 12 | 17 |
| 40 × 31 | 1.5 | 16 - 14 - 12 | 11 | 17 |
| 46 × 36 | 1.5 | 12 | 11 | 17 |
| 53 × 41 | 1.5 | 12 | 11 | 17 |
| 60 × 46 | 1.5 | 12 | 17 | 27 |
| 66 × 51 | 1.5 | 12 | 17 | 27 |

| DESIGN LIFE - 50 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (in)** | **MINIMUM FILL FOR 2 tons/ft$^2$ (ft)** | **GAGE** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft)** | |
| | | | **2 tons** | **3 tons** |
| 20 × 16 | 1.5 | 16 - 14 | 14 | 20 |
| 23 × 19 | 1.5 | 16 - 14 - 12 | 13 | 19 |
| 27 × 21 | 1.5 | 16 - 14 - 12 | 12 | 17 |
| 33 × 26 | 1.5 | 16 - 14 - 12 | 12 | 17 |
| 40 × 31 | 2 | 16 | 11 | 14 |
| | 1.5 | 14 - 12 | 11 | 17 |
| 46 × 36 | 1.5 | 12 | 11 | 17 |
| 53 × 41 | 1.5 | 12 | 11 | 17 |
| 60 × 46 | 1.5 | 12 | 17 | 27 |
| 66 × 51 | 1.5 | 12 | 17 | 27 |

| DESIGN LIFE - 100 YR | | | | |
|---|---|---|---|---|
| **SPAN × RISE (in)** | **MINIMUM FILL FOR 2 tons/ft$^2$ (ft)** | **GAGE** | **MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft)** | |
| | | | **2 tons** | **3 tons** |
| 23 × 19 | 1.5 | 12 | 13 | 19 |
| 27 × 21 | 1.5 | 12 | 12 | 17 |
| 33 × 26 | 1.5 | 12 | 12 | 17 |
| 40 × 31 | 1.5 | 12 | 11 | 17 |
| 46 × 36 | 1.5 | 12 | 11 | 17 |
| 53 × 41 | 1.5 | 12 | 11 | 15 |
| 60 × 46 | 2 | 12 | 11 | 12 |
| 66 × 51 | 2 | 12 | 11 | 11 |

# TABLE 10.B.34 (METRIC)
# ALLOWABLE FILL HEIGHTS FOR
# SPIRAL RIB ALUMINUM ALLOY PIPE ARCHES
# (19 mm x 19 mm x 190 mm CORRUGATIONS)

**DESIGN LIFE - 25 YR**

| SPAN × RISE (mm) | MINIMUM FILL FOR 20 tonne/m$^2$ (m) | THICKNESS (mm) | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m$^2$ (m) | |
|---|---|---|---|---|
| | | | 20 tonne | 30 tonne |
| 500 × 400 | 0.6 | 1.52 - 1.91 | 4.3 | 6.1 |
| 575 × 475 | 0.6 | 1.52 - 1.91 - 2.67 | 4.0 | 5.8 |
| 675 × 525 | 0.6 | 1.52 - 1.91 - 2.67 | 3.7 | 5.2 |
| 825 × 650 | 0.6 | 1.52 - 1.91 - 2.67 | 3.7 | 5.2 |
| 1000 × 775 | 0.6 | 1.91 - 2.67 - 3.43 | 3.4 | 5.2 |
| 1150 × 900 | 0.6 | 2.67 - 3.43 | 3.4 | 5.2 |
| 1325 × 1025 | 0.6 | 2.67 - 3.43 | 3.4 | 5.2 |
| 1500 × 1150 | 0.6 | 3.43 | 5.2 | 8.2 |
| 1650 × 1275 | 0.6 | 3.43 | 5.2 | 8.2 |

**DESIGN LIFE - 50 YR**

| SPAN × RISE (mm) | MINIMUM FILL FOR 20 tonne/m$^2$ (m) | THICKNESS (mm) | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m$^2$ (m) | |
|---|---|---|---|---|
| | | | 20 tonne | 30 tonne |
| 500 × 400 | 0.6 | 1.52 - 1.91 | 4.3 | 6.1 |
| 575 × 475 | 0.6 | 1.52 | 4.0 | 5.5 |
| | 0.6 | 1.91 - 2.67 | 4.0 | 5.8 |
| 675 × 525 | 0.6 | 1.52 | 3.7 | 4.6 |
| | 0.6 | 1.91 - 2.67 | 3.7 | 5.2 |
| 825 × 650 | 0.6 | 1.52 | 3.7 | 3.7 |
| | 0.6 | 1.91 - 2.67 | 3.7 | 5.2 |
| 1000 × 775 | 0.6 | 1.91 | 3.4 | 4.6 |
| | 0.6 | 2.67 - 3.43 | 3.4 | 5.2 |
| 1150 × 900 | 0.6 | 2.67 - 3.43 | 3.4 | 5.2 |
| 1325 × 1025 | 0.6 | 2.67 - 3.43 | 3.4 | 5.2 |
| 1500 × 1150 | 0.6 | 3.43 | 5.2 | 8.2 |
| 1650 × 1275 | 0.6 | 3.43 | 5.2 | 8.2 |

**DESIGN LIFE - 100 YR**

| SPAN × RISE (mm) | MINIMUM FILL FOR 20 tonne/m$^2$ (m) | THICKNESS (mm) | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tonne/m$^2$ (m) | |
|---|---|---|---|---|
| | | | 20 tonne | 30 tonne |
| 1000 × 775 | 0.6 | 3.43 | 3.4 | 5.2 |
| 1150 × 900 | 0.6 | 3.43 | 3.4 | 5.2 |
| 1325 × 1025 | 0.6 | 3.43 | 3.4 | 5.2 |
| 1500 × 1150 | 0.6 | 3.43 | 5.2 | 5.8 |
| 1650 × 1275 | 0.6 | 3.43 | 5.2 | 5.5 |

# TABLE 10.B.34 (ENGLISH)
# ALLOWABLE FILL HEIGHTS FOR
# SPIRAL RIB ALUMINUM ALLOY PIPE ARCHES
# (3/4 in x 3/4 in x 7 1/2 in CORRUGATIONS)

**DESIGN LIFE - 25 YR**

| SPAN × RISE (in) | MINIMUM FILL FOR 2 tons/ft$^2$ (ft) | GAGE | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft) | |
|---|---|---|---|---|
| | | | 2 tons | 3 tons |
| 20 × 16 | 2 | 16 - 14 | 14 | 20 |
| 23 × 19 | 2 | 16 - 14 - 12 | 13 | 19 |
| 27 × 21 | 2 | 16 - 14 - 12 | 12 | 17 |
| 33 × 26 | 2 | 16 - 14 - 12 | 12 | 17 |
| 40 × 31 | 2 | 14 - 12 - 10 | 11 | 17 |
| 46 × 36 | 2 | 12 - 10 | 11 | 17 |
| 53 × 41 | 2 | 12 - 10 | 11 | 17 |
| 60 × 46 | 2 | 10 | 17 | 27 |
| 66 × 51 | 2 | 10 | 17 | 27 |

**DESIGN LIFE - 50 YR**

| SPAN × RISE (in) | MINIMUM FILL FOR 2 tons/ft$^2$ (ft) | GAGE | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft) | |
|---|---|---|---|---|
| | | | 2 tons | 3 tons |
| 20 × 16 | 2 | 16 - 14 | 14 | 20 |
| 23 × 19 | 2 | 16 | 13 | 18 |
| | 2 | 14 - 12 | 13 | 19 |
| 27 × 21 | 2 | 16 | 12 | 15 |
| | 2 | 14 - 12 | 12 | 17 |
| 33 × 26 | 2 | 16 | 12 | 12 |
| | 2 | 14 - 12 | 12 | 17 |
| 40 × 31 | 2 | 16 | 11 | 15 |
| | 2 | 12 - 10 | 11 | 17 |
| 46 × 36 | 2 | 12 - 10 | 11 | 17 |
| 53 × 41 | 2 | 12 - 10 | 11 | 17 |
| 60 × 46 | 2 | 10 | 17 | 27 |
| 66 × 51 | 2 | 10 | 17 | 27 |

**DESIGN LIFE - 100 YR**

| SPAN × RISE (in) | MINIMUM FILL FOR 2 tons/ft$^2$ (ft) | GAGE | MAXIMUM HEIGHTS OF FILL FOR CORNER BEARING PRESSURES IN tons/ft$^2$ (ft) | |
|---|---|---|---|---|
| | | | 2 tons | 3 tons |
| 40 × 31 | 2 | 10 | 11 | 17 |
| 46 × 36 | 2 | 10 | 11 | 17 |
| 53 × 41 | 2 | 10 | 11 | 17 |
| 60 × 46 | 2 | 10 | 17 | 19 |
| 66 × 51 | 2 | 10 | 17 | 18 |

# TABLE 10.B.35
# FILL HEIGHT TABLE
# THERMOPLASTIC PIPES
# (FOR PIPES 450 mm (18 in) DIAMETER OR LARGER)

| GROUP OF PIPE* | MINIMUM FILL HEIGHT** | MAXIMUM FILL HEIGHT** |
|---|---|---|
| Thermoplastic Pipe Groups I & IP | 0.5 m (1.5 ft) | 4.5 m (15.0 ft) |
| Thermoplastic Pipe Groups II & IIP | 0.5 m (1.5 ft) | 3.5 m (12.0 ft) |
| Thermoplastic Pipe Groups III & IIIP | 0.6 m (2.0 ft) | 2.5 m (8.0 ft) |
| Thermoplastic Pipe Groups IV & IVP | 0.8 m (2.5 ft) | 2.0 m (7.0 ft) |
| Thermoplastic Pipe - Corrugated PE, Groups V & VP | 0.8 m (2.5 ft) | 2.0 m (7.0 ft) |
| Thermoplastic Pipe Groups VI & VIP | 0.6 m (2.0 ft) | 4.5 m (15.0 ft) |

LEGEND: P = Perforated

* For Group Description see Publication 408, Section 601.

** Fill height is defined as the material from the top of pipe barrel to the riding surface, including the pavement structure. Refer to Publication 72M, *Roadway Construction Standards*, RC-30M for minimum cover over pipe under pavements.

# CHAPTER 10, APPENDIX C

## HYDRAULIC MODELING REQUIREMENTS FOR PENNDOT H&H REPORTS

This document was prepared to outline the hydraulic modeling requirements for PennDOT H&H Reports when a project is in a FEMA regulated area. FEMA regulated areas may be based on detailed or approximate studies; hydraulic models were used in detailed areas, whereas limited calculations or estimations were used to map approximate areas. FEMA regulations require a higher level of analysis and documentation when a project encroaches on a delineated FEMA floodplain or floodway; therefore, PennDOT and PA DEP also require a more thorough hydraulic analysis in detailed FEMA study areas. The guidance that follows lists the PennDOT, PA DEP, and FEMA hydraulic modeling requirements and is broken into two different sections:

- **Section 1**: Projects with flooding increases within the allowable limits
- **Section 2**: Projects with flooding increases that require a FEMA map revision

Publication 13M, Design Manual, Part 2, *Highway Design*, and the Code of Federal Regulations (CFR) are cited where appropriate. In addition, the guidance in Section 1.a is recommended for projects not located in FEMA regulated areas. The following table outlines the modeling requirements based on the location of the project and the anticipated increases in the 100-year water surface elevation.

| Location of Project | Increase in 100-year WSE | Follow Modeling Requirements in Section |
|---|---|---|
| Not in a FEMA Study Area | N/A | 1.a |
| Approximate FEMA Study Area | ≤ 1.00 ft | 1.a |
| Approximate FEMA Study Area | > 1.00 ft | 2.a (CLOMR Required) |
| Detailed FEMA Study with no fill in the Floodway | ≤ 1.00 ft | 1.b |
| Detailed FEMA Study with fill in the Floodway | ≤ 0.00 ft | 1.b |
| Detailed FEMA Study with fill in the Floodway | > 0.00 ft | 2.b (CLOMR Required) |
| Detailed FEMA Study with no designated Floodway | ≤ 1.00 ft | 1.b |
| Detailed FEMA Study with no designated Floodway | > 1.00 ft | 2.b (CLOMR Required) |

The hydrologic and hydraulic models used in FEMA studies must be evaluated according to current design guidance and current modeling practices for sizing highway waterway structures. Many FEMA studies were performed in the 1970's for the purpose of defining floodplain and floodway boundaries for the National Flood Insurance Program, whereas PennDOT usually conducts hydraulic studies to design waterway structures. Therefore, it is to be expected that different levels of detail and different methodologies are appropriate for these two types of studies.

It is common for existing water surface elevations to differ from the published elevations in the FEMA studies. The purpose of the existing model is to adequately reflect existing site conditions. If a FEMA model is used as the basis for the existing model, this will involve documenting differences and/or correcting errors in the FEMA model, adding cross sections, incorporating more detailed topographic data, and accounting for any channel/floodplain modifications since the FEMA model was published. **The existing model is required to provide an updated model to support conclusions about the actual impact of the proposed project.** When a map revision is required, the hydraulic model may need to be extended beyond the PennDOT study limits. FEMA and township (or local governing body) coordination is necessary to determine the limits of the hydraulic models to ensure that the Duplicate Effective, Corrected Effective, Existing, and Proposed Models tie into the published FEMA profiles. Additional survey may be required beyond the PennDOT study limits. Changes that have occurred since the FEMA model was created (e.g., channel geometry, buildings in floodplain, other bridges/culverts/etc.) must be surveyed and incorporated within the FEMA-required limits of the hydraulic model. If a map revision is not required, it is not necessary to incorporate/update data from the entire reach of a FEMA study. Any relevant FEMA data within the limits of the PennDOT study should be evaluated and incorporated, if appropriate. It may also be prudent to incorporate the nearest upstream/downstream FEMA section beyond the study limits, to enable a comparison with the published FEMA profile.

Another reason for differences between existing and published flood elevations is usually due to the differences in modeling software. There are significant differences between the current HEC-RAS program, which FEMA strongly supports, and the other programs (e.g., HEC-2, WSPRO, E431, J635, etc.) that were accepted at the time of the original FEMA study. For instance, HEC-RAS uses none of the same computational routines as its predecessor, HEC-2. Appendix C of the HEC-RAS Reference Manual describes all of the major computational differences between HEC-RAS and HEC-2.

There are a number of frequently encountered situations that do <u>not</u> require a FEMA map revision or Conditional Letter of Map Revision (CLOMR), but do require additional documentation in the H&H Report.

- There are differences between current survey data and FEMA geometric data (e.g., channel data, stream alignment, structure geometry, etc.).
- The existing and/or proposed water surface elevations differ from the published elevations in the FEMA Flood Insurance Study.
- The hydrologic analysis using current methods produces different peak flow values than the published FEMA flows.
- An existing bridge crossing that was originally mapped is proposed for removal, or a new structure crossing is proposed for construction.

**FEMA will require a CLOMR when there is an increase in the 100-year flood elevation between the existing and proposed models in excess of the allowable limits. A CLOMR will be required when the proposed project is in:**

- an Approximate FEMA area with 100-year increases > 1.00 ft, per Chapter 10, Appendix A, *Procedures for Coordinating Highway Encroachments on Floodplains with FEMA*;
- a Detailed FEMA area without a floodway and 100-year increases > 1.00 ft, per 44 CFR 60.3(c)(10);
- the floodway fringe of a Detailed FEMA area and 100-year increases > 1.00 ft, per 44 CFR 60.3(c)(10); or
- the floodway of a Detailed FEMA area and 100-year increases > 0.00 ft, per 44 CFR 60.3(d)(3).

**SECTION 1: Projects with flooding increases within the allowable limits**

1. Increases in 100-year water surface elevation between existing and proposed within the allowable limits

***a. Approximate FEMA Study (100-year increases ≤ 1.00 ft) or No FEMA Study***

- Calculate hydrology with PennDOT accepted method(s), per Chapter 10, Section 10.6.C
- Model the PennDOT design, Chapter 105-classified flood, 100-, and 500-year (if applicable) events, per Chapter 10, Section 10.6.E
- Hydraulic model output and electronic files for:
  - Existing model
  - Proposed model
  - Temporary model (if applicable)
- In Approximate Study areas, the PennDOT District will send a courtesy copy of final H&H Report sent to FEMA, per Chapter 10, Section 10.7.D.2

***b. Detailed FEMA Study with no fill in floodway (100-year increases ≤ 1.00 ft), or Detailed FEMA Study with fill in floodway (100-year increases ≤ 0.00 ft), or Detailed FEMA Study with no designated floodway (100-year increases ≤ 1.00 ft)***

- Calculate hydrology with PennDOT accepted method(s), per Chapter 10, Section 10.6.C
- Compare FEMA published flows with calculated flows and justify use of flows, per Chapter 10, Section 10.6.C.2
- Model the PennDOT design, Chapter 105-classified flood, 100-, and 500-year (if applicable) events, per Chapter 10, Section 10.6.E
- If the use of the calculated flows is justified over the FEMA flows, modeler must run the FEMA published 100-year flow in addition to the calculated 100-year flow, per Chapter 10, Section 10.7.D.2
- Hydraulic model output and electronic files for:
  - Existing model*
  - Proposed model
  - Temporary model (if applicable)
- Compare the existing model water surface elevations to the published regulatory base flood elevations (**Note:** Adjustment may be necessary between FEMA datum and survey datum.)
  - Include copies of floodway tables, flood profiles, and other pertinent data from the Flood Insurance Study, per Chapter 10, Section 10.7.C.6
  - Document and justify any differences, per Chapter 10, Section 10.7.D.2.
- The PennDOT District will send a courtesy copy of final H&H Report sent to FEMA, per Chapter 10, Section 10.7.D.2

* The original FEMA hydraulic data should be utilized to the maximum extent as deemed appropriate, per Chapter 10, Section 10.7.C.3. (**Note:** Adjustment may be necessary between FEMA datum and survey datum.)
  - Request the model data from FEMA (Note: If the original data is not available, include the letter from FEMA in the H&H Report as proof.)
  - Review the information
  - Evaluate differences in FEMA data and current survey data
  - Incorporate FEMA data within the PennDOT study limits where appropriate

**SECTION 2: Projects with flooding increases that require a FEMA map revision**

2. Increases in 100-year water surface elevation between existing and proposed and a CLOMR is required

   ***a. Approximate FEMA Study (100-year increases > 1.00 ft)***

   - Same modeling requirements as Section 1.a of this document
   - Map of existing and proposed 100-year floodplain boundaries, per CFR Title 44, Part 65.6.a.11
   - Submit with appropriate FEMA CLOMR MT-2 Forms http://www.fema.gov/plan/prevent/fhm/dl_mt-2.shtm

   ***b. Detailed FEMA Study with no designated floodway (100-year increases > 1.00 ft) or Detailed FEMA Study with fill in floodway (100-year increases > 0.00 ft)***

   - Calculate hydrology with PennDOT accepted method(s), per Chapter 10, Section 10.6.C
   - Compare FEMA published flows with calculated flows, per Chapter 10, Section 10.6.C
   - In order to use the calculated flows, the change between published and calculated flows must be statistically significant, per CFR Title 44, Part 65.6.a.5. FEMA defines "statistically significant" as determined by a confidence limits analysis of the new discharge estimates.
   - Hydraulic model input, output, and electronic files, per CFR Title 44, Part 65.6.a.8 and FEMA MT-2 Form Instructions:
     - **Effective FEMA Model** – Original FEMA hydraulic model used to develop the published base flood elevations.
     - **Duplicate Effective Model** – Obtain and reproduce the original Effective FEMA Model in HEC-RAS to produce the Duplicate Effective Model. Compare HEC-RAS Duplicate Effective Model water surface elevations to published FEMA profile (should be within 6 inches). FEMA coordination will be necessary to determine the limits of the hydraulic model to ensure that they tie into the published FEMA profiles.
     - **Corrected Effective Model** - Correct any errors in the Duplicate Effective Model (e.g., bridge data, modeling methods, errors in data) and add any additional cross sections or detailed topographic data. The Corrected Effective Model must not add any man-made changes since the Effective FEMA Model.
     - **Existing (Pre-project) Model** - Update the Corrected Effective Model with any man-made changes that have occurred since the development of the Effective FEMA Model. (**Note**: If there are no man-made changes to the model then the Corrected Effective Model will become the Existing Model.)
     - **Proposed (Revised or Post-Project) Model** - Add the proposed bridge/roadway geometry to the Existing Model.
     - **Existing Floodway Model** (if FEMA-delineated floodway is present) – Perform a floodway run using the Existing Model. This model must force the floodway widths to match the effective published floodway.
     - **Proposed Floodway Model** (if FEMA delineated floodway is present) – Using the Proposed Model, perform a floodway run and force increases to be 1.00 foot or less. This model will show the proposed 100-year floodway widths and elevations.
   - Map of effective, existing, and proposed 100-year floodplain boundaries, per CFR Title 44, Part 65.6.a.11, and effective and proposed floodway boundaries (if applicable), per CFR 65.7.b.5
   - Submit with appropriate FEMA CLOMR MT-2 Forms http://www.fema.gov/plan/prevent/fhm/dl_mt-2.shtm

DATE: June 17, 2008

SUBJECT: Hydraulic Modeling Guidance

TO: PennDOT District Executives and PADEP Regional Chiefs

FROM: Brian Thompson, PE
Director
PennDOT Bureau of Design

John Hines
Executive Director
PA DEP

The Pennsylvania Department of Transportation (PennDOT) and The Department of Environmental Protection (PA DEP) have worked jointly to develop *Hydraulic Modeling Requirements for PennDOT H&H Reports*. The guidance document has been developed by a joint taskforce of PennDOT and PA DEP representatives from PennDOT Bureau of Design and District Offices and PA DEP Central Office and Regional Offices.

This document was prepared to outline the hydraulic modeling requirements for PennDOT H&H Reports when a project is located in a Federal Emergency Management Agency (FEMA) regulated floodplain. The guidance is based on PennDOT's Design Manual 2 (DM-2) requirements, the Federal Code of Regulations (CFR) requirements related to FEMA study areas, and DEP Chapter 105 and 106. In addition, the guidance in Section 1.a is recommended for PennDOT projects not located in FEMA regulated areas.

Attached is a copy of the Joint Guidance document dated June 17, 2008. This guidance document should clarify the hydraulic requirements for projects located in FEMA study areas. For PennDOT the Hydraulic Modeling Guidance will become part of Design Manual Part 2, Chapter 10 – Appendix C. For PA DEP this document will be available online in the Chapter 105 Online Guidance Manual and should be part of PA DEP's desk manual for review of permit applications.

If you have any questions please contact Harold Rogers at PennDOT at 717-787-3767 or Jeff Means at PADEP at 717-772-5643.

Attachment

cc: Richard H. Hogg, PE Reading File
Highway Administration Bureau Directors
PennDOT District ADE's Design
PennDOT District Bridge Engineers
PennDOT District H&H and Permit Coordinators
Kelly Heffner, PA DEP
Jeffrey Means, PA DEP
PA DEP T-21 Staff

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# CHAPTER 10, APPENDIX D

## HYDROLOGIC AND HYDRAULIC CHECKLISTS

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D-3 (03-15)

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# Hydrologic and Hydraulic Report Checklist

## PROJECT DETAILS

Road: ____________________

Waterbody: ____________________

District: ____________________

Municipality: ____________________

County: ____________________

H&H Report Sealed by Licensed Engineer: ____________________

District or Company: ____________________

## CHECKLISTS

| Checklists Completed | Designer(s) | Reviewer(s) | Date(s) |
|---|---|---|---|
| ☐ H&H Report | | | |
| ☐ Abbreviated | | | |
| ☐ Full | | | |
| ☐ Hydrology | | | |
| ☐ HEC-RAS | | | |
| ☐ HY-8 | | | |
| ☐ Scour* | | | |

*Not required with a Preliminary H&H Report submission

**Instructions:**

1. These checklists are intended to provide documentation that a quality assurance review was performed. All applicable checklists must be completed by an internal reviewer and included with H&H Report submission. If the report is submitted as a paper copy for review, the completed QA checklists must be attached to the transmittal letter. If the report is uploaded to the $JPA_2$ Expert System for review, these completed QA forms must be placed in the "PennDOT Files" section of $JPA_2$ Expert. These forms are not intended to be transmitted to PADEP with the permit submission. Information stored in the "PennDOT Files" section of $JPA_2$ Expert will not be transferred to PADEP with the permit application.

2. The check boxes on the right side of the H&H Report checklists are used to indicate whether an item has been included. If the item is not required or does not apply to the particular project, check N/A.

3. When filling out the forms electronically, the individual sheet headings are automatically updated based on information from the summary sheet input.

4. Additional space for comments is provided in the last tab; please indicate the applicable QA sheet and section.

5. **Printing Instructions**: When the applicable checklists have been completed, select those worksheets and select file - print. (To select multiple worksheets, Hold the shift key and select the worksheet tabs at the bottom of the page). The page numbers will automatically be updated to correspond to the total number of pages printed.

**Notes:**

The summary sheet should be printed and submitted with the applicable checklists. Depending on the project type, not all checklists will be required for an H&H Report submission. For example, a small culvert replacement project may include the H&H Report, Hydrology and HY-8 checklists (unless HEC-RAS was used). Whereas a bridge replacement project may require the H&H Report, Hydrology, HEC-RAS and Scour checklists.

D-3 (3-15)
pennsylvania DEPARTMENT OF TRANSPORTATION
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# Abbreviated Hydrologic and Hydraulic Report Checklist

Project: District:
Municipality: County:
Reviewer(s): Date:

| DESCRIPTION | | ITEM PRESENT YES | NO | N/A |
|---|---|---|---|---|
| **B.1.a. LOCATION MAP** | | | | |
| Acceptable forms (one required): | | | | |
| ☐ USGS quadrangle map (or map of equal detail) | page ____ | | | |
| ☑ Aerial photographs | page ____ | | | |
| **B.1.b. ENVIRONMENTAL CONCERNS** | | | | |
| 1. PA Code Chapter 93 stream classification (check all that apply)<br>☐ WWF ☐ CWF ☐ MF<br>☐ TSF ☐ HQ* ☐ EV*<br>*Note if HQ or EV Stream, Antidegredation analysis may be required - see DM2, Chapter 13.7 | page ____ | | | |
| 2. PA Fish and Boat Classification (check all that apply)<br>☐ Approved Trout Stream (stocked) ☐ Class A Wild Trout<br>☐ Verified Natural Reproduction ☐ None | page ____ | | | |
| **B.1.c. STREAM BED MATERIAL** | page ____ | | | |
| Type of material in stream bed from site inspection (i.e., sand, gravel, cobbles, etc.) | | | | |
| **B.1.d. PHOTOGRAPHS** | page ____ | | | |
| a. Existing structure (upstream and downstream face) | | | | |
| b. Upstream / downstream channel and floodplain | | | | |
| c. Past floods (if available) | | | | |
| d. Roadway station ahead and station back (recommended) | | | | |
| e. Photo location map (recommended) | | | | |
| **B.1.e. SITE INSPECTION RECORDS** | page ____ | | | |
| Dates and other information relative to site inspection(s) made by designer | date ____ | | | |
| **B.2. HYDROLOGIC ANALYSIS** | | | | |
| a. Show drainage area above proposed crossing (note method of determining area) | page ____ | | | |
| b. Include design discharge(s) per Section 10.6.E | page ____ | | | |
| **B.3. HYDRAULIC ANALYSIS** | | | | |
| a. The project is located in a FEMA mapped area? ☐ yes ☐ no<br>If Yes is it a Detailed or Approximate area? ____________ | | | | |
| (1) Original FIS study and flood map(s) provided | page ____ | | | |
| (2) Study is referenced in the text | page ____ | | | |
| (3) Was FEMA model obtained or documentation provided if unavailable? | | | | |
| (4) Proposed structure encroaches on (check one):<br>☐ 100-year floodplain (floodway fringe)<br>☐ 100-year floodway ☐ neither | page ____ | | | |
| (5) Were existing flood elevations compared to FEMA's published? | page ____ | | | |
| (6) Were any differences in flood elevations > 0.5 ft explained? | page ____ | | | |
| b/c. Existing versus proposed conditions: | | | | |
| (1) velocities* | page ____ | | | |
| (2) backwater elevations* | page ____ | | | |
| (3) bridge opening sizes (i.e., area of hydraulic openings) | page ____ | | | |
| (4) Is there an increase in the proposed 100-year flood elevation? ☐ yes ☐ no<br>* Recommend including a table to compare all cross sections for the PennDOT design event and the 100-year event | | | | |

**Abbreviated Hydrologic and Hydraulic Report Checklist**

Project: District:
Municipality: County:
Reviewer(s): Date:

| DESCRIPTION | | YES | NO | N/A |
|---|---|---|---|---|
| c. Acceptable hydraulic methods for the site (check the method used) | | | | |
| ☐ HEC-RAS (bridge and culvert design, water surface profiles) | | | | |
| ☐ HY-8 (culvert design) | | | | |
| ☐ Other | | | | |
| d. Estimated scour depths (refer to DM-4, Chapter 7) | page | | | |
| e. Riprap sizing for bank, pier, abutment, and/or culvert protection | page | | | |
| f. Construction measures (temp. stream crossings, causeways, roads, etc.) | page | | | |
| Comments or computations included | page | | | |
| **B.4. RISK ASSESSMENT OR ANALYSIS*** | | | | |
| Narrative description of factors related to the 100-year flood | page | | | |
| Narrative description of factors related to the 2-year flood (temporary conditions) | page | | | |
| * Refer to Section 10.7.C.4 for the definition and additional requirements of a risk analysis | | | | |
| **B.5. SUMMARY DATA SHEET** | | | | |
| Complete all information listed in the Summary Data Sheet (Figure 10.7.1) (available for download from http://www.dot.state.pa.us/hh/Summary-Data-Sheet.Zip) | page | | | |
| Summary data matches the report tables, output/calculations, and TS&L | | | | |
| **B.6. DRAWINGS AND FIGURES** | | | | |
| a. Roadway plans and profiles indicating the following information: | | | | |
| 1. Locations of existing and/or proposed structures, stream channels and wetlands | page | | | |
| - Structure or culvert plan showing plan and elevation view (Box culvert plans should show baffle layout) | | | | |
| 2. 100-year floodplain boundary | page | | | |
| 3. Temporary stream crossing, access road, cofferdam, diversion facility, etc. | page | | | |
| 4. The magnitude, frequency and pertinent water surface elevation for PennDOT design and 100-year flood | page | | | |
| b. Plan drawing showing the location and orientation of all cross sections used in the hydraulic model (with scale, contours, and all important hydraulic features) | page | | | |
| Cross-sections perpendicular to flood flow (minimum): | page | | | |
| ☐ Upstream (500 ft) | | | | |
| ☐ Immediately upstream of proposed and/or existing crossings | | | | |
| ☐ Immediately downstream of proposed and/or existing crossings | | | | |
| ☐ Downstream (500 ft) | | | | |
| Items 6.c and 6.d below do not require separate drawings provided that the information is available in the HEC-RAS model submitted with the report | | | | |
| c. Profile of stream showing bed slope, normal water surface, and flood water surface elevations | page | | | |
| d. Cross section output of all cross sections used for backwater analysis | page | | | |
| e. Floodway maps and flood profiles from FEMA Flood Insurance Studies (when in a detailed FEMA study area) | page | | | |
| **ELECTRONIC FILES** | | | | |
| Electronic files for the hydrologic and hydraulic models (as applicable) | | | | |

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# Hydrologic and Hydraulic Report Checklist

Project: District:

Municipality: County:

Reviewer(s): Date:

| DESCRIPTION | | ITEM PRESENT? YES | NO | N/A |
|---|---|---|---|---|
| **C.1.a. LOCATION MAP** | | | | |
| Acceptable forms (one required): | | | | |
| ☐ USGS quadrangle map (or map of equal detail) | page ________ | | | |
| ☐ Aerial photographs | page ________ | | | |
| Required information: | | | | |
| (1) Project location including proposed highway alignment | | | | |
| (2) Drainage area | | | | |
| (3) Label stream and direction, river reach studied | | | | |
| **C.1.b. EXISTING STRUCTURES (IF APPLICABLE)** | page ________ | | | |
| 1. Identify existing hydraulic structures (by map), including upstream and downstream of site | | | | |
| 2. Must describe: | | | | |
| (1) Type of structure, span lengths, pier orientation | | | | |
| (2) Cross section beneath structure - stream clearance and skew | | | | |
| 3. Compare stream and existing structure locations with the proposed crossing | | | | |
| 4. Indicate whether existing structures are to remain in place | | | | |
| **C.1.c. FLOOD INFORMATION** | page ________ | | | |
| 1. Elevations of available highwater marks along the stream w/ dates of occurrence | | | | |
| 2. Critical flood elevations of interest (possible damage) | | | | |
| 3. Local testimony of flooding (if available) or structure performance (non-flooding) per Section 10.7.C.1.i | | | | |
| **C.1.d. ENVIRONMENTAL CONCERNS** | | | | |
| - PA Code Chapter 93 stream classification (check all that apply) | page ________ | | | |
| ☐ WWF ☐ CWF ☐ MF | | | | |
| ☐ TSF ☐ HQ* ☐ EV* | | | | |
| *Note if HQ or EV Stream, Antidegredation analysis may be required - see DM2, Chapter 13.7 | | | | |
| PA Fish and Boat Classification (check all that apply) | | | | |
| ☐ Approved Trout Stream (stocked) ☐ Class A Wild Trout | page ________ | | | |
| ☐ Verified Natural Reproduction ☐ None | | | | |
| - Comments on other environmental concerns | | | | |
| - Perennial, ephemeral, or intermittent stream? | ____________________ | | | |
| **C.1.e. HISTORY OF DRIFT, ICE AND STREAM BANK STABILITY** | page ________ | | | |
| - Stability of stream banks (i.e., exposed soil, slumping, tilting trees, etc.) | | | | |
| - Type of material in stream bed from site inspection (i.e., sand, gravel, cobbles, etc.) | | | | |
| - History of ice accumulation or damage | | | | |
| **C.1.f. PHOTOGRAPHS** | page ________ | | | |
| - Existing structure (upstream and downstream face) | | | | |
| - Upstream / downstream channel and floodplain | | | | |
| - Past floods (if available) | | | | |
| - Roadway station ahead and station back (recommended) | | | | |
| - Photo location map (recommended) | | | | |
| - Upstream and downstream structures | | | | |
| **C.1.g. FACTORS AFFECTING WATER STAGES** | page ________ | | | |
| 1. High water from other streams | | | | |
| 2. Reservoirs (existing or proposed) and approximate date of construction | | | | |
| 3. Flood control projects and status (e.g., control structures, operator, operating policy) | | | | |
| 4. Other controls | | | | |

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# Hydrologic and Hydraulic Report Checklist

Project: District:

Municipality: County:

Reviewer(s): Date:

| DESCRIPTION | | ITEM PRESENT? YES | NO | N/A |
|---|---|---|---|---|
| **C.1.h. DEBRIS** | | | | |
| Indicate if debris can be a problem at the structure site | page ______ | | | |
| **C.1.i. SITE INSPECTION RECORDS** | page ______ | | | |
| - Dates and other information relative to site inspection(s) made by designer | date ______ | | | |
| - If applicable, documentaion of local testimony is included | | | | |
| **C.1.j. LINE AND GRADE APPROVAL** | page ______ | | | |
| Indicate date of Line and Grade Approval or if pending | date ______ | | | |
| **C.2. HYDROLOGIC ANALYSIS** | | | | |
| a. Show drainage area above proposed crossing (note method of determining area) | page ______ | | | |
| b. List flood records available | page ______ | | | |
| c. Include design discharge(s) per Section 10.6.E | page ______ | | | |
| d. Show flood-frequency curve for the site | page ______ | | | |
| e. Show stage-discharge-frequency curves for the site (existing and proposed conditions) | page ______ | | | |
| **C.3. HYDRAULIC ANALYSIS** | | | | |
| a. The project is located in a FEMA mapped area? ☐ yes ☐ no | | | | |
| If Yes is it a Detailed or Approximate area? ______________ | | | | |
| (1) Original FIS study and flood map(s) provided | page ______ | | | |
| (2) Study is referenced in the text | page ______ | | | |
| (3) Was FEMA model obtained or documentation provided if unavailable? | | | | |
| (4) Proposed structure encroaches on (check one): ☐ 100-year floodplain (floodway fringe) ☐ 100-year floodway ☐ neither | page ______ | | | |
| (5) Were existing flood elevations compared to FEMA's published? | page ______ | | | |
| (6) Were any differences in flood elevations > 0.5 ft explained? | page ______ | | | |
| b. Existing versus proposed conditions: | | | | |
| (1) velocities* | page ______ | | | |
| (2) backwater elevations* | page ______ | | | |
| (3) bridge opening sizes (i.e., area of hydraulic openings) | page ______ | | | |
| (4) Is there an increase in the proposed 100-year flood elevation? ☐ yes ☐ no | | | | |
| * Recommend including a table to compare all cross sections for the PennDOT design event and the 100-year event | | | | |
| c. Acceptable hydraulic methods for the site (check the method used) | | | | |
| ☐ HEC-RAS (bridge and culvert design, water surface profiles) | | | | |
| ☐ HY-8 (culvert design) ☐ HDS-5 (culvert design - equivalent to HY-8) | | | | |
| ☐ HEC-2 (water surface profiles) ☐ WSPRO (only if FEMA map revision necessary) | | | | |
| ☐ Visual Urban (HY-22 - mostly urban drainage applications) | | | | |
| ☐ Other List: ______________ | | | | |
| d. Was the HEC-RAS or HY-8 checklist completed? | | | | |
| e. Model validation | page ______ | | | |
| (1) Calibration with high water marks, storm events, and local testimony | | | | |
| (2) Explanation of model warnings and errors | | | | |
| f. Estimated scour depths (refer to DM-4, Chapter 7) | page ______ | | | |
| g. Riprap sizing for bank, pier, abutment, and culvert protection | page ______ | | | |
| h. Construction measures (temp. stream crossings, causeways, roads, etc.) | page ______ | | | |
| Supporting model or calculations included | page ______ | | | |

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# Hydrologic and Hydraulic Report Checklist

Project: District:
Municipality: County:
Reviewer(s): Date:

| DESCRIPTION | | ITEM PRESENT? | |
|---|---|---|---|
| | YES | NO | N/A |
| **C.4. RISK ASSESSMENT OR ANALYSIS*** | | | |
| Narrative description of factors related to: page ____ | | | |
| - 100-year flood | | | |
| - overtopping flood | | | |
| - 2-year flood for temporary conditions | | | |
| * Refer to Section 10.7.C.4 for the definition and additional requirements of a risk analysis | | | |
| **C.5. SUMMARY DATA SHEET** | | | |
| Complete all information listed in the Summary Data Sheet (Figure 10.7.1) page ____ (available for download from http://www.dot.state.pa.us/hh/Summary-Data-Sheet.Zip) | | | |
| Summary data matches the report tables, output/calculations, and TS&L | | | |
| **C.6. DRAWINGS AND FIGURES** | | | |
| a. Roadway plans and profiles indicating the following information: | | | |
| 1. Locations of existing and proposed structures, stream channels and wetlands page ____ | | | |
| - Structure or culvert plan showing plan and elevation view (Box culvert plans should show baffle layout) | | | |
| 2. Adjacent topographic features with key elevations or contours shown page ____ | | | |
| - Profile drawing showing proposed structure and ground line | | | |
| 3. 100-year floodplain boundary page ____ | | | |
| 4. Flood easement (if required) page ____ | | | |
| 5. Temporary stream crossing, access road, cofferdam, diversion facility, etc. page ____ | | | |
| 6. The magnitude, frequency and pertinent water surface elevation for specified floods page ____ | | | |
| b. Profile of stream showing bed slope, normal water surface, and flood water surface elevations page ____ | | | |
| c. Plan drawing showing the location and orientation of all cross sections used for backwater analysis (with scale, contours, and all important hydraulic features) page ____ | | | |
| Cross-sections perpendicular to flood flow (minimum): page ____ | | | |
| ☐ Upstream (500 ft) | | | |
| ☐ Immediately upstream of proposed and/or existing crossings | | | |
| ☐ Immediately downstream of proposed and/or existing crossings | | | |
| ☐ Downstream (500 ft) | | | |
| d. Floodway maps and flood profiles from FEMA Flood Insurance Studies (when in a detailed FEMA study area) page ____ | | | |
| **ELECTRONIC FILES** | | | |
| Electronic files provided for hydrologic & hydraulic models (as applicable) | | | |

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# Hydrology Checklist
# Quality Assurance Review

Project: District:
Municipality: County:
Reviewer(s): Date:

| DESCRIPTION | YES | NO | N/A |
|---|---|---|---|
| **1. FEMA CONSIDERATIONS** | | | |
| Is the proposed project in a detailed FEMA study area? | | | |
| If yes, are the following provided: | | | |
| - Published FIS flows page ________ | | | |
| - Is FEMA hydrologic method acceptable per DM-2, Chapter 10? page ________ | | | |
| - Are FEMA flows compared with calculated flows using PennDOT acceptable methods? | | | |
| - Is FEMA's published 100-year flow included in the analysis? | | | |
| **Comments:** | | | |
| **2. ACT 167** | | | |
| Is there a DEP approved Act 167 Stormwater Management Plan? | | | |
| How were the flows developed in the Act 167? ________ | | | |
| Were there flows provided in the vicinity of the project site? | | | |
| Have the flows been included for comparison to calculated flows? page ________ | | | |
| **Comments:** | | | |
| **3. DESIGN FLOODS** | | | |
| PennDOT roadway classification ________ | | | |
| PennDOT design event (check one) ☐ 10-yr ☐ 25-yr ☐ 50-yr | | | |
| PADEP event (check one) ☐ 25-yr (rural) ☐ 50-yr (suburban) ☐ 100-yr (urban) | | | |
| **Comments:** | | | |
| **4. HYDROLOGIC ANALYSIS** | | | |
| Drainage area at site (DA) is correct ________ square miles | | | |
| Applicable hydrologic method used (check all that apply) | | | |
| ☐ WRC method ☐ EFH2 (1 to 2000 ac) | | | |
| ☐ Rational method (up to 200 acres)* ☐ TR-55* (10 ac to 3.1 sq mi) | | | |
| ☐ PSU-IV (comparison only) ☐ WinTR-55 (1ac to 25 sq mi) | | | |
| ☐ USGS WRIR 2000-4189* ☐ USGS SIR 2008-5102* | | | |
| ☐ HEC-1/HEC-HMS* ☐ Other** | | | |
| * Methods may be used within the Watershed Modeling System (WMS) program | | | |
| ** Project Engineer should ensure that the model is appropriate and that approvals are obtained from the Department | | | |
| Which method was chosen for the design flows? ________ | | | |
| Was justification provided for the selection of the peak flow method? page ________ | | | |
| **Comments:** | | | |

# Hydrology Checklist
# Quality Assurance Review

Project: District:
Municipality: County:
Reviewer(s): Date:

| DESCRIPTION | YES | NO | N/A |
|---|---|---|---|
| **5. METHOD SELECTION DETAILS** | | | |
| Fill out the appropriate section below based on the hydrologic method(s) used in Section 4. | | | |
| **A. WRC Method (gage)** page ________ | | | |
| USGS gage # ________ | | | |
| Gage location (i.e, town and stream/river name) ________ | | | |
| Gage is on the same main stem as the project site | | | |
| Print out of gage record is included | | | |
| DA at gage ________ square miles | | | |
| $DA_{site}$ is between 0.5 and 1.5 $DA_{gage}$ | | | |
| Years of record ________ | | | |
| Record is greater than 10 years | | | |
| Historic peaks (i.e., not recorded by gage) are excluded | | | |
| Record not partially influenced by regulation or diversion (e.g., reservoir, levee, etc.) | | | |
| Watershed characteristics consistent for entire record (e.g., landuse) | | | |
| Skew calculation method is appropriate (check one): ☐ Station ☐ Regional ☐ Weighted | | | |
| If gage is not at project site, were flows correctly translated to the site? | | | |

| Return Period (yrs) | $Q_{gage}$ (cfs) | $Q_{site}$ (cfs) |
|---|---|---|
| | | |
| | | |
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| | | |

**Comments:**

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# Hydrology Checklist
# Quality Assurance Review

Project: District:

Municipality: County:

Reviewer(s): Date:

| DESCRIPTION | YES | NO | N/A |
|---|---|---|---|
| **B. Rational Method** page ________ | | | |
| DA is less than 200 acres | | | |
| Weighted C value is correct C = ________ | | | |
| Time of concentration ($T_c$) is correct $T_c$ = ________ | | | |
| Storm duration equals the $T_c$ for intensity determination | | | |
| Rainfall intensity from PDT-IDF curves | | | |

| Return Period (yrs) | Intensity (in) | Q (cfs) |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |

**Comments:**

| DESCRIPTION | YES | NO | N/A |
|---|---|---|---|
| **C. USGS WRIR 2000-4189 Method** page ________ | | | |
| DA at site between 1.5 and 2,000 square miles | | | |
| Region is correct (check one) ☐ A ☐ B | | | |
| % Forest is reasonable ________ % | | | |
| % Urban is reasonable ________ % | | | |
| In Region B, urban % does not exceed 5% | | | |
| % Carbonate is reasonable ________ % | | | |
| % Controlled is reasonable ________ % | | | |

| Return Period (yrs) | Q (cfs) |
|---|---|
| | |
| | |
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| | |

**Comments:**

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# Quality Assurance Review

Project: District:
Municipality: County:
Reviewer(s): Date:

| DESCRIPTION | | YES | NO | N/A |
|---|---|---|---|---|
| **D. USGS SIR 2008-5102 Method** | page ________ | | | |
| DA at site between 1.0 and 2,000 square miles | | | | |
| Region is correct (check one) | ☐ 1 ☐ 2 ☐ 3 ☐ 4 | | | |
| % Forest is reasonable | ________ % | | | |
| % Urban is reasonable | ________ % | | | |
| % Carbonate is reasonable | ________ % | | | |
| % Storage is reasonable* | ________ % | | | |
| *surface area of lakes, ponds, wetlands, etc. | | | | |
| Mean basin elevation is is correct (Region 3) | | | | |

| Return Period (yrs) | Q (cfs) |
|---|---|
| | |
| | |
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| | |

**Comments:**

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# Hydrology Checklist
# Quality Assurance Review

Project: District:

Municipality: County:

Reviewer(s): Date:

| DESCRIPTION | | YES | NO | N/A |
|---|---|---|---|---|
| **E. PSU IV (Comparison Method Only)** | page ________ | | | |
| DA at site between 1.5 and 150 square miles | | | | |
| Region is correct (check one) | ☐ 1 ☐ ☐ ☐ 4 | | | |
| Standard Deviation is correct | ________ | | | |
| Skew Coefficient is correct | ________ | | | |
| Divide Elevation is correct | ________ feet | | | |
| % Forest is reasonable | ________ % | | | |
| Adjustment for carbonate area applied | | | | |
| Indicate other adjustments applied | ________ | | | |

| Return Period (yrs) | Q (cfs) |
|---|---|
| | |
| | |
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| | |

**Comments:**

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## Hydrology Checklist
## Quality Assurance Review

Project: District:
Municipality: County:
Reviewer(s): Date:

| DESCRIPTION | | | YES | NO | N/A |
|---|---|---|---|---|---|
| **F. TR-55 Method / WinTr-55** | | page ________ | | | |
| DA at site is between 10 and 2,000 acres (< 3.1 square miles) for TR-55 | | | | | |
| DA at site is between 1 acre and 25 square miles for WinTR-55 | | | | | |
| Note if multiple drainage areas are used, attach additional sheets for CN, etc. | | | | | |
| CN calculated correctly | CN = ________ | | | | |
| Time of concentration ($T_c$) calculated correctly | ________ | hrs (0.1<$T_c$<10 hr) | | | |
| Sheet flow length no greater than 100' | ________ | feet | | | |
| Shallow concentrated flow length appropriate | ________ | feet | | | |
| Channel flow length appropriate | ________ | feet | | | |
| Rainfall from PDT-IDF curves (24-hour duration) | | | | | |
| PDT-IDF Curve or SCS Type II 24-hr rainfall distribution used | | | | | |

| Return Period (yrs) | Rainfall (in) | Q (cfs) |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |

**Comments:**

________________________________________

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# Hydrology Checklist
# Quality Assurance Review

Project: District:

Municipality: County:

Reviewer(s): Date:

| DESCRIPTION | YES | NO | N/A |
|---|---|---|---|
| **G. EFH2 Method** page ________ | | | |
| DA at site between 1 and 2,000 acres (< 3.1 square miles) | | | |
| CN calculated correctly CN = ________ | | | |
| Urban % does not exceed 10% ________ % | | | |
| Hydraulic length is between 200 and 26,000 feet ________ feet | | | |
| Average watershed slope, Y ________ % | | | |
| Y is the average overland slope between drainage divide and stream channel | | | |
| Rainfall from PDT-IDF curves (24-hour duration) | | | |
| PDT-IDF Curve or SCS Type II 24-hr rainfall distribution used | | | |

| Return Period (yrs) | Rainfall (in) | Q (cfs) |
|---|---|---|
| | | |
| | | |
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| | | |

**Comments:**

________________________________________

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# Hydrology Checklist
# Quality Assurance Review

Project: District:
Municipality: County:
Reviewer(s): Date:

| DESCRIPTION | YES | NO | N/A |
|---|---|---|---|
| **H. HEC-1 / HEC-HMS Method** page ________ | | | |
| DA subareas ≤ 3.1 square miles or justification provided for larger subareas | | | |
| Note if multiple drainage areas are used, attach additional sheets for CN, etc. | | | |
| CN calculated correctly CN = ________ | | | |
| Lag time, $t_L$ ________ hours | | | |
| Lag time calculated with SCS method | | | |
| If subdivided, routing was performed | | | |
| Rainfall from PDT-IDF curves (24-hour duration) | | | |
| PDT-IDF Curve or SCS Type II 24-hr rainfall distribution used | | | |

| Return Period (yrs) | Rainfall (in) | Q (cfs) |
|---|---|---|
| | | |
| | | |
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**Comments:**

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# Hydrology Checklist
# Quality Assurance Review

Project: District:
Municipality: County:
Reviewer(s): Date:

| DESCRIPTION | YES | NO | N/A |
|---|---|---|---|
| **I. Other Method** ______________ page ______ | | | |
| Calculations included | | | |
| Method appropriate for location | | | |
| Rationale / justification provided | | | |

| Return Period (yrs) | Rainfall (in) | Q (cfs) |
|---|---|---|
| | | |
| | | |
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| | | |
| | | |

**Comments:**

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# HEC-RAS Model Checklist
# Quality Assurance Review

Project: District:

Municipality: County:

Reviewer(s): Date:

**1. File Management****

HEC-RAS program version ____________________
Project file name (*.prj) ____________________
Plan name for existing conditions ____________________
Plan Short ID ____________________
Geometry file name (*.gxx) ____________________
Steady flow file name (*.fxx) ____________________
Final date of run file (*.rxx) ____________________
Plan name for proposed conditions ____________________
Plan Short ID ____________________
Geometry file name (*.gxx) ____________________
Steady flow file name (*.fxx) ____________________
Final date of run file (*.rxx) ____________________
Plan name for temp conditions (if applicable) ____________________
Plan Short ID ____________________
Geometry file name (*.gxx) ____________________
Steady flow file name (*.fxx) ____________________
Final date of run file (*.rxx) ____________________

**The following HEC-RAS files must be submitted for review: project (*.prj), geometry (*.gxx), steady flow (*.fxx), plan (*.pxx), run (*.rxx), and output (*.oxx). The run file and output file extensions will correspond to the appropriate plan file extension.

**Comments:**

____________________
____________________

| | DESCRIPTION | YES | NO | N/A |
|---|---|---|---|---|
| 2. | **FEMA Study (this section required if the project is in a detailed FEMA study area)** | | | |
| | - Hydraulic model used in the FEMA study ____________ page ____ | | | |
| | - Was the original FEMA model obtained? (check all that apply) | | | |
| | ☐ Paper copy of model input page ____ | | | |
| | ☐ Paper copy of model output page ____ | | | |
| | ☐ Electronic files | | | |
| | - If FEMA modeling data was unavailable, letter from FEMA stating such is provided? | | | |
| | - Datum: FEMA ________ Project ________ | | | |
| | - Datum Conversion (FEMA to project): ________ ft | | | |
| | - List the FEMA cross sections used as-is in existing conditions model ____________________ ____________________ | | | |
| | - List the FEMA cross sections modified with current survey in existing conditions model ____________________ | | | |
| | - List the new survey cross sections in existing conditions model ____________________ ____________________ | | | |
| | - Does the hydraulic cross section plan show all FEMA sections and surveyed sections used in the existing conditions model? page ____ | | | |
| | **Comments:** ____________________ ____________________ ____________________ ____________________ | | | |

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# HEC-RAS Model Checklist
# Quality Assurance Review

Project: District:

Municipality: County:

Reviewer(s): Date:

| DESCRIPTION | YES | NO | N/A |
|---|---|---|---|
| **3. Steady Flow Data** | | | |
| Boundary Conditions — Upstream / Downstream | | | |
| ☐ Normal depth — S= ______ S= ______ | | | |
| ☐ Known WS — WS Elev= ______ WS Elev= ______ | | | |
| ☐ Critical depth | | | |
| ☐ Rating curve — source= ______ source= ______ | | | |
| - Are the boundary conditions appropriate? | | | |
| - Are the same boundary conditions used in the existing and proposed models? | | | |
| - If applicable, was a known WS used for the FEMA published flow? | | | |
| Discharge Information (see also Hydrology checklist) | | | |
| - 100-year, DEP and PennDOT design events were modeled | | | |
| - Temporary conditions event modeled ______ year | | | |
| - Flows for the modeled events match peak flows in the H&H Report | | | |
| - Flow change(s) reflects tributary location(s) | | | |
| **Comments:** | | | |
| **4. Geometric Data** | | | |
| Plan Information / River System Schematic | | | |
| - Plan showing the location and orientation of all cross sections provided (with scale, contours, and all important hydraulic features) page ______ | | | |
| - Number of reaches ______ | | | |
| - Number of junctions ______ | | | |
| - Cross section numbers increase from downstream to upstream | | | |
| Cross Section Geometry | | | |
| - Cross sections extend across 100-year floodplain | | | |
| - Cross sections are perpendicular to flow direction (except at bounding structure sections) | | | |
| - Cross sections do not overlap | | | |
| - Cross section data is entered from left to right (looking downstream) | | | |
| - Left and right bank stations: - are reasonable | | | |
| - have consistent elevations | | | |
| - Reach lengths are correct | | | |
| - Manning's n values are reasonable (Table 3.1 in Reference 1) | | | |
| - Contraction/expansion coefficients are reasonable (contr = 0.3, exp = 0.5 bounding structure sections) | | | |
| - Ineffective flow areas reflect contraction / expansion reach near hydraulic structure (Reference 2) | | | |
| - Ineffective flow areas in overbanks are used where appropriate | | | |
| - Levees are used where appropriate | | | |
| - Blocked obstructions are used where appropriate | | | |
| **Comments:** | | | |

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**HEC-RAS Model Checklist**
**Quality Assurance Review**

Project: District:
Municipality: County:
Reviewer(s): Date:

| | DESCRIPTION | YES | NO | N/A |
|---|---|---|---|---|
| | **Geometric Data continued** | | | |
| 4a. | Bridge Geometry* | | | |
| | - Plan with high/low chord elevations included page ______ | | | |
| | - Bridge cross section ______ (E) ______ (P) | | | |
| | - Bounding bridge sections are at or beyond the embankment toe and parallel to each other | | | |
| | - High chord (max.) ______ (E) ______ (P) | | | |
| | - Low chord (min.) ______ (E) ______ (P) | | | |
| | - High/low chords match the report/drawings | | | |
| | - Bridge width ______ (E) ______ (P) | | | |
| | - Bridge widths match the report/drawings | | | |
| | - Distance to US section ______ (E) ______ (P) | | | |
| | - US distances match the hydraulic section plan | | | |
| | - Number of spans ______ (E) ______ (P) | | | |
| | - Normal clear span length(s) ______ (E) ______ (P) | | | |
| | - Bridge normal clear span lengths match the report/drawings | | | |
| | - Number of piers ______ (E) ______ (P) | | | |
| | - Existing pier centerline(s), width(s) and elevation(s) are correct | | | |
| | - Proposed pier centerline(s), width(s) and elevation(s) are correct | | | |
| | - Ineffective areas "turn off" when weir flow passes over bridge | | | |
| | - Minimum weir flow elevation is reasonable | | | |
| | - Bridge modeling methods Existing / Proposed | | | |
| | Low flow ______ ______ | | | |
| | High flow ______ ______ | | | |
| | - Methods are appropriate per Reference 1 | | | |

* Check for existing (E) and proposed (P) structure; low chord elevations and normal clear span lengths are not applicable to arch structures.

**Comments:**

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**Quality Assurance Review**

Project: District:
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| | DESCRIPTION | | | YES | NO | N/A |
|---|---|---|---|---|---|---|
| | **Geometric Data continued** | | | | | |
| 4b. | *Culvert Geometry | | | | | |
| | - Plan with inverts elevations included | | page ______ | | | |
| | - Structure cross section | ______ (E) | ______ (P) | | | |
| | - Bounding culvert cross sections are at or beyond the embankment toe | | | | | |
| | - Ineffective areas "turn off" when weir flow passes over road | | | | | |
| | - Minimum weir flow elevation is reasonable | | | | | |
| | | Existing | Proposed | | | |
| | - Number of barrels | ______ | ______ | | | |
| | - Shape | ______ | ______ | | | |
| | ☐ Diameter | ______ | ______ | | | |
| | ☐ Span x Rise | ______ | ______ | | | |
| | - Spans/diameters are correct | | | | | |
| | - Chart # | ______ | ______ | | | |
| | - Scale # | ______ | ______ | | | |
| | - Chart and Scale match the culvert type and entrance conditions | | | | | |
| | - Distance to US section | ______ ft | ______ ft | | | |
| | - US distances match the hydraulic section plan | | | | | |
| | - Culvert length | ______ ft | ______ ft | | | |
| | - Culvert lengths match the hydraulic section and structure plans | | | | | |
| | - Entrance loss coeff | ______ | ______ | | | |
| | - Exit loss coeff | ______ | ______ | | | |
| | - Loss coefficients are appropriate for entrance/exit conditions | | | | | |
| | - Manning's n for top | ______ | ______ | | | |
| | - Manning's n for bottom | ______ | ______ | | | |
| | - Manning's n for top and bottom are appropriate | | | | | |
| | - Depth to use bottom n | ______ | ______ | | | |
| | - Depth blocked | ______ | ______ | | | |
| | - Blocked depth reflects the depressed depth for fish passage | | | | | |
| | - US invert elevation | ______ ft | ______ ft | | | |
| | - DS invert elevation | ______ ft | ______ ft | | | |
| | - Invert elevations match the report/drawings | | | | | |
| | - High chord (max.) | ______ ft | ______ ft | | | |
| | - High chords match structure drawings | | | | | |

* Check for existing (E) and proposed (P) structure

**Comments:**

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# HEC-RAS Model Checklist
# Quality Assurance Review

Project: District:
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| DESCRIPTION | YES | NO | N/A |
|---|---|---|---|
| **Geometric Data continued** | | | |
| 4c. *Roadway Profile | | | |
| - Roadway profile plan provided page ________ | | | |
| - Roadway stations are entered from left to right (looking downstream) | | | |
| - Roadway (high chord) stations and elevations match drawings (exist and prop) | | | |
| - Highest roadway elevation is coded as the US side so that weir flow is correctly calculated. | | | |
| * Check for existing (E) and proposed (P) structure | | | |
| **Comments:** | | | |
| 4d. Temporary Conditions | | | |
| - Temporary fill and/or structure(s) proposed in the channel? (check all that apply) | | | |
| ☐ Cofferdam (e.g., sheet piling, Jersey barrier, sand bags) | | | |
| ☐ Causeway | | | |
| ☐ Temporary road | | | |
| ☐ Other ________ | | | |
| - Dimension and locations match report and E&S Plan page ________ | | | |
| - Geometry reflects worst-case construction scenario (i.e., generally the most obstructed area) | | | |
| **Comments:** | | | |
| **5. Plan File** | | | |
| Flow Regime | | | |
| ☐ Subcritical | | | |
| ☐ Supercritical | | | |
| ☐ Mixed | | | |
| - If subcritical only, is the Froude number < 1.0 at every section? | | | |
| - If supercritical only, is the Froude number > 1.0 at every section? | | | |
| **Comments:** | | | |

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## HEC-RAS Model Checklist
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| | |
|---|---|
| Project: | District: |
| Municipality: | County: |
| Reviewer(s): | Date: |

| DESCRIPTION | YES | NO | N/A |
|---|---|---|---|
| **6. Output** | | | |
| Existing versus Proposed Output | | | |
| - Water surface profiles are in the correct order in the cross section output | | | |
| - Is the existing low chord elevation equal to or below the proposed? | | | |
| - Hydraulic opening area stated ________ (sf) Exist. ________ (sf) Prop. | | | |
| - Is the proposed opening area equal to or larger than the existing? | | | |
| - Errors, warnings, and notes reviewed and discussed page ______ | | | |
| - Are there increases at any cross section for the proposed 100-year event? | | | |
| - Existing and proposed HEC-RAS cross section plot output are included page ______ | | | |
| - Existing and proposed HEC-RAS profile output are included (table & plot) page ______ | | | |
| - Output shows 100-year, DEP and PennDOT design events | | | |
| **Comments:** | | | |
| Temporary Conditions Output | | | |
| - The H&H report states that the ________ year event does not overtop the temporary measures | | | |
| - The magnitude and extent of temporary increases are quantified page ______ | | | |
| - Are the temporary increases contained within the channel? page ______ | | | |
| - Do the temporary wsels tie in to existing wsels within the study limits? page ______ | | | |
| **Comments:** | | | |

References

[1] Hydrologic Engineering Center. 2002. HEC-RAS, River Analysis System Hydraulic Reference Manual. U.S. Army Corps of Engineers, Davis, CA.

[2] Hydrologic Engineering Center. 1995. RD-42, Flow Transitions in Bridge Backwater Analysis, U.S. Army Corps of Engineers, Davis, CA.

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## HY-8 Model Checklist
## Quality Assurance Review

Project: ______ District: ______

Municipality: ______ County: ______

Reviewer(s): ______ Date: ______

| DESCRIPTION | YES | NO |
|---|---|---|
| **1. File Management** | | |
| HY-8 Version ______ | | |
| Project file name ______ | | |
| Is HY-8 Run (input/output) attached? | ☐ | ☐ |
| **Comments:** ______ | | |
| **2. Discharge Data** (Crossing Properties) | | |
| Flows Input: Minimum ______ cfs; Design ______ cfs; Maximum ______ cfs | | |
| Discharge Information | | |
| 100-year and DEP's & PennDOT's design events were modeled | ☐ | ☐ |
| Flows for the modeled events are correct | ☐ | ☐ |
| **Comments:** ______ | | |
| **3. Tailwater Data** (Crossing Properties) | | |
| Channel Type (check one): ☐ Rectangular ☐ Trapezoidal ☐ Triangular ☐ Irregular ☐ Rating Curve ☐ Constant Tailwater Elevation | | |
| Channel type selection is reasonable | ☐ | ☐ |
| Channel input dimensions are consistent with plans | ☐ | ☐ |
| **Comments:** ______ | | |
| **4. Roadway Data** (Crossing Properties) | | |
| Roadway Profile Shape (check one): ☐ Constant ☐ Irregular | | |
| Roadway profile dimensions are consistent with plans | ☐ | ☐ |
| **Comments:** ______ | | |

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# HY-8 Model Checklist
# Quality Assurance Review

Project:
Municipality:
Reviewer(s):

District:
County:
Date:

| DESCRIPTION | YES | NO |
| --- | --- | --- |
| **5a. Existing Culvert Data** (Culvert Properties) | | |
| Culvert Name ______________________ | | |
| Shape (check one) | | |
| ☐ Circular ☐ Arch-Open Bottom | | |
| ☐ Concrete Box ☐ Low Profile Arch | | |
| ☐ Elliptical ☐ High Profile Arch | | |
| ☐ Pipe Arch ☐ Metal Box | | |
| ☐ User Defined ☐ Arch-Box-Concrete | | |
| Culvert material and size: ______________________ | | |
| Culvert specifications are consistent with plans and/or site survey data | | |
| **Comments:** | | |
| **5b. Proposed Culvert Data** (Culvert Properties) | | |
| Culvert Name ______________________ | | |
| Shape (check one) | | |
| ☐ Circular ☐ Arch-Open Bottom | | |
| ☐ Concrete Box ☐ Low Profile Arch | | |
| ☐ Elliptical ☐ High Profile Arch | | |
| ☐ Pipe Arch ☐ Metal Box | | |
| ☐ User Defined ☐ Arch-Box-Concrete | | |
| Culvert material and size: ______________________ | | |
| Culvert specifications are consistent with plans | | |
| **Comments:** | | |
| **6. Site Data** (Culvert Properties) | | |
| Site Data Input Option (check one) | | |
| ☐ Culvert Invert Data | | |
| ☐ Embankment Toe Data | | |
| Site data is consistent with plans | | |
| **Comments:** | | |

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# HY-8 Model Checklist
# Quality Assurance Review

Project: District:

Municipality: County:

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| DESCRIPTION | YES | NO |
|---|---|---|
| **7. Results** | | |
| Overtopping? | | |
| If yes, overtopping discharge: | | |
| Existing ________ cfs | | |
| Proposed ________ cfs | | |
| Upstream 100-year water surface elevation | | |
| Existing ________ ft | | |
| Proposed ________ ft | | |
| Is the proposed 100-year flood elevation greater than existing? | | |
| Velocities | | |
| Design storm velocity | | |
| Existing ________ ft/s | | |
| Proposed ________ ft/s | | |
| 100-year flood velocity | | |
| Existing ________ ft/s | | |
| Proposed ________ ft/s | | |
| Results are acceptable for HY-8 use | | |
| Entrance velocities < 5 fps | | |
| **Comments:** | | |

Federal Highway Administration (FHWA) HY-8 Version 7.0, March 16, 2007
Software developed by: Environmental Modeling Systems, Inc.
Based on HDS-5 Documentation

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# Scour Analysis & Riprap Sizing Checklist
# Quality Assurance Review

Project: District:

Municipality: County:

Reviewer(s): Date:

| DESCRIPTION | YES | NO | N/A |
|---|---|---|---|

**1. Streambed Particle Size**

- $D_{50}$ ________ in = ________ ft

Typical $D_{50}$ Values:

| | | |
|---|---|---|
| Clay and silt | 0.00024 - 0.062 mm | |
| Sand | 0.062 - 2.00 mm | 0.002 - 0.08 in |
| Gravel | 2 - 64 mm | 0.08 - 2.5 in |
| Cobbles | 64 - 250 mm | 2.5 - 10 in |

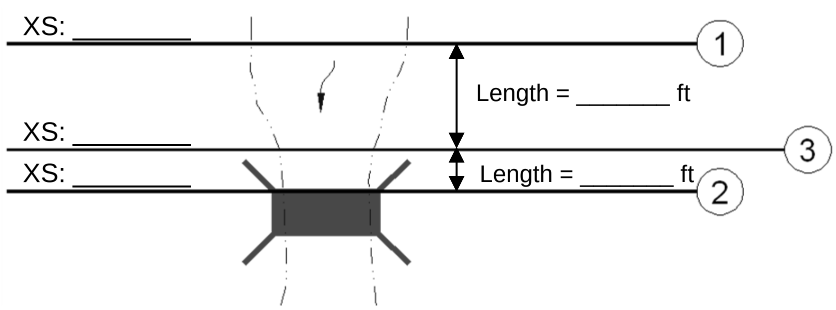
- Method used to determine $D_{50}$
  - ☐ visual inspection ☐ sieve analysis
  - ☐ pebble count ☐ core boring* (see notes on applicability below)
- Location of streambed sample ________
- Streambed material description ________ page ________
- Is bedrock visible?
- Is $D_{50}$ appropriate for studied reach?
- Evidence of long-term streambed elevation change (aggradation or degradation)?

* For limitations on core borings use see requirements in DM-4, Chapter 7. Also for most PA streams core borings may underestimate the size of the streambed material. If the approximate $D_{100}$ particle size is less than the core diameter and the sample is taken in the stream channel, the core borings may provide a reasonable $D_{50}$ for the armor layer.

**Comments:** ________

**2. Contraction Scour**

HEC-RAS Sections - fill in the appropriate information from the proposed HEC-RAS model




| Key |
|---|
| 1. Upstream uncontracted cross section (XS output) |
| 2. Internal bridge cross section (BR U or BR D in HEC-RAS output) |
| 3. Upstream bounding cross section (XS output) |

**Comments:** ________

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# Scour Analysis & Riprap Sizing Checklist
# Quality Assurance Review

Project: District:

Municipality: County:

Reviewer(s): Date:

| DESCRIPTION | YES | NO | N/A |
|---|---|---|---|
| **2 (continued)** | | | |
| Critical Velocity | | | |
| - Was HEC-18, Equation 6.1 used? | | | |
| - $K_u$ coefficient is correct (6.19 - SI units / 11.17 - English units) | | | |
| - y is channel hydraulic depth variable from XS (1) | | | |
| - V is channel velocity from XS (1) | | | |
| - 100-year scour type (check one) ☐ Clear ☐ Live | | | |
| - 500-year scour type (check one) ☐ Clear ☐ Live | | | |
| - HEC-RAS output tables are included with input parameters labeled page ______ | | | |
| **Comments:** | | | |
| **Live-Bed Scour** - calculate for the event(s) determined to be live-bed* | | | |
| *Where coarse sediments are present, it is recommended that scour depths be calculated for live-bed scour conditions using the clear-water and live-bed equations, and the smaller scour depth be used. | | | |
| - Were HEC-18, Equations 6.2 and 6.3 used? | | | |
| - $y_1$ is channel hydraulic depth variable from XS (1) | | | |
| - $y_o$ is hydraulic depth variable from XS (2) | | | |
| - $W_1$ (check one) ______ ft ☐ Top ☐ Bottom | | | |
| - $W_1$ is the estimated bottom or top channel width from XS (1) | | | |
| - $W_2$ (check one) ______ ft ☐ Top ☐ Bottom | | | |
| - $W_2$ is the estimated bottom or top channel width from XS (2) | | | |
| - $W_1$ and $W_2$ are consistent (both top or both bottom) | | | |
| - $Q_1$ is the channel flow from XS (1) | | | |
| - $Q_2$ is the flow in the contracted channel** from XS (2) | | | |
| - $k_1$ coefficient correct (0.59 - mostly contact, 0.64 - some suspended, 0.69 - mostly suspended) | | | |
| - $y_s$ (100-yr event) ______ ft | | | |
| - $y_s$ (500-yr event) ______ ft | | | |
| - HEC-RAS output tables are included with input parameters labeled page ______ | | | |
| **If the proposed bridge abutments are located in the channel (HEC-18, Case 1a) or at the channel banks (HEC-18, Case 1b), $Q_2$ should be the flow through the bridge opening. | | | |
| **Comments:** | | | |

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# Scour Analysis & Riprap Sizing Checklist
# Quality Assurance Review

Project: District:

Municipality: County:

Reviewer(s): Date:

| DESCRIPTION | YES | NO | N/A |
|---|---|---|---|

**Clear-Water Scour** - calculate for the event(s) determined to be clear-water

- Were HEC-18, Equations 6.4 and 6.5 used?
- $K_u$ coefficient is correct (0.025 - SI units / 0.0077 - English units)
- $y_o$ is hydraulic depth variable from XS (2)
  W (check one) ________ ft ☐ Top ☐ Bottom
- W is the bottom or top channel width from XS (2)
- Q is the flow through the bridge opening or on the set-back over bank area at the bridge associated with the width, W, from XS (2)
- HEC-RAS output tables are included with input parameters labeled page ________

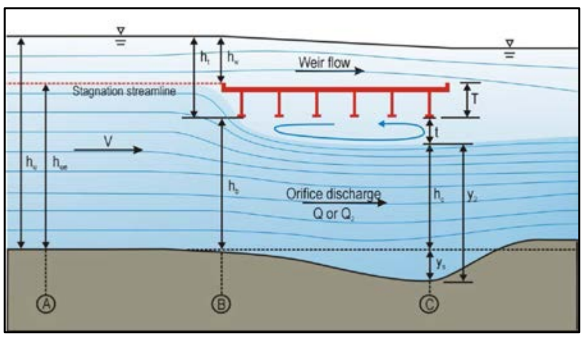
**Comments:** ________________________________________

________________________________________

________________________________________

**3.** **Pressure Flow Scour** (Vertical Contraction Scour)

*Pressure flow scour should be calculated for all events that submerge the low chord




- Were HEC-18, Equations 6.4, 6.14 and 6.16 used (Clear-water Application)?
- Were HEC-18, Equation 6.2, 6.14, and 6.16 used (Live-bed Application)?
- $h_b$, vertical size of the bridge opening prior to scour (same as $Y_0$) ________ ft
- $h_b$ dimension calculations provided/appropriate?
- $h_u$ Upstream channel flow depth is from XS (1) (same as $y_1$) ________ ft
- $h_t$ Distance from the water surface to the lower face of the bridge girders = $h_u$ - $h_b$, ft
- T, Height of the obstruction including girders, deck, and parapet ________ ft
- If bridge railing has openings, T extends up to the lower edge of railing opening
- $h_t$ is greater than T for which event (overtopping case)? ________ year
- $h_w$ Weir flow height = $h_t$ - T for $h_t > T$ (overtopping), hw = 0 for $h_t \leq T$ (non overtopping)
- Was $h_{ue}$ (adjusted upstream channel flow depth) used instead of $y_1$ for Live bed overtopping application?
- Was $Q_{ue}$ calculated using HEC-18 equation 6.15 and applied in HEC-18 Equation 6.2 instead of $Q_1$ for Live Bed overtopping application?
- $y_s$ (100-yr event) ________________ ft
- $y_s$ (500-yr event) ________________ ft
- HEC-RAS output tables are included with input parameters labeled page ________

**Comments:** ________________________________________

________________________________________

________________________________________

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# Scour Analysis & Riprap Sizing Checklist
# Quality Assurance Review

| | |
|---|---|
| Project: | District: |
| Municipality: | County: |
| Reviewer(s): | Date: |

| DESCRIPTION | YES | NO | N/A |
|---|---|---|---|
| **3. Local Pier Scour (if applicable)** | | | |
| Local Pier Scour for Simple Piers | | | |
| - Was HEC-18, Equation 7.1 used? | | | |
| - Pier nose shape ______ | | | |
| - $K_1$ pier nose coefficient is correct (HEC-18, Table 7.1) | | | |
| - Angle of attack of flow, θ ______ (θ is 0 when the pier is aligned with the flow direction) | | | |
| - $K_2$ angle of attack coefficient is correct (HEC-18, Table 7.2) | | | |
| - $K_3$ bed condition coefficient is correct (HEC-18, Table 7.3) | | | |
| - $y_1$ is hydraulic depth directly upstream of the pier from XS (3) flow distribution table | | | |
| - $V_1$ is velocity directly upstream of the pier from XS (3) flow distribution table | | | |
| - g, acceleration of gravity (check one) ☐ 9.81 $m/s^2$ ☐ 32.2 $ft/s^2$ | | | |
| - $Fr_1$ is the Froude number directly upstream of the pier from XS (3) and $Fr_1 = V_1 / (gy_1)^{0.5}$ | | | |
| - a, pier width ______ ft | | | |
| - a is the pier width perpendicular to the flow direction (i.e., projected pier width) | | | |
| - Equation 7.32 is used to calculate effective width of weir ($a^*_d$) if debris is present and $a^*_d$ is used instead of a in HEC-18 Equation 7.1 or Equation 7.3 | | | |
| - $K_1$ in Equation 7.32 is either 0.79 (rectangular debris) or 0.21 (triangular debris) | | | |
| - $K_w$ calculated with Eqn. 7.1 or 7.3 if y/a < 0.8, $a/D_{50}$ > 50, and Fr < 1 | | | |
| - $y_s$ (100-yr event) ______ ft | | | |
| - $y_s$ (500-yr event) ______ ft | | | |
| - HEC-RAS output tables are included with input parameters labeled page ______ | | | |
| **Comments:** | | | |
| **4. Total Scour** | | | |
| - If live-bed contraction scour depths are limited by streambed armoring, was the lesser of the clear-water and live-bed contraction scour depths used? | | | |
| - If multi-layered riprap protection is proposed for the piers, was the local pier scour depth reduced by 50%? | | | |
| - If the structure has piers, was the total pier scour depth calculated as the sum of the contraction scour <u>or</u> pressure scour (whichever equation is applicable), and local scour that includes both the pier scour and scour from debris, if applicable. | | | |
| - Scour prism plot is illustrated on the HEC-RAS bridge section page ______ | | | |
| - Total scour depths are included in the H&H Report page ______ | | | |
| - If any aggradation or degradation was indicated in bridge inspection reports was it included with total scour? | | | |
| **Total Scour Continued** | | | |
| Scour depths were calculated for the temporary bridge (25-year event) per DM-4, Chap 5. | | | |
| *Note 1: Per DM-4, Chapter 7 local abutment scour calculations are not required when the substructure is protected with multi-layered riprap protection. | | | |

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## Scour Analysis & Riprap Sizing Checklist
## Quality Assurance Review

Project: District:

Municipality: County:

Reviewer(s): Date:

| DESCRIPTION | YES | NO | N/A |
|---|---|---|---|

**4 (continued)**

**Note 2: The use of Equations 6.2 or 6.4 in combination with Equation 6.14 incorporates the contraction of the channel and floodplain flows (lateral contraction) and pressure flow (vertical contraction).

***Note 3: Pressure flow scour can occur even when there is no lateral contraction due to vertical contraction of the flow and the development of the flow separation zone.

**Comments:**

______________________________

______________________________

______________________________

______________________________

**5. Riprap Sizing**

- Unfactored velocities

| Abutment | | | Piers | | |
|---|---|---|---|---|---|
| $V_{100}$ | ________ | ft/s | $V_{100}$ | ________ | ft/s |
| $V_{500}$ | ________ | ft/s | $V_{500}$ | ________ | ft/s |

- For abutments, V is the BR Open Vel variable for the velocity inside the bridge
- For piers, V is the avg upstream velocity in the section upstream of the piers - XS (3)
- HEC-RAS bridge output table shows inside bridge velocity page ________
- What event has the highest velocity inside the bridge? ________ year
- Was the highest velocity used?**

Abutments

- Was the 1.8 safety factor applied to the velocity before sizing the riprap?
- Riprap size meets DM-4 Chapter 7 requirements R - ________

Piers

- Was the 1.5 safety factor applied to the velocity before sizing the riprap?
- Riprap size meets DM-4 Chapter 7 requirements R - ________

Temporary Bridge

- Was the 1.8 safety factor applied to the 25-year velocity per DM-4, Chapter 5?
- Riprap size meets DM-4 Chapter 7 requirements R - ________

**Note: Per DM-4 Chapter 7, riprap has to be designed to withstand the 500-year velocity only when the 500-year scour depth is below the bottom of footing elevation. If a lower event has the highest velocity inside the bridge, it should be used for riprap sizing.

**Comments:**

______________________________

______________________________

______________________________

______________________________

US Department of Transportation, FHWA. Hydraulic Engineering Circular No. 18 (HEC-18), Evaluating Scour at Bridges, 5th Edition. April 2012.

D-3 (3-15)

pennsylvania
DEPARTMENT OF TRANSPORTATION
www.dot.state.pa.us

# Additional Comments
# Quality Assurance Review

Project: District:
Municipality: County:

**Checklist** ________ **Section** ________

**Checklist** ________ **Section** ________

**Checklist** ________ **Section** ________

**Checklist** ________ **Section** ________

**Checklist** ________ **Section** ________

**Checklist** ________ **Section** ________

**Checklist** ________ **Section** ________

# CHAPTER 10, APPENDIX E

## FHWA REFERENCES ON HYDROLOGY AND HYDRAULICS

**1.** A website for the Federal Highway Administration, Office of Bridge Technology provides current and archived information on highway hydraulics in its section titled "Hydraulics Engineering". This information includes publications and software, both current and archived. Most of the information may be downloaded or viewed in electronic format. Current and archived information includes Hydraulic Design Series (HDS), Hydraulic Engineering Circulars (HEC), and Hydraulic Reports.

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# CHAPTER 10, APPENDIX F

## POLICY FOR USE OF HEC-RAS IN THE NFIP

# Federal Emergency Management Agency

Washington, D.C. 20472


April 30, 2001

**MEMORANDUM FOR:** Hazards Study Branch, Washington, DC Office
Regional Engineers, Regions I-X
Map Coordination Contractors

[original signed]

**FROM:** Michael K. Buckley, P.E.
Director, Technical Services Division
Mitigation Directorate

**SUBJECT:** Policy for Use of HEC-RAS in the NFIP

**Background:**
The U.S. Army Corps of Engineers (USACE) is a leading Federal agency in the development of hydrologic and hydraulic computer modeling programs. These programs have been used throughout the history of the National Flood Insurance Program (NFIP) for flood hazard mapping and the creation of Flood Insurance Studies (FISs) and Flood Insurance Rate Maps (FIRMs). The HEC-2 computer model is one specific model that has been used extensively throughout the history of the NFIP for hydraulic calculations to determine base (1-percent-annual-chance) flood elevations (BFEs).

The Hydrologic Engineering Center of the USACE released the River Analysis System, HEC-RAS, to replace the HEC-2 hydraulic model. It is a completely new piece of software; in fact, none of the hydraulic routines from HEC-2 were used in the HEC-RAS software. This memorandum addresses the policy for the use of HEC-RAS to replace HEC-2 models for flood hazard mapping in the NFIP.

**Issues:**
The majority of detailed FISs and FIRMs in existence today have used the HEC-2 model to calculate BFEs. Paragraph 65.6(a)(8) of the NFIP regulations states that computer model used in support of a map revision must use the same computer model as was used in the original study. Since the USACE no longer supports the use of the HEC-2 model, FEMA must determine when it is appropriate to use HEC-RAS when the original study used HEC-2 to determine BFEs.

FEMA issued a policy statement on March 14, 1997, that explained the appropriate uses of HEC-RAS. Briefly, it stated that HEC-RAS could be used for a FIS revision or restudy when one of the following conditions had been met:

- The entire stream was rerun using HEC-RAS; or
- the stream reach remodeled using HEC-RAS was hydraulically independent from the rest of the stream, e.g. the stream was restudied from the downstream confluence with the

receiving stream (or other hydraulic control section) upstream to a dam or other hydraulic control section.

Given that the USACE replaced HEC-2 with HEC-RAS, FEMA is hereby revising its policy statement to encourage the use of HEC-RAS when appropriate, using the following guidance.

**Final Procedure:**

New detailed Flood Insurance Studies:

For FISs that have not yet been started, and for streams for which there is not an effective detailed study, FEMA encourages the use of HEC-RAS rather than HEC-2. Note that other computer models may also be used; FEMA's complete list of acceptable computer models may be viewed on our web site at http://www.fema.gov/fhm/en_modl.shtm. HEC-2 is still considered an acceptable hydraulic model; however the use of HEC-RAS instead of HEC-2 is strongly encouraged.

Revisions to Effective Flood Insurance Studies:

For revisions or restudies of detailed-studied streams, where the effective model is HEC-2, the conversion to HEC-RAS is encouraged. The following guidelines must be followed to convert an effective HEC-2 model to HEC-RAS.

- The effective HEC-2 model should be rerun on the requestor's computer in HEC-RAS to create the duplicate effective model. The differences in water-surface elevation between the effective model and the duplicate effective model must be fully documented and thoroughly explained. Most differences in water-surface elevation can be attributed to the (1) differences in bridge/culvert modeling routines, (2) method of conveyance calculations, (3) critical depth default, and (4) floodway computations. The *HEC-RAS User's Manual* and the *HEC-RAS Hydraulics Reference Manual* provide details on computational differences between the two models and guidance on simulating HEC-2 results; these manuals should be consulted to explain the differences between the effective and duplicate effective models.

- Once the duplicate effective model has been established, the corrected effective, existing conditions, and post-project conditions models can be created in HEC-RAS, using the duplicate effective HEC-RAS model as the basis.

- The HEC-RAS models must tie in to the effective water-surface profile within 0.5 foot at the upstream and downstream ends of the revised reach, in compliance with Subparagraph 65.6(a)(2) of the NFIP regulations.

Because the USACE has replaced the HEC-2 model with HEC-RAS, we support the use of HEC-RAS wherever practicable. I trust that this adequately explains the procedures to convert HEC-2 models to HEC-RAS for flood hazard mapping purposes in the NFIP. If you have any comments or questions, please do not hesitate to contact Ms. Sally P. Magee of our Headquarters staff in Washington, D.C. at (202) 646-8242, or by e-mail at sally.magee@fema.gov.

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# CHAPTER 10, APPENDIX G

## JOINT AGENCY GUIDANCE FOR PERMITTING REQUIREMENTS FOR HYDRAULIC MODELING OF TEMPORARY CONSTRUCTION ACTIVITIES

**DATE:** April 1, 2010

**SUBJECT:** Joint Agency Guidance for Permitting Requirements for Hydraulic Modeling of Temporary Construction Activities

**TO:** PennDOT District Executives and PADEP Program Managers

**FROM:**

| | |
|---|---|
| Brian Thompson, PE | Glenn Rider |
| Director | Director |
| PennDOT Bureau of Design | PA DEP Bureau of Watershed Management |

The Pennsylvania Department of Transportation (PennDOT) and The Department of Environmental Protection (PA DEP) have worked jointly to develop *Joint Agency Guidance for Permitting Requirements for Hydraulic Modeling of Temporary Construction Activities*. The guidance document has been developed by a joint taskforce of PennDOT and PA DEP, representatives from PennDOT Bureau of Design and District Offices, PA DEP Central Office and Regional Offices.

The purpose of this document is to provide guidance concerning some of the issues related to the permitting of temporary structures needed to facilitate the construction of permanent bridges and culverts. Attached is a copy of the Joint Guidance document dated April 1, 2010. For PennDOT, the guidance will become part of Design Manual Part 2, Chapter 10 in the next update. For PA DEP, this document will be available online in the Chapter 105 Online Guidance Manual and should be part of PA DEP's desk manual for review of permit applications.

The guidance is available for immediate use. If you have any questions, please contact Crystal Newcomer at PennDOT at 717-787-3590 or Jeff Means at PA DEP at 717-772-5643.

Attachment

cc: Scott Christie, PE Reading File
Highway Administration Bureau Directors
PennDOT District ADE's Design
PennDOT District Bridge Engineers
PennDOT District H&H and Permit Coordinators
Sid Freyermuth, PA DEP
Ken Murin, PA DEP
Jeffrey Means, PA DEP
PA DEP T-21 Staff

# Joint Agency Guidance for Permitting Requirements for Hydraulic Modeling of Temporary Construction Activities

**April 1, 2010**

The purpose of this document is to provide guidance concerning some of the issues relating to the permitting of temporary structures needed to facilitate the construction of permanent bridges and culverts.

One of the purposes of DEP regulation of water obstructions and encroachments, including temporary structures such as cofferdams, causeways and temporary road crossings, is to protect the health, safety, welfare and property of the people of the Commonwealth (105.2(1)). Temporary encroachments should be constructed of clean rock material to prevent stream channel sedimentation or pollution during placement, removal and periods of overtopping. The length of causeways across the stream channel should be limited as much as practicable. The design of temporary structures should consider the risk of backwater, scour and the potential loss of the structure during periods of high water. Temporary structures should be evaluated for a 2-year storm event. For temporary increases in backwater (within the 100-yr floodplain boundary) associated with the construction, operation and maintenance of temporary structures, PennDOT will determine whether or not an easement is appropriate. This determination is not required to obtain a permitting decision under Chapter 105. Granting the permit does not provide PennDOT with any property rights. See 25 Pa. Code §105.31(a). Normal flow should be maintained downstream of the structures to provide for existing in-stream water uses. The owner or applicant may be held responsible for any damages resulting from increased backwater caused by the temporary structure through common law remedies. The permittee, therefore, should consider the expected construction time period along with the associated potential for backwater and overtopping when determining the design of the temporary structure. Once the need for the temporary structures ceases, the structure should be removed and the stream channel restored to its original condition.

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# CHAPTER 10, APPENDIX H

## PERMIT COORDINATION PROCEDURES FOR EROSION AND SEDIMENT POLLUTION CONTROL PLAN APPROVALS AND NPDES PERMITS

Since January 28, 2000 the following permitting procedure has been agreed to by PennDOT and the Pennsylvania Department of Environmental Protection (PA DEP). This permitting procedure pertains to acceptance of permit applications for projects which also require NPDES Permit for Stormwater Discharge Associated with Construction Activities or Erosion and Sediment Pollution Control Plan approvals.

Individual permit applications for Waterway Obstruction and Encroachment Permits pursuant to 25 PA Code §105 may be submitted by PennDOT to the PA DEP for regulatory review prior to meeting the requirements of §105.13(f), which requires that Chapter 105 permit application contain proof that an application for a NPDES Permit for Stormwater Discharge Associated with Construction Activities has been submitted or that an Erosion and Sediment Pollution Control Plan for the project has been found satisfactory by the County Conservation District. PA DEP and PennDOT staffs have worked cooperatively to develop written guidance for permit applications that do not include Erosion and Sediment Pollution Control Plans. A complete copy of PA DEP's guidance is attached; however, highlights are as follows:

**1.** PA DEP will accept and review PennDOT's Chapter 105 permit applications without accompanying information related to Erosion and Sediment Pollution Control Plans. When the permit application satisfies all other administrative and technical requirements of Chapter 105, PA DEP will notify PennDOT by letter that the permit application is in compliance with Chapter 105, and PA DEP will attach an unsigned Chapter 105 permit containing all pertinent standard and special permit conditions. PA DEP will not sign and issue the permit until after the Erosion and Sediment Pollution Control Plan is approved, or the NPDES Permit is issued for the project.

**2.** When PennDOT receives approval of the Erosion and Sediment Pollution Control Plan, or the NPDES Permit for Stormwater Discharge Associated with Construction Activities, PennDOT MUST forward a copy of the approval letter, or the NPDES permit, to the PA DEP Regional Office. After PA DEP receives these items, PA DEP will complete the permit coordination process and issue the signed Chapter 105 permit.

**3.** The Chapter 105 permit application MUST contain ALL temporary and permanent water obstructions and encroachments associated with the project so that the project can be reviewed as a single and complete project. PennDOT must ensure that all stream diversions, cofferdams, causeways, temporary roads, and other water obstructions or encroachments, and all environmental impacts that may result from the proposed waterway encroachments are included in the application. When uncertainty exists about the need for a specific encroachment item, PennDOT should include the item in the permit application. This should eliminate the need for a subsequent permit amendment, which may be more difficult to process when Chapter 105 permit applications and Erosion and Sediment Pollution Control Plans are being processed independently.

**4.** This change in permit coordination does NOT affect PennDOT's obligations or regulatory requirements related to Erosion and Sediment as required by 25 PA Code §102 or the National Pollutant Discharge Elimination System (NPDES).

**5.** Copies of the Chapter 105 permits, Erosion and Sediment Pollution Control Plans, and NPDES permits will be included in the bidding and construction document packages to ensure that construction personnel are aware that they are responsible to implement the Erosion and Sediment Pollution Control Plan and to comply with permit conditions.

**6.** PennDOT will ensure that construction contractors are added to NPDES permits as co-permittees.

A copy of PA DEP's Chapter 105 permit transmittal letter and a copy of the permit including standard and special permit conditions are required items for approval of TS&L submissions to the Bridge Design and Technology Division.

**COMMONWEALTH OF PENNSYLVANIA**
**Department of Environmental Protection**
**Bureau of Water Quality Protection**
December 15, 1999
717-787-6827

**SUBJECT:** Permit Coordination

**TO:**

Bob Thompson, Section Chief
Soils and Waterways Section
Northwest Regional Office

Larry Busack, Section Chief
Soils and Waterways Section
Southwest Regional Office

Al Sever, Section Chief
Soils and Waterways Section
Northcentral Regional Office

Ray Zomok, Section Chief
Soils and Waterways Section
Southcentral Regional Office

John Chernesky, Section Chief
Soils and Waterways Section
Northeast Regional Office

Domenic Rocco, Section Chief
Soils and Waterways Section
Southeast Regional Office

**FROM:** Ken Reisinger, Chief
Division of Waterways, Wetlands and Erosion Control
Bureau of Water Quality Protection

After much discussion and deliberation, the attached guidance for coordination of PennDOT's highway development process, Chapter 105 permits, and Erosion and Sediment Control Plan approvals has been finalized. This process should serve to remove some of the controversy and impediments to highway project development and environmental permit approvals. Please implement this permit process immediately. If problems arise, contact me at your convenience.

Attachments

cc: Marrocco
Newman, PennDOT
File W74:30
Reading File

12/10/99

# PERMIT COORDINATION

**Chapter 105 Permit Processing Procedure**
**Pennsylvania Department of Transportation Projects**
**and**
**Erosion and Sediment Control Plan Approvals**

**PROBLEM:** Persons applying for Chapter 105 Water Obstruction and Encroachment Permits are required by the regulations to include with the application proof that an application for an NPDES Permit for Stormwater Discharge Associated with Construction Activities has been submitted to the County Conservation District, or a letter from the County Conservation District that indicates that an Erosion and Sediment Control Plan has been reviewed and considered satisfactory for the project. Without this information or a specific waiver of the information in accordance with 105.13(j), the permit application is not administratively complete and cannot be accepted for processing and approval. This permit application requirement, found at 105.13(f), applies to all permit applications with the exception of Small Project Permit applications.

The Department of Transportation's (PennDOT) highway construction project planning, design, and construction process requires that Chapter 105 Water Obstruction and Encroachment permits for the type, size, and location (TS&L) of bridges, culverts, or other water obstructions and encroachments be obtained before the final design phase of the project commences. PennDOT implements this process to ensure that design time and project dollars are not wasted on detailed final designs that are subject to modification or change during the Chapter 105 permit review and approval process.

The development of an Erosion and Sediment Control Plan which meets the requirements of Chapter 102 and an NPDES Permit for Stormwater Discharge Associated with Construction Activities depends on site specific details that are not normally prepared until after PennDOT receives the final review and approval of the TS&L including an approved 105 permit. Essentially, DEP's Chapter 105 permit application requirements and PennDOT's project development procedures contain interdependent requirements creating an unsynchronized process which has on occasion created, and continues to create, permitting and project hurdles for both agencies.

**BACKGROUND:** DEP and PennDOT staff have cooperatively worked together to move permit applications through the permit application and review process in a variety of fashions to manage these permit and project development inconsistencies. Nevertheless, in the absence of clear guidance, staff within both agencies is, on more than an occasional basis, challenged and confounded when attempting to process PennDOT permit applications. A permanent long term programmatic solution to this interagency issue is required to enable both agencies to more effectively meet their respective obligations to the citizens of the Commonwealth in the provision of safe and efficient transportation facilities and the protection of the environment.

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Section 105.13(j) of the Dam Safety and Waterway Management regulations provides the authority to waive permit application requirements where the Department finds that specific information is not necessary to review the permit application. This provides the Department with the flexibility to eliminate or reduce information requirements where such information is clearly redundant to another process or not necessary for processing the permit application. The regulations require that the reason for the waiver of information requirement be stated in writing, in the permit record of decision that is used to document the Department's review and decision process.

PennDOT, as a state agency, ensures that transportation projects comply with all state and federal laws and have the appropriate authorizations before they are available for competitive bidding and construction. This requirement is a critical component of PennDOT's commitment to the provision of public service, relating to transportation, including the protection of the Commonwealth's environmental resources. All PennDOT projects, including those which are not subject to the permitting requirements of the Chapter 105 program, must comply with the requirements found in Chapter 102 (Erosion and Sediment Control), and NPDES Permit for Stormwater Discharges Associated with Construction Activities (where applicable). Specifically:

> PennDOT's Final Draft Design Manual Part 1A, (anticipated publication date of January 2000), Chapter 7.0, specifies that the final design begins after approval of the environmental documentation. Chapter 7.1 identifies Erosion and Sediment Control Plans as a component of a Final Design Plan. Chapter 7.9 references DEP's Erosion and Sediment Control Program Manual and Erosion and Sediment Control Plan Development Checklist as providing the specifications for the final design of Erosion and Sediment Control Plans. Final design begins after approval of preliminary engineering document which includes TS&L.
>
> Chapter 13 of the Design Manual Part 2 provides the design specifications for Erosion and Sediment Control Plans for highway construction projects.
>
> Chapter 6 of the Design Manual Part 3, requires that Erosion and Sediment Control Plans be submitted to County Conservation Districts for their review and approval.
>
> PennDOT's Specifications 1994, Pub. 408, provides the Legal Relations and Responsibilities to the Public. Section 107.27 requires work to be done in accordance with all approvals by DEP. Section 107.28 specifically requires the implementation of erosion and sediment devices as indicated on plans. This section also requires approval from the County Conservation District for any changes to the Erosion and Sediment Control Plans or for amendments to NPDES permits.

Overall, these PennDOT procedures clearly require all highway construction projects be conducted with approved Erosion and Sediment Control Plans.

**RECOMMENDATION:** Recognizing the project and permit coordination constraints, and PennDOT's obligation to comply with all state permit requirements, DEP believes that it is in the mutual interest of both Departments to waive the requirement that an Erosion and Sediment Control Plan or approval must be included as part of a Chapter 105 permit application for highway construction projects for purposes of administrative completeness and technical reviews. **This administrative change does not eliminate the requirements for PennDOT to obtain an NPDES Permit for Stormwater Discharges Associated with Construction Activities, develop Erosion and Sediment Control Plans, or to have Erosion and Sediment Control Plans reviewed and approved by County Conservation Districts or the Department in the case of a non-delegated county, prior to Chapter 105 permit issuance.***

**PROCESS**: Applications submitted for Chapter 105 Water Obstruction and Encroachment permits must include all temporary and permanent water obstructions and encroachments associated with the project so the project can be reviewed as a single and complete project. The application shall show the locations of all permanent and temporary water obstructions and encroachments necessary for the construction of the project, including stream diversions, cofferdams, causeways, temporary roads, and other water obstructions and encroachments, and also include an environmental assessment of all potential environmental impacts that may result from those water obstructions and encroachments.

Water Obstruction and Encroachment Permit applications will be reviewed in accordance with the requirements of Chapter 105. Once the project meets the engineering and environmental requirements of Chapter 105, DEP will notify PennDOT by letter (see Attachment A) that the type, size, and location of the water obstruction and encroachment is in compliance with Chapter 105 Rules and Regulations and, in accordance with established Department procedures, the 105 permit will not be issued until permit coordination is complete and the erosion and sediment control plan required by 105.13 (f) is considered to be satisfactory. A copy of the unsigned Chapter 105 permit with the standard and special conditions will be included with the letter to facilitate the continuation of PennDOT's project development process. After receiving approval of the Erosion and Sediment Control Plan or the NPDES Permit for Stormwater Discharges Associated with Construction Activities from the Conservation District, or DEP in the case of a non-delegated district, PennDOT will forward the notice of the Erosion and Sediment Control Plan approval to the DEP Regional Office to complete the permit coordination process and DEP will issue the Chapter 105 permit.

PennDOT will include the approved Chapter 105 permit and Erosion and Sediment Control Plan in all available project construction documents to ensure potential contractors are aware of the entire scope of the project including the obligation to implement the Erosion and Sediment Control Plan as approved by the County Conservation District or appropriate DEP Regional Office, in the case of a non-delegated District. Where an NPDES Permit is required, it will also be included in the project construction documents. Once a contractor has been approved and selected, PennDOT will ensure the contractor is added to the NPDES Permit utilizing DEP's Co-Permittee/Transferee Form.

*NOTE: Small project permits do not require approved Erosion and Sediment Control Plans prior to the issuance of Chapter 105 Permits. This process does not change that regulatory provision.

ATTACHMENT A
Sample Letter

Address
Date

_____________ **Regional Office**

Phone:_________

District Engineer
PennDOT District ________
____________________
____________________

Re: Water Obstruction & Encroachment Permit
DEP File No. E _______ & APS# _______

Dear

We are pleased to inform you that the technical review of your permit application has been completed and your application has been found to be in compliance with the Department's Chapter 105 rules and regulations. However, the permit cannot be issued at this time since it must be coordinated with other Department permits as well as Erosion and Sediment Control Plan approval. Please forward the approval of the Erosion and Sediment Control Plan to this office when it is available. You will be advised when the other Department authorizations have been completed.

If you have any questions, please contact this office at the above number.

Sincerely,

Water Management Program

Attachment: Permit E __________ (unsigned w/conditions)

4

# CHAPTER 10, APPENDIX I

## CLARIFICATION OF CONSISTENCY LETTER REQUIREMENTS FOR STORMWATER MANAGEMENT ANALYSIS AND FLOODPLAIN MANAGEMENT ANALYSIS

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

**MEMO**

**TO** Regional Watershed Managers
Regional Soil and Waterway Section Chiefs

**FROM** Ken Murin, Chief, Division of Waterways, Wetlands and Stormwater Management

**DATE** January 8, 2009

**RE** Stormwater Management Analysis - Clarification of Consistency Letter Requirements per Chapter 105, Section 105.13(d)(1)(v)

As a part of the Chapter 105 application review process, consistency letters from counties and municipalities for stormwater plans are required only in those watersheds with a stormwater plan developed in accordance with the Stormwater Management Act (32 P.S. §§ 680.1 – 680.17) commonly referred to as Act 167 that has been approved by the Department and adopted by the County and local municipalities. There is no requirement by the Act that a County or local municipality provide consistency letters for projects covered by their stormwater plans. In the event that an applicant is unable to obtain a consistency letter from the County or local municipality, the Department will determine whether the proposed project is consistent based upon all other Chapter 105 and Chapter 106 requirements.

To facilitate the Department's review the applicant should provide a copy of the letter (with proof of receipt) sent to both the County and local municipality requesting a review of the project for consistency with the approved stormwater plan and allow them a minimum of (30) days to comment on whether or not a consistency letter will be provided along with the expected time frame for the completion of the review and preparation of the consistency letter. One consistency letter provided by **either** the County or local municipality will be sufficient, a response is not required by both.

If the applicant receives correspondence from the municipality indicating that a consistency letter will not be provided with respect to the approved stormwater plan, the applicant should include that notification along with a copy of the original letter to the County and municipality (with proof of receipts) as a part of the application package. The applicant should include a statement from the Project Manager indicating that the project location, design and proposed construction is in accordance with the approved stormwater plan.

In the event that the applicant receives no response from either the County or local municipality within the specified 30 day period (after proof of receipt) indicating that a review of the project will take place and/or a consistency letter will be provided; the applicant should send a second letter to both the County and municipality indicating that it is the applicant's intent to proceed with the project and that any future comments regarding consistency with the approved stormwater plan be directed to the appropriate regional office of DEP, permitting and technical services section ( or other section as appropriate). The applicant should include a statement from the Project Manager indicating that the project location, design and proposed construction is in accordance with the approved stormwater plan.

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**pennsylvania**
DEPARTMENT OF ENVIRONMENTAL PROTECTION

**MEMO**

**TO** Regional Watershed Managers
Regional Soil and Waterway Section Chiefs

**FROM** Ken Murin, Chief, Division of Waterways, Wetlands and Stormwater Management

**DATE** January 8, 2009

**RE** Clarification of Consistency Letter Requirements per Chapter 105, Section 105.13(d)(1)(vi) Floodplain Management Analysis

As a part of the Chapter 105 application review process, a letter from the local municipality commenting on floodplain consistency is only required if the proposed dam, water obstruction or encroachment is located within a floodway delineated on a FEMA map. There is no requirement within the Floodplain Management Act (32 P.S. § 679.101 et seq.), compelling a local municipality to provide consistency letters for projects located within the floodway. In the event that and applicant is unable to obtain a consistency letter from the local municipality, the Department will determine whether the proposed project is consistent with the Act or other National Flood Insurance Minimum Standards based upon all other Chapter 105 and Chapter 106 requirements.

To facilitate the Department's review the applicant should provide a copy of the letter (with proof of receipt) sent to the local municipality requesting a review of the project for consistency with floodplain management ordinances and allow the municipality a minimum of (30) days to comment on whether or not a consistency letter will be provided along with the expected time frame for the completion of the review and preparation of the consistency letter.

If the applicant receives correspondence from the municipality indicating that a consistency letter will not be provided for the project, the applicant should include that notification along with the copy of the original letter to the municipality (with proof of receipt) as a part of the application package.

In the event that the applicant receives no response from the local municipality within the specified 30 day period (after proof of receipt) indicating that a review of the project will take place and/or a consistency letter will be provided; the applicant should send a second letter to the municipality indicating that it is the applicant's intent to proceed with the project and that any future comments regarding consistency with the local floodplain management ordinances be directed to the appropriate regional office of DEP, permitting and technical services section ( or other section as appropriate).

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# CHAPTER 11

## PAVEMENT DESIGN

### 11.0 INTRODUCTION

The policies, guidelines and procedures for the construction, restoration, rehabilitation, resurfacing and reconstruction of pavement structures for all Department projects shall conform to the current Publication 242, *Pavement Policy Manual*.

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# CHAPTER 12

## GUIDE RAIL, MEDIAN BARRIER AND ROADSIDE SAFETY DEVICES

### 12.0 INTRODUCTION

Highways should be designed through judicious arrangement and balance of geometric features to preclude or minimize the need for roadside or median barrier. To provide for maximum roadside safety, a thorough study during the early stages of design is necessary to recognize and eliminate, where practical, those items and conditions which require barrier and impact attenuating devices.

While every reasonable effort should be made to keep a motorist on the roadway, the highway design engineer should acknowledge the fact that this goal will never be fully realized. Motorists continue to run off the road for many reasons, including driver error in the form of excessive speed, falling asleep, reckless or inattentive driving, or driving under the influence of alcohol or other drugs. A driver may also leave the road deliberately to avoid a collision with another motor vehicle or with objects on the road.

The consistent application of geometric design standards for roads and streets provides motorists with a high degree of safety. Design features such as horizontal and vertical curvature, pavement and shoulder width, and signing and pavement markings each play an important role towards achieving the desired level of safety. Roadside safety features, such as breakaway supports, bridge railings and impact attenuating devices provide an extra margin of safety to motorists who inadvertently leave the roadway. Most appurtenances are installed based on an analysis of their benefits to the motorists. In some instances, however, it may not be immediately obvious that the benefits to be gained from a specific safety design feature or treatment equal or exceed the additional costs. The design engineer must decide how and where limited funds should be spent to achieve the greatest overall benefits.

Railing systems mounted on bridges require a high level of protection be afforded to motorists. Select railing system Test Levels in accordance with the criteria of Section 12.11.

Policy and/or guidelines presented in this chapter, relative to clear zone, are applicable to all projects including new location, reconstruction and 3R projects. For resurfacing, restoration and rehabilitation (3R) projects, where major upgrading to horizontal or vertical alignment is not practical, clear zone widths less than those indicated in Table 12.1 may be suitable for attainment or retention. The cost of full reconstruction for these facilities will often not be justified. The designer must do specific site investigation and crash history analysis to determine a cost effective design by selectively upgrading the roadway and roadside to optimize the clear zone widths. Consideration must be given to the location and type of obstruction, existing roadway geometry and right-of-way widths, the ability to improve existing roadway geometry, signing and pavement marking and/or to require additional right-of-way, and the costs and benefits involved.

The following information and criteria are a guide and should be supplemented with sound engineering judgment. For additional guidelines, refer to the Standard Drawings for typical guide rail and median barrier placement and installation details. Also refer to the AASHTO Roadside Design Guide for additional source references.

### 12.1 THE CLEAR ZONE CONCEPT

Clear zone is defined as the total roadside border area, starting at the edge of traveled way, available for safe use by errant vehicles. This area may consist of a shoulder, a recoverable slope, a non-recoverable slope, and/or a clear run-out area. The width of the clear zone is influenced by the traffic volume, the design speed and embankment slope.

Table 12.1 can be used to determine the clear zone width recommended for selected traffic volumes, design speeds and embankment slopes. Clear zone widths shown in Table 12.1 represent values that are extrapolated from the curves in the AASHTO Roadside Design Guide and are a general approximation since they are based on limited empirical data.

## TABLE 12.1 (METRIC)
## CLEAR ZONE WIDTH
## (in meters from edge of through traveled way)

| DESIGN SPEED | DESIGN ADT | FORESLOPE | | | BACKSLOPE | | |
|---|---|---|---|---|---|---|---|
| | | **1V:6H OR FLATTER** | **1V:5H TO 1V:4H** | **1V:3H** | **1V:3H** | **1V:5H TO 1V:4H** | **1V:6H OR FLATTER** |
| 60 km/h or less | Under 750 | 2.0 | 2.0 | ** | 2.0 | 2.0 | 2.0 |
| | 750 - 1500 | 3.0 | 3.5 | ** | 3.0 | 3.0 | 3.0 |
| | 1500 - 6000 | 3.5 | 4.5 | ** | 3.5 | 3.5 | 3.5 |
| | Over 6000 | 4.5 | 5.0 | ** | 4.5 | 4.5 | 4.5 |
| 70-80 km/h | Under 750 | 3.0 | 3.5 | ** | 2.5 | 2.5 | 3.0 |
| | 750 - 1500 | 4.5 | 5.0 | ** | 3.0 | 3.5 | 4.5 |
| | 1500 - 6000 | 5.0 | 6.0 | ** | 3.5 | 4.5 | 5.0 |
| | Over 6000 | 6.0 | 7.5 | ** | 4.5 | 5.5 | 6.0 |
| 90 km/h | Under 750 | 3.5 | 4.5 | ** | 2.5 | 3.0 | 3.0 |
| | 750 - 1500 | 5.0 | 6.0 | ** | 3.0 | 4.5 | 5.0 |
| | 1500 - 6000 | 6.0 | 7.5 | ** | 4.5 | 5.0 | 6.0 |
| | Over 6000 | 6.5 | 8.0 | ** | 5.0 | 6.0 | 6.5 |
| 100 km/h | Under 750 | 5.0 | 6.0 | ** | 3.0 | 3.5 | 4.5 |
| | 750 - 1500 | 6.0 | 8.0 | ** | 3.5 | 5.0 | 6.0 |
| | 1500 - 6000 | 8.0 | 9.0 | ** | 4.5 | 5.5 | 7.5 |
| | Over 6000 | 9.0 | 9.0 | ** | 6.0 | 7.5 | 8.0 |
| 110 km/h | Under 750 | 5.5 | 6.0 | ** | 3.0 | 4.5 | 4.5 |
| | 750 - 1500 | 7.5 | 8.5 | ** | 3.5 | 5.5 | 6.0 |
| | 1500 - 6000 | 8.5 | 9.0 | ** | 5.0 | 6.5 | 8.0 |
| | Over 6000 | 9.0 | 9.0 | ** | 6.5 | 8.0 | 8.5 |

** Since recovery is less likely on the unshielded, traversable 1V:3H slopes, consider removal of fixed objects present beyond the toe of these slopes. Determination of the width of the recovery area provided, if any, at the toe of slope should take into consideration right-of-way availability, environmental concerns, economic factors, safety needs, and crash histories. Also, the distance between the edge of the through traveled lane and the beginning of the 1V:3H slope should influence the recovery area provided at the toe of slope.

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## TABLE 12.1 (ENGLISH)
## CLEAR ZONE WIDTH
## (in feet from edge of through traveled way)

| | | FORESLOPE | | | BACKSLOPE | | |
|---|---|---|---|---|---|---|---|
| **DESIGN SPEED** | **DESIGN ADT** | **1V:6H OR FLATTER** | **1V:5H TO 1V:4H** | **1V:3H** | **1V:3H** | **1V:5H TO 1V:4H** | **1V:6H OR FLATTER** |
| 40 mph or less | Under 750 | 7 | 7 | ** | 7 | 7 | 7 |
| | 750 - 1500 | 10 | 12 | ** | 10 | 10 | 10 |
| | 1500 - 6000 | 12 | 14 | ** | 12 | 12 | 12 |
| | Over 6000 | 14 | 16 | ** | 14 | 14 | 14 |
| 45-50 mph | Under 750 | 10 | 12 | ** | 8 | 8 | 10 |
| | 750 - 1500 | 14 | 16 | ** | 10 | 12 | 14 |
| | 1500 - 6000 | 16 | 20 | ** | 12 | 14 | 16 |
| | Over 6000 | 20 | 24 | ** | 14 | 18 | 20 |
| 55 mph | Under 750 | 12 | 14 | ** | 8 | 10 | 10 |
| | 750 - 1500 | 16 | 20 | ** | 10 | 14 | 16 |
| | 1500 - 6000 | 20 | 24 | ** | 14 | 16 | 20 |
| | Over 6000 | 22 | 26 | ** | 16 | 20 | 22 |
| 60 mph | Under 750 | 16 | 20 | ** | 10 | 12 | 14 |
| | 750 - 1500 | 20 | 26 | ** | 12 | 16 | 20 |
| | 1500 - 6000 | 26 | 30 | ** | 14 | 18 | 24 |
| | Over 6000 | 30 | 30 | ** | 20 | 24 | 26 |
| 65-70 mph | Under 750 | 18 | 20 | ** | 10 | 14 | 14 |
| | 750 - 1500 | 24 | 28 | ** | 12 | 18 | 20 |
| | 1500 - 6000 | 28 | 30 | ** | 16 | 22 | 26 |
| | Over 6000 | 30 | 30 | ** | 22 | 26 | 28 |

** Since recovery is less likely on the unshielded, traversable 1V:3H slopes, consider removal of fixed objects present beyond the toe of these slopes. Determination of the width of the recovery area provided, if any, at the toe of slope should take into consideration right-of-way availability, environmental concerns, economic factors, safety needs, and crash histories. Also, the distance between the edge of the through traveled lane and the beginning of the 1V:3H slope should influence the recovery area provided at the toe of slope.

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When obstructions exist behind curbs, a minimum horizontal clearance of 0.5 m (1.5 ft) should be provided beyond the face of curbs to the obstructions. This offset may be considered the minimum allowable horizontal clearance (or operational offset), but **IT SHOULD NOT BE CONSTRUED AS AN ACCEPTABLE CLEAR ZONE DISTANCE**. Since curbs do not have a significant redirectional capability, obstructions behind a curb should be located at or beyond the minimum clear-zone distances shown in Table 12.1. In many instances, it will not be practical to obtain the recommended clear zone distances on existing facilities. On new construction where minimum recommended clear zones cannot be provided, fixed objects should be located as far from traffic as practical on a project-by-project basis, but in no case closer than 0.5 m (1.5 ft) from the face of the curb.

The designer must keep in mind site-specific conditions, design speeds, rural versus urban locations, and practicality. The numbers in Table 12.1 suggest only the approximate values to be considered and not a precise distance to be held as absolute.

The designer may choose to modify the clear zone width obtained from Table 12.1 for horizontal curvature by using the horizontal curve adjustment factors in Table 12.2. These modifications are normally considered only where crash histories indicate a need, or a specific site investigation shows a definitive crash potential. This potential could be significantly lessened by increasing the clear zone width, provided such increases are cost-effective. Horizontal curves, particularly for high-speed facilities, are usually superelevated to increase safety and to provide a more comfortable ride.

For relatively flat and level roadsides, the clear zone concept is simple to apply. Application is more complex when the roadway is in a fill or cut section where roadside slopes may be either positive, negative, or variable, or where a ditch exists near the traveled way. For additional clear zone information refer to the 2004 AASHTO Green Book and the AASHTO Roadside Design Guide.

**A. Foreslopes.** Foreslopes parallel to the flow of traffic may be identified as recoverable, non-recoverable, or critical. Recoverable foreslopes are 1V:4H or flatter. If such slopes are relatively smooth and traversable, the suggested clear zone width may be taken directly from Table 12.1. Motorists who encroach on recoverable foreslopes can generally stop their vehicles or slow them enough to return to the roadway safely.

A non-recoverable foreslope is defined as one that is traversable, but from which most vehicles are unable to stop or to return to the roadway easily. Vehicles traversing such slopes typically can be expected to reach the bottom. Foreslopes between 1V:3H and 1V:4H generally fall into this category. Since a high percentage of encroaching vehicles may reach the toe of these slopes, the clear zone distance cannot logically end on the slope. Fixed obstacles are normally not constructed along such slopes and a clear runout area at the base is desirable. Figure 12.1 provides an example of parallel embankment slope design thru recoverable and non-recoverable slopes. The basic philosophy behind the recovery area is that a vehicle can traverse a 1V:3H slope but is not likely to recover (control steering) and therefore, recovery may be expected to occur beyond the toe of slope. Determination of the width of the clear zone distance at the toe of slope should take into consideration right-of-way availability, environmental concerns, economic factors, safety needs and crash history.

A critical foreslope is one which a vehicle is likely to overturn. Foreslopes steeper than 1V:3H generally fall into this category. If a foreslope steeper than 1V:3H begins closer to the through traveled way than the suggested clear zone width for that specific roadway, a roadside barrier might be required (Table 12.5) if the slope cannot readily be flattened.

**B. Transverse Slopes.** Common obstacles on roadsides are transverse slopes created by median crossovers, berms, driveways or intersecting side roads. These are generally more critical to errant motorists than foreslopes or backslopes because they are typically struck head-on by run-off-the-road vehicles. Transverse slopes of 1V:6H or flatter are suggested for high-speed roadways, particularly for that section of the transverse slope that is located immediately adjacent to traffic. This slope can then be transitioned to a steeper slope as the distance from the through traveled way increases.

Transverse slopes of 1V:10H are desirable; however, their practicality may be limited by width restrictions and the maintenance problems associated with the long tapered ends of pipes or culverts. Transverse slopes steeper than 1V:6H may be considered for urban areas or for low-speed facilities.

## TABLE 12.2 (METRIC)
## HORIZONTAL CURVE ADJUSTMENTS
## $K_{cz}$ (CURVE CORRECTION FACTOR)

| RADIUS (m) | DESIGN SPEED (km/h) | | | | | |
|---|---|---|---|---|---|---|
| | **60** | **70** | **80** | **90** | **100** | **110** |
| 900 | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 |
| 700 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 | 1.3 |
| 600 | 1.1 | 1.2 | 1.2 | 1.2 | 1.3 | 1.4 |
| 500 | 1.1 | 1.2 | 1.2 | 1.3 | 1.3 | 1.4 |
| 450 | 1.2 | 1.2 | 1.3 | 1.3 | 1.4 | 1.5 |
| 400 | 1.2 | 1.2 | 1.3 | 1.3 | 1.4 | — |
| 350 | 1.2 | 1.2 | 1.3 | 1.4 | 1.5 | — |
| 300 | 1.2 | 1.3 | 1.4 | 1.5 | 1.5 | — |
| 250 | 1.3 | 1.3 | 1.4 | 1.5 | — | — |
| 200 | 1.3 | 1.4 | 1.5 | — | — | — |
| 150 | 1.4 | 1.5 | — | — | — | — |
| 100 | 1.5 | — | — | — | — | — |

$CZ_c = (L_c)\ (K_{cz})$

Where: $CZ_c$ = CLEAR ZONE WIDTH ON OUTSIDE OF CURVATURE (m)
$L_c$ = CLEAR ZONE WIDTH (m), TABLE 12.1
$K_{cz}$ = CURVE CORRECTION FACTOR

Note: THE CLEAR ZONE CORRECTION FACTOR IS APPLIED TO THE OUTSIDE OF CURVES ONLY. CURVES WITH A RADIUS GREATER THAN 900 m DO NOT REQUIRE AN ADJUSTED CLEAR ZONE WIDTH.

## TABLE 12.2 (ENGLISH)
## HORIZONTAL CURVE ADJUSTMENTS
## $K_{cz}$ (CURVE CORRECTION FACTOR)

| RADIUS (ft) | DESIGN SPEED (mph) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
| 2860 | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 | 1.3 |
| 2290 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 | 1.3 | 1.3 |
| 1910 | 1.1 | 1.2 | 1.2 | 1.2 | 1.3 | 1.3 | 1.4 |
| 1640 | 1.1 | 1.2 | 1.2 | 1.3 | 1.3 | 1.4 | 1.5 |
| 1430 | 1.2 | 1.2 | 1.3 | 1.3 | 1.4 | 1.4 | — |
| 1270 | 1.2 | 1.2 | 1.3 | 1.3 | 1.4 | 1.5 | — |
| 1150 | 1.2 | 1.2 | 1.3 | 1.4 | 1.5 | — | — |
| 950 | 1.2 | 1.3 | 1.4 | 1.5 | 1.5 | — | — |
| 820 | 1.3 | 1.3 | 1.4 | 1.5 | — | — | — |
| 720 | 1.3 | 1.4 | 1.5 | — | — | — | — |
| 640 | 1.3 | 1.4 | 1.5 | — | — | — | — |
| 570 | 1.4 | 1.5 | — | — | — | — | — |
| 380 | 1.5 | — | — | — | — | — | — |

$CZ_c = (L_c)(K_{cz})$

Where: $CZ_c$ = CLEAR ZONE WIDTH ON OUTSIDE OF CURVATURE (ft)
$L_c$ = CLEAR ZONE WIDTH (ft), TABLE 12.1
$K_{cz}$ = CURVE CORRECTION FACTOR

Note: THE CLEAR ZONE CORRECTION FACTOR IS APPLIED TO THE OUTSIDE OF CURVES ONLY. CURVES WITH RADII GREATER THAN 2860 ft DO NOT REQUIRE AN ADJUSTED CLEAR ZONE WIDTH.

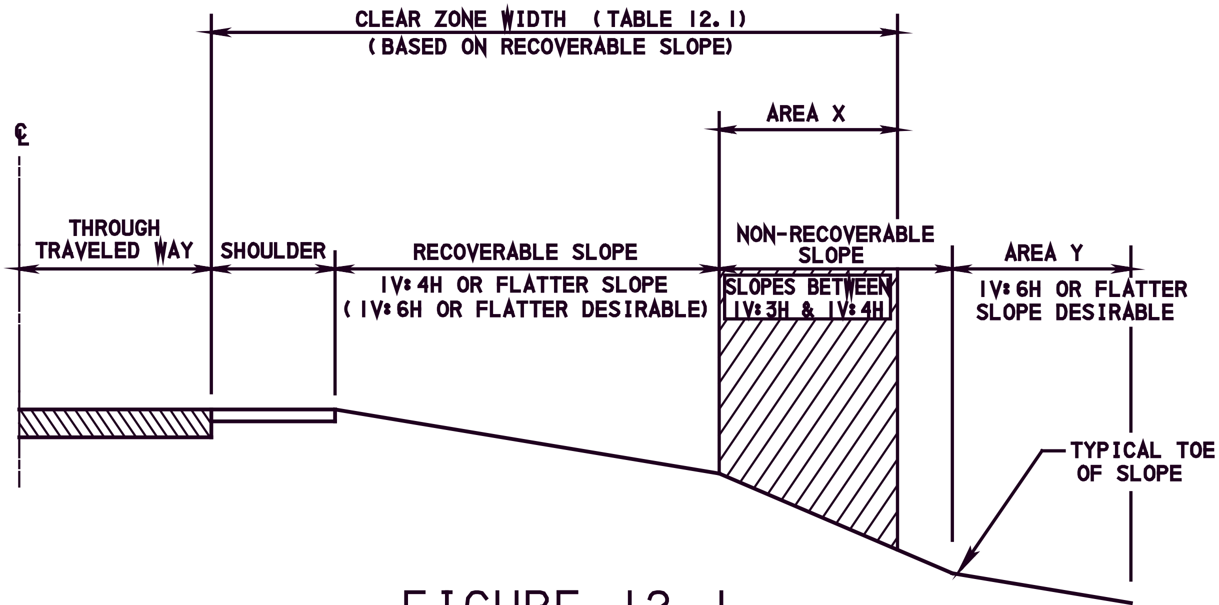


FIGURE 12.1
EXAMPLE OF A PARALLEL EMBANKMENT SLOPE DESIGN

THIS FIGURE ILLUSTRATES A RECOVERABLE SLOPE FOLLOWED BY A NON-RECOVERABLE SLOPE. SINCE THE CLEAR ZONE WIDTH EXTENDS ONTO A NON-RECOVERABLE SLOPE, THE PORTION OF THE CLEAR ZONE WIDTH ON SUCH A SLOPE MAY BE PROVIDED BEYOND THE NON-RECOVERABLE SLOPE IF PRACTICAL.

NOTE:

A. WHEN THE ENTIRE SLOPE IS RECOVERABLE, THE RECOVERY AREA EQUALS THE CLEAR ZONE WIDTH.

B. AREA X IS EQUAL TO AREA Y. IF AREA Y IS LESS THAN 3 m (10 ft), USE 3 m (10 ft).

**C. Backslopes.** When a highway is located in a cut section, the backslope may be traversable depending upon its relative smoothness and the presence of fixed obstacles. If the foreslope between the roadway and the base of the backslope is traversable (1V:3H or flatter) and the backslope is obstacle-free, it may not be a potential concern, regardless of its distance from the roadway. On the other hand, a steep, rough-sided rock cut should normally begin outside the clear zone or be shielded. A rock cut is normally considered to be rough-sided when the face can cause excessive vehicle snagging rather than provide relatively smooth redirection.

## 12.2 BREAKAWAY SUPPORTS

The term "breakaway support" refers to all types of signs, luminaire and traffic signal supports that are designed to yield when impacted by a vehicle. The release mechanism may be a slip plane, plastic hinge, fracture element or a combination thereof. The criteria used to determine if a support is considered breakaway are presented in the AASHTO publication, *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals* and National Cooperative Highway Research Program (NCHRP) Report 350, *Recommended Procedures for the Safety Performance Evaluation of Highway Features*. These criteria require that a breakaway support fail in a predictable manner when struck head-on by an 820 kg (1800 lb) vehicle, or its equivalent, at speeds of 35 km/h and 100 km/h (20 mph and 60 mph). It is desirable to limit the longitudinal component of the occupant impact velocity to 3.0 m/s (10 ft/s), but values as high as 5.0 m/s (15 ft/s) are considered acceptable. These specifications also establish a maximum stub height of 100 mm (4 in) to lessen the possibility of snagging the undercarriage of a vehicle after a support has broken away from its base (see Figure 12.2).

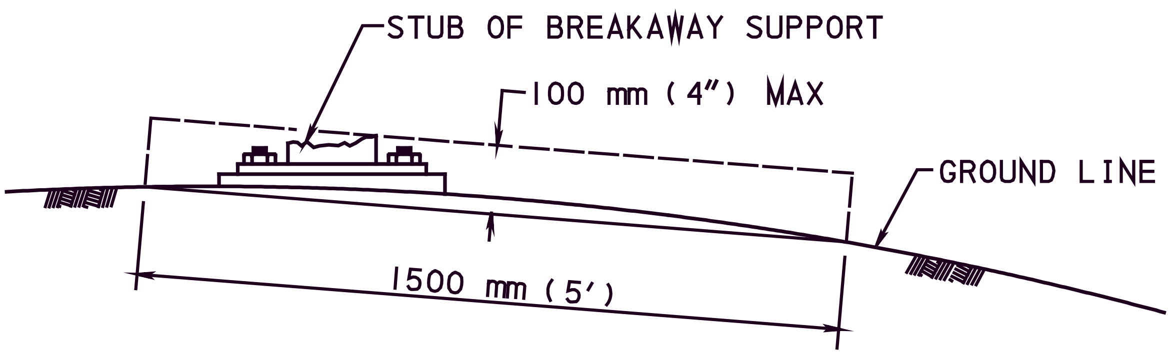


FIGURE 12.2
BREAKAWAY SUPPORT STUB HEIGHT MEASUREMENTS

As a general rule, breakaway supports should be used unless an engineering study indicates otherwise. However, concern for pedestrian involvement has led to the use of fixed supports in some urban areas. Examples of sites where breakaway supports may be imprudent are adjacent to bus shelters or in areas of extensive pedestrian concentrations.

## 12.3 ROADSIDE BARRIERS

A roadside barrier is a longitudinal barrier used to shield motorists from natural or man-made obstructions located along either side of a traveled way for unidirectional traffic. It may occasionally be used to protect bystanders, pedestrians and cyclists from vehicular traffic under special conditions.

The primary purpose of all roadside barriers is to prevent a vehicle from leaving the traveled way and striking a fixed object or terrain feature that is less forgiving than the barrier itself.

**A. Standard Roadside Barriers.** Roadside barriers are usually categorized as flexible, semi-rigid or rigid, depending on their deflection characteristics on impact. Flexible systems are generally more forgiving than the other categories since much of the impact energy is dissipated by the deflection of the barrier and lower impact forces are imposed upon the vehicle.

Barrier systems that have been accepted for use in Pennsylvania are:

**1.** FLEXIBLE SYSTEMS: W-Beam (Weak Post) Guide Rail
**2.** SEMI-RIGID SYSTEMS: W-Beam (Strong-Steel Post) Guide Rail with Wood or Plastic Block
**3.** RIGID SYSTEMS: Concrete F-Shape Barrier

**B. Barrier Guidelines.** The barrier guidelines in this document are to be considered an indicator that **consideration** should be given to utilizing the barrier. Satisfaction of these guidelines is not a guarantee that a barrier is needed. As such, these guidelines should be considered in the determination of the need for a barrier rather than absolute criteria. Since these guidelines are based on average or normal conditions, they are not conclusive justification for the installation of a barrier at any particular location, and they are not a substitute for engineering judgment. The unique circumstances of each location and the amount of funds available will dictate if and when a barrier should be installed. These barrier guidelines are based on the premise that a traffic barrier should be installed only if it reduces the severity of potential crashes.

Typically, barrier guidelines have been based on an analysis of certain roadside elements or conditions. There are instances where it is not immediately obvious whether the barrier or the unshielded condition presents the greater undesirable situation. In such instances, barrier guidelines may be established by using a benefit/cost analysis whereby factors such as design speed and traffic volumes can be evaluated in relation to barrier need. Costs associated with the barrier (installation costs, maintenance costs and crash costs) are compared to similar costs associated with the unshielded condition. This procedure is typically used to evaluate three options: (1) remove or reduce the condition so that it no longer requires shielding, (2) install an appropriate barrier or (3) leave the condition unshielded. The one-time cost to flatten foreslopes and eliminate guide rail may be cost effective when compared against the life-cycle cost of installation and maintenance of guide rail.

Consideration should be given to eliminating short lengths of guide rail since these sections are often more undesirable than no section at all. Where guide rail cannot be eliminated, it shall be a minimum of 15 m (50 ft) plus proper end treatment.

If guide rail is not required due to the height of the slope, consideration should be given to keep the slope clear of fixed objects.

Avoid short gaps between guide rail installations. If the points of need are determined to be about 60 m (200 ft) apart or less, the guide rail protection should be made continuous between them.

Extending guide rail to be buried with an anchored backslope terminal (see Section 12.9.D.1) is cost effective and provides superior performance over the cost and maintenance of an impact attenuating device.

Guide rail should be considered in sensitive areas such as school playgrounds or reservoirs even when they are outside the clear zone.

**C. Design and Selection Procedures.** GUIDE RAIL SHOULD ONLY BE USED WHERE THE RESULT OF STRIKING THE OBJECT OR LEAVING THE ROADWAY WOULD BE MORE SEVERE THAN THE CONSEQUENCE OF STRIKING THE GUIDE RAIL. Where guide rail is required, the roadway should be examined to determine the feasibility of adjusting site features so that the guide rail can be eliminated (e.g., flattening an embankment slope, removing a fixed object or eliminating a drainage head wall). The initial cost to eliminate the guide rail may appear excessive; however, a guide rail installation including impact attenuating devices requires maintenance for many years and this fact should not be overlooked.

Consult Publication 72M, *Roadway Construction Standards*, for the details of all barrier systems (RC-50M Series). Table 12.3 shows the "minimum unobstructed distance" that shall be provided behind the various types of guide rail and median barrier systems. The values of the "minimum unobstructed distance" (measured from the rear face of the guide rail post to the front face of the obstruction), as specified in the Table, are based on the anticipated barrier deflection under maximum impact on a 25° hit at 100 km/h (60 mph) by a 2000 kg (4500 lb) vehicle.

Table 12.4 gives the maximum post spacing for weak post guide rail on curves such as ramps. Do not use weak post guide rail around radii at intersections where it can be hit at severe impact angles.

To determine the need for guide rail, refer to Section 12.4, Barrier Placement, and the preceding sections of this Chapter. Additional selection guidelines and criteria for standard and nonstandard conditions are presented below in Sections 12.3.D and 12.3.E.

## TABLE 12.3 (METRIC)
## GUIDE RAIL AND MEDIAN BARRIER SYSTEMS

| TYPE DESIGNATION | DESCRIPTION | MOUNTING HEIGHT | MINIMUM UNOBSTRUCTED DISTANCE | POST SPACING |
|---|---|---|---|---|
| 2 - W | WEAK POST W-BEAM GUIDE RAIL (NORMAL POST SPACING) | 815 mm TO TOP OF BEAM | 2.1 m | 3810 mm |
| 2 - WC | WEAK POST W-BEAM GUIDE RAIL (CLOSE POST SPACING) | 815 mm TO TOP OF BEAM | 1.5 m | 1905 mm |
| 2 - WCC | WEAK POST W-BEAM GUIDE RAIL (VERY CLOSE POST SPACING) | 815 mm TO TOP OF BEAM | 1.2 m | 952.5 mm |
| 2 - S | STRONG POST W-BEAM GUIDE RAIL (NORMAL POST SPACING) | 706 mm TO TOP OF BEAM | 0.9 m | 1905 mm |
| 2 - SC | STRONG POST W-BEAM GUIDE RAIL (CLOSE POST SPACING) | 706 mm TO TOP OF BEAM | 0.6 m | 952.5 mm |
| 2 - SCC | STRONG POST W-BEAM GUIDE RAIL (VERY CLOSE POST SPACING) | 706 mm TO TOP OF BEAM | 0.3 m | 476.25 mm |
| — | CONCRETE MEDIAN BARRIER SINGLE & DOUBLE FACE | 810 mm TO TOP OF BARRIER | 0.0 m | — |
| — | CONCRETE GLARE SCREEN | 1270 mm TO TOP OF BARRIER (TYP) | 0.0 m | — |

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## TABLE 12.3 (ENGLISH)
## GUIDE RAIL AND MEDIAN BARRIER SYSTEMS

| TYPE DESIGNATION | DESCRIPTION | MOUNTING HEIGHT | MINIMUM UNOBSTRUCTED DISTANCE | POST SPACING |
|---|---|---|---|---|
| 2 - W | WEAK POST W-BEAM GUIDE RAIL (NORMAL POST SPACING) | 32" TO TOP OF BEAM | 7' - 0" | 12' - 6" |
| 2 - WC | WEAK POST W-BEAM GUIDE RAIL (CLOSE POST SPACING) | 32" TO TOP OF BEAM | 5' - 0" | 6' - 3" |
| 2 - WCC | WEAK POST W-BEAM GUIDE RAIL (VERY CLOSE POST SPACING) | 32" TO TOP OF BEAM | 4' - 0" | 3' - 1 1/2" |
| 2 - S | STRONG POST W-BEAM GUIDE RAIL (NORMAL POST SPACING) | 27 3/4" TO TOP OF BEAM | 3' - 0" | 6' - 3" |
| 2 - SC | STRONG POST W-BEAM GUIDE RAIL (CLOSE POST SPACING) | 27 3/4" TO TOP OF BEAM | 2' - 0" | 3' - 1 1/2" |
| 2 - SCC | STRONG POST W-BEAM GUIDE RAIL (VERY CLOSE POST SPACING) | 27 3/4" TO TOP OF BEAM | 1' - 0" | 1' - 6 3/4" |
| — | CONCRETE MEDIAN BARRIER SINGLE & DOUBLE FACE | 32" TO TOP OF BARRIER | 0' - 0" | — |
| — | CONCRETE GLARE SCREEN | 50" TO TOP OF BARRIER (TYP) | 0' - 0" | — |

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**TABLE 12.4**
**WEAK POST W-BEAM GUIDE RAIL SYSTEMS ON CURVES**

| TYPE DESIGNATION | CURVE DESCRIPTION | POST SPACING |
|---|---|---|
| 2-W | R > 70 m<br>(R > 220' - 0") | 3810 mm<br>(12' - 6") |
| 2-WC | R = 35 m TO 70 m<br>(R = 110' - 0" TO 220' - 0") | 1905 mm<br>(6' - 3") |
| 2-WCC | R < 35 m<br>(R < 110' - 0") | 952.5 mm<br>(3' - 1 1/2") |

**D. Standard Conditions.**

**1.** Generally, the guide rail system which provides the largest dynamic deflection should be used.

**2.** Weak post guide rail (2-W or 2-WC) should be used where guide rail is required, if the minimum unobstructed distance behind the guide rail is available. Weak post systems shall not be used where the fill slope is steeper than 1V:1.5H.

**3.** Strong post guide rail (2-S and 2-SC) should be used when the minimum unobstructed distance behind the guide rail is not adequate to permit the use of a weak post system.

**4.** Types 2-S and 2-SC guide rail should be used at approaches to structures (see Standard Drawings). Where this requires a transition from a weak post system, the transition shown on the Standard Drawings shall be used.

**5.** Mixing of strong post and weak post systems in the same run of guide rail shall be used only when the proper transition treatment between systems can be provided, as shown on the Standard Drawings. Frequent transitions between strong post and weak post systems should be avoided.

**E. Nonstandard Conditions.** The following criteria may be used where special conditions exist:

**1.** Type 2-WCC guide rail should be used for the following conditions:

**a.** Weak post to strong post transitions (see Publication 72M, *Roadway Construction Standards*),

**b.** Where isolated obstructions are located more than 1.2 m (4 ft) but less than 1.5 m (5 ft) behind the back of the guide rail in areas where a continuous run of weak post guide rail is used and

**c.** Weak post guide rail systems on curves as presented in Table 12.4.

**2.** Side road intersections close to the ends of structures should be avoided. However, if this condition exists and cannot be avoided, the recommended guide rail treatment should be installed as shown in Publication 72M, *Roadway Construction Standards*, Drawing RC-54M.

**3.** The use of guide rail/curb combinations should be avoided where high speed, high-angle impacts are likely. Where it is necessary to use guide rail behind concrete curbed areas, the guide rail shall be positioned so that the front face of the rail element is in front or flush with the front face of the curb. The height of the curb should be 100 mm (4 in) maximum and the guide rail should be Type 2-SC or 2-S. In areas where curb 100 mm (4 in) or lower is not possible, use Type 2-SC guide rail or nested panels.

**4.** When the minimum unobstructed distance is not available, consideration should be given to using single-face barrier as indicated in Section 12.7.

**5.** When a strong post guide rail system is installed and the 0.6 m (2 ft) minimum clearance from the rear face of the guide rail post to the fill slope break point cannot be maintained, use strong posts that are a minimum of 0.3 m (1 ft) longer. The locations and the number of extra-length posts should be shown in the project proposal.

**6.** A weak post guide rail system, without extra-length posts, may be installed out to the fill slope if the fill slope is not steeper than 1V:2H. A weak post guide rail system may be installed out to the fill slope if the slope is steeper than 1V:2H but is not steeper than 1V:1.5H, provided weak posts that are a minimum of 0.3 m (1 ft) longer are used. The locations and the number of extra-length posts should be shown in the PS&E package. Weak post systems shall not be used where the fill slope is steeper than 1V:1.5H.

Chapter 2 of the AASHTO Roadside Design Guide presents an analysis procedure called the Roadside Safety Analysis Program (RSAP), a cost-effectiveness selection procedure that can be used to compare several alternative safety treatments and to provide guidance to the designer for selecting an appropriate design.

**F. Embankment Protection.** Embankment height and side slope are the basic factors to consider in determining barrier requirements as shown in Table 12.5. These criteria are based on studies of the relative severity of encroachments on embankments versus impacts with roadside barriers. Embankments with slopes of 1V:3H or flatter do not require shielding unless they contain obstructions within the clear zone. Table 12.5 takes into account the decreased probability of encroachments on lower volume roads and the relative cost of installing a traffic barrier versus leaving the slope unshielded. This is based on site-specific conditions in Pennsylvania and associated crash costs with a safety factor applied to account for increased traffic volumes approaching the design year.

Rounding at the shoulder and at the toe of an embankment can reduce the severity of run-off-the-road crashes. A rounded slope should reduce the chances of an errant vehicle becoming airborne, and should afford the driver more control over the vehicle. In view of the safety benefits, rounding should be considered in the design process. Refer to the Typical Roadway Cross Sections in Chapter 1 for shoulder rounding details and to the AASHTO Roadside Design Guide for rounding at the toe of an embankment slope.

**G. Protection from Roadside Obstructions.** Although a traversable and unobstructed roadside is highly desirable from a safety standpoint, some appurtenances simply must be placed near the pavement. Man-made fixed objects which frequently occupy highway right-of-way include highway signs, roadway lighting, traffic signals, railroad warning devices, motorist-aid call boxes, mailboxes and utility poles.

The AASHTO Roadside Design Guide, Chapter 11 contains information on mailbox supports and their location on the roadside. These guidelines are compatible with the requirements of the US Postal Service and are presented in the interest of providing the highest degree of safety practicable for the motoring public, mail carriers and postal patrons. Mailboxes are predominant in rural and suburban roads and streets and need to be considered as part of roadside safety management. These guidelines may be useful when necessary to explain installation and control procedures to the general public.

The designer should provide the safest facility practical, within given constraints. Generally, there are six options from which to choose a safe design. In order of preference, these are:

**1.** Remove the obstruction.

**2.** Redesign the obstruction so it can be traversed safely.

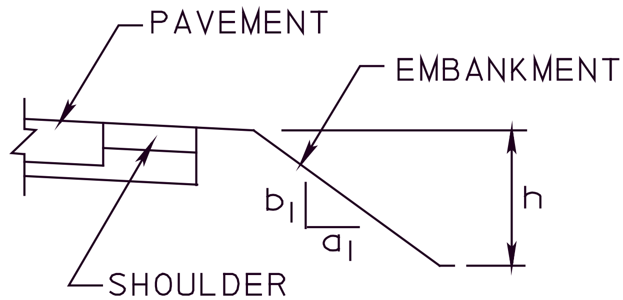
**3.** Relocate the obstruction to a point where it is less likely to be struck.

**4.** Reduce impact severity by using an appropriate breakaway device or impact attenuator.

**5.** Shield the obstruction with a longitudinal traffic barrier if it cannot be eliminated, relocated or redesigned.

**6.** Delineate the obstruction if the above alternatives are not appropriate.

# TABLE 12.5
# BARRIER REQUIREMENTS FOR EMBANKMENT HEIGHTS




**METRIC:**

| EMBANKMENT SLOPE ($S = b_1 : a_1$) | EMBANKMENT HEIGHT (h) | | | |
|---|---|---|---|---|
| | AVERAGE DAILY TRAFFIC (ADT) | | | |
| | > 5000 | 751 - 5000 | 401 - 750 | ≤ 400 |
| 1V:1.5H | 1.2 m | 1.8 m | 2.7 m | 5.2 m |
| 1V:2H | 2.4 m | 3.0 m | 4.9 m | 9.4 m |
| 1V:2.5H | 3.7 m | 4.9 m | 7.6 m | 14.9 m |
| 1V:3H OR FLATTER | GUIDE RAIL NOT REQUIRED | | | |

**ENGLISH:**

| EMBANKMENT SLOPE ($S = b_1 : a_1$) | EMBANKMENT HEIGHT (h) | | | |
|---|---|---|---|---|
| | AVERAGE DAILY TRAFFIC (ADT) | | | |
| | > 5000 | 751 - 5000 | 401 - 750 | ≤ 400 |
| 1V:1.5H | 4.0 ft | 6.0 ft | 9.0 ft | 17.0 ft |
| 1V:2H | 8.0 ft | 10.0 ft | 16.0 ft | 31.0 ft |
| 1V:2.5H | 12.0 ft | 16.0 ft | 25.0 ft | 49.0 ft |
| 1V:3H OR FLATTER | GUIDE RAIL NOT REQUIRED | | | |

While options 1 and 2 are the preferred choices, these solutions are not always practical, especially for highway signing and lighting which must remain near the roadway to serve their intended functions.

Every effort should be made to lessen the number of roadside obstructions along the highway. Special effort should be given to keeping gore areas and other high-exposure areas free from obstructions that would require guide rail.

Usually, posts of breakaway design should be used for sign supports regardless of their distance from the pavement except when the post is located behind guide rail installed for other reasons or located a sufficient distance up a backslope where it is unlikely to be hit by an errant vehicle. Table 12.6 provides the requirements for barrier placement for fixed objects within the clear zone.

If the required clear zone adjacent to the pavement cannot be cleared of roadside obstructions due to practical or economic reasons, adequate guide rail should be provided, as determined from Table 12.6 except as justified elsewhere in this Chapter. The amount that the guide rail deflects upon impact is the critical factor to consider when installing guide rail in front of obstructions. The minimum unobstructed distance should be sufficient to avoid vehicle contact with the fixed object during impact and should not be less than the values presented in Table 12.3.

## TABLE 12.6
## GUIDE RAIL REQUIREMENTS FOR FIXED OBJECTS WITHIN THE CLEAR ZONE

| FIXED OBJECTS WITHIN THE CLEAR ZONE | BARRIER REQUIRED | |
|---|---|---|
| | **YES** | **NO** |
| 1. SIGN SUPPORT (GROUND MOUNTED): | | |
| (A) POST OF BREAKAWAY DESIGN | | **X** |
| (B) SIGN BRIDGE SUPPORTS | **X** | |
| (C) CONCRETE BASE EXTENDING 100 mm (4 in) OR MORE ABOVE GROUND | **X** | |
| 2. LIGHTING POLES AND SUPPORTS OF BREAKAWAY DESIGN | | **X** |
| 3. BRIDGE PIERS AND ABUTMENTS AT UNDERPASSES | **X** | |
| 4. CULVERT HEADWALLS 100 mm (4 in) OR MORE ABOVE GROUND | **X** | |
| 5. TREES * | | **X** |
| 6. UTILITY POLES * | | **X** |
| 7. LIGHTING POLES WITH HIGH MAST LIGHTING | **X** | |
| 8. RETAINING WALLS ** | | **X** |

* The designer shall exercise sound engineering judgment and consider protection in some special cases where such obstructions are likely to be hit due to geometric roadway conditions (outside of a curve, steep grade at beginning of a curve, etc.). Protection should also be considered in sensitive areas, such as school playgrounds or reservoirs.

** A judgment decision based on relative smoothness of wall and anticipated maximum angle of impact (refer to AASHTO Roadside Design Guide, Table 5-2).

At the trailing end of guide rail, a distance of 15.0 m (50 ft) beyond the end treatment is to be kept clear of all roadside obstructions. This "downstream clear zone" is intended to minimize the likelihood that a vehicle may be directed into an obstruction by the barrier.

**H. Non-Traversable Roadside Obstructions.** Non-traversable roadside obstructions require special consideration to provide safety and to afford protection if encountered by motorists and pedestrians within the clear zone or adjacent to the highway right-of-way. These obstructions include: (1) permanent bodies of water; (2) mined areas including coal strip mining, stone quarries and other open pit mining operations and (3) storage locations of hazardous substances.

Because of the size of some of these features along the roadway, the probability of an errant vehicle encountering such a condition is greater than that of a vehicle encountering a fixed object. Therefore, any non-traversable obstruction that requires shielding should be removed, if practical. Otherwise, a longitudinal barrier system, such as guide rail, should be considered. A barrier system shall be provided for permanent bodies of water, with depths greater than 0.6 m (2 ft), that are located within the clear zone or adjacent to the right-of-way. For mined areas, earthen barrier and safety barricades for protection of both motorists and pedestrians should be provided.

**I. Utility Poles and Trees.** For new construction or reconstruction projects, every effort should be made to install or relocate utility poles as far from the traveled way as practical.

For existing utility pole installations, a concentration of crashes at a site or a certain type of crash that seems to occur frequently in a given jurisdiction may indicate that the highway/utility system is contributing to the crash potential. Utility pole crashes are subject to the same patterns as other types of roadway crashes; thus, they are subject to traditional highway crash study procedures.

Generally, guide rail should not be used to shield a line of utility poles or trees. However, where guide rail is used in front of utility poles and trees due to other roadside obstacles, the minimum unobstructed distance behind the guide rail post shall be as presented in Table 12.3.

The removal of individual trees should be considered when they are determined both to be an obstruction and to be in a location where they are likely to be hit. Such trees can often be identified by past crash history at similar sites, by scars indicating previous crashes or by field reviews. Because tree removal can be expensive and often has adverse environmental impacts, this countermeasure should be used only when it is an effective solution.

Roadways through wooded areas with heavy nighttime traffic volumes, frequent fog and narrow lanes should be well delineated. Pavement markings and post mounted delineators are among the most effective and least costly improvements that can be made to a roadway.

**J. Guide Rail End Treatments.** The terminal end of the guide rail should be designed and located so that there are no exposed rail element ends on which a vehicle could be impaled. The preferred treatment is to bury the end of the guide rail into a backslope, retaining its full height even if the guide rail must be extended a short distance to accomplish this. Evaluate opportunities for nearby locations to bury the end of the guide rail into a backslope.

Provide appropriate end treatments, on both the approach and trailing ends of the guide rail on two-lane highways with two-way traffic. On four-lane divided highways, end treatments are required on the approach ends only for strong post guide rail. End treatments are required on both ends of weak post guide rail for anchoring purposes.

A crashworthy end treatment is considered essential if the barrier terminates within the clear zone and/or is in an area where it is likely to be hit by an errant vehicle.

The designer must exercise sound engineering judgment and ensure that the most appropriate available guide rail terminals are specified and provisions incorporated so they can be properly installed based on the type of facility. Higher type treatments should be considered in sensitive locations, in areas with tight geometrics, areas with an unusually high crash history, etc.

Type 2 Strong Post End Treatments and Type 2 Weak Post End Treatments cannot be used to terminate the approach end of: (a) any guide rail on the National Highway System (NHS) or (b) any guide rail on non-NHS high-speed, high-volume routes. Use crashworthy end treatments on all NHS routes and on non-NHS roadways with a posted speed limit of 70 km/h (45 mph) and above and with current traffic volumes of 4000 vehicles per day and above. On two-lane roadways where crashworthy end treatments are required, use on both the approach and trailing ends. For high-speed, NHS divided roadways, Type 2 Strong Post End Treatments or Type 2-S Post Anchorages may be used on the trailing end of guide rail. For Weak Post Guide Rail, if crashworthy end treatments are required, the Weak Post Guide Rail must be transitioned with a 15.2 m (50 ft) Type 2-S Guide Rail section to anchor the Type 2-W Guide Rail prior to the attachment of a crashworthy end treatment.

As an alternative to Type 2 Strong Post End Treatments and Type 2 Weak Post End Treatments, the non-proprietary Modified Eccentric Loader Terminal (MELT), as described in FHWA Acceptance Letter CC-84, may be used on the NHS as a Test Level 2 (TL-2) W-beam guide rail anchor when anticipated impact speeds are not expected to exceed 70 km/h (44 mph).

The approach terrain to any end treatment should be graded to a 1V:10H slope or flatter. For gating terminals, the flat slope should extend behind the terminal as shown on the Standard Drawings and this Chapter.

Use Publication 72M, *Roadway Construction Standards*, RC-50M Series when specifying end treatments for either Type 2 Weak Post or Type 2 Strong Post Guide Rail and Section 12.9.

**K. Bridge Barrier End Transitions.** When updating guide rail systems, barrier systems, end treatments, and crash cushions for Pavement Preservation projects, refer to the pavement guidelines in Publication 242, *Pavement Policy Manual*. Chapter 12, Appendix A includes details of bridge barrier end transitions for the retro-fit of certain bridge barrier ends. These retro-fits provide an opportunity to attach to upgraded guide rail systems. A decision tree is included for selection of the applicable retro-fit details.

**L. Weathering Steel Guide Rail.** The use of weathering steel (sometimes called Cor-Ten, A-588, or Rusting Steel) in guide rail should be limited. Where aesthetic concerns are primary, weathering steel guide rail may be used if the owner agency adopts a frequent periodic inspection and replacement schedule.

Roadside barriers and bridge rails are usually close enough to the traveled way that they can be sprayed with water from passing traffic. In most parts of the country this water contains deicing chemicals during winter months. In seaside locations in warmer climates the salt laden air deposits corrosive chemicals on barriers. In northern climates plows can throw snow onto the rail and the abrasive action of the snow can erode the protective layer. When exposed to these environments, weathering steel never develops the 'patina' that slows corrosion as in other less aggressive environments. Within a few years significant section loss may result. The interior lap splice of W-beams can corrode rapidly to the point where the barrier may become more hazardous than the feature it was meant to shield.

Weathering steel may continue to be used on the backside of steel backed timber rail as the steel thickness is significantly greater than the typical 12 gage W-beam section.

Use of thicker sections (exclusive of the terminal) may also prolong the life, but maintenance should still include inspection of the sections and joints. Powder or zinc coating of galvanized guide rail may be an acceptable aesthetic option.

Barrier terminals are also subject to section loss at rail splices. Questions on aesthetic treatments of barrier terminals should be addressed to the manufacturer.

## 12.4 ROADSIDE BARRIER PLACEMENT

Upon deciding that a roadside barrier is to be considered at a given location, and selecting the type of barrier to be used, the designer should specify the exact layout required. The major factors that must be considered include the following:

- Lateral Offset (from the edge of traveled way)
- Terrain Effects
- Flare Rate
- Length of Need

Most of these factors are interrelated to the extent that the final design may be a compromise selected by the designer. More detailed guidelines on each of these factors are included in the next subsections.

**A. Lateral Offset.** A roadside barrier should be placed as far from the traveled way as possible, while maintaining the proper operation and performance of the system. Such placement reduces the likelihood of errant vehicles impacting the barrier. It also provides better sight distance, particularly at nearby intersections.

The minimum unobstructed distance behind a barrier is a critical factor in its selection as well as in its placement, especially if the obstruction being shielded is a rigid object. In some cases, the available space between the barrier and the object may not be adequate. In such cases, the barrier should be stiffened in advance of and alongside the fixed object. Commonly used methods to reduce deflection in a semi-rigid or flexible barrier system include reduced post spacing, increased post size, use of soil plates, intermediate anchorages, and stiffened rail elements. The effects on deflection of reduced post spacing are shown in Table 12.3 with the individual barrier descriptions. In some cases, a more rigid barrier type may be needed.

A barrier-to-embankment distance of 0.6 m (2 ft), as shown in the AASHTO Roadside Design Guide, Figure 5-33, is desirable for adequate post support but may vary depending on the slope of the embankment, soil type, expected impact conditions, and post cross section and embedment. Increasing the embedment length of guide rail posts by 0.3 m (1 ft) or more can compensate for the reduced soil foundation support near the slope break point.

**B. Terrain Effects.** Regardless of the type of roadside barrier being used or the size and type of vehicle that strikes it, the best results will usually occur if, at the moment of impact, all of the vehicle's wheels are on the ground and its suspension system is neither compressed nor extended. Thus, terrain conditions between the traveled way and the barrier can have significant effects on the barrier's impact performance.

Curbs and roadside slopes are two particular features that deserve special attention. A vehicle which traverses one of these features prior to impact may override the barrier if the vehicle is partially airborne at the moment of impact or may "underride" the rail elements and snag on the support posts if it strikes the barrier too low. Use of guide rail/curb combinations should be discouraged where high-speed, high-angle impacts are likely.

Roadside barriers perform most effectively when they are installed on slopes of 1V:10H or flatter. Caution should be taken when considering installations on slopes as steep as 1V:6H and any such installation should be offset so that an errant vehicle is in its normal attitude at the moment of impact. Depending on actual encroachment conditions, the distance from the traveled way at which a barrier can be installed and expected to perform adequately will vary, but in general, the placement recommendations shown in the AASHTO Roadside Design Guide, Figure 5-38 should be followed.

**C. Flare Rate.** A roadside barrier is considered flared when it is not parallel to the edge of traveled way. The flare is normally used to locate the barrier terminal farther from the roadway in order to minimize a driver's reaction to an obstruction near the road. The flare gradually introduces a parallel barrier installation, transitions a roadside barrier to an obstruction nearer the roadway such as a bridge parapet or railing, or reduces the total length of barrier needed.

One disadvantage to flaring a section of roadside barrier is that the greater the flare rate, the higher the angle at which the barrier can be hit. As the angle of impact increases, the severity of the crash increases, particularly for rigid and semi-rigid barrier systems.

As shown in Table 12.7, the maximum recommended flare rates are a function of design speed and barrier type. Flatter flare rates may be used and often are, particularly where extensive grading would be required to ensure a flat approach to the barrier from the traveled way.

## TABLE 12.7 (METRIC)
## FLARE RATES FOR BARRIER DESIGN

| DESIGN SPEED (km/h) | MAXIMUM FLARE RATES | |
|---|---|---|
| | CONCRETE BARRIER | GUIDE RAIL |
| 110 | 20:1 | 15:1 |
| 100 | 18:1 | 14:1 |
| 90 | 16:1 | 12:1 |
| 80 | 14:1 | 11:1 |
| 70 | 12:1 | 10:1 |
| 60 | 10:1 | 8:1 |
| 50 | 8:1 | 7:1 |

## TABLE 12.7 (ENGLISH)
## FLARE RATES FOR BARRIER DESIGN

| DESIGN SPEED (mph) | MAXIMUM FLARE RATES | |
|---|---|---|
| | CONCRETE BARRIER | GUIDE RAIL |
| 70 | 20:1 | 15:1 |
| 60 | 18:1 | 14:1 |
| 55 | 16:1 | 12:1 |
| 50 | 14:1 | 11:1 |
| 45 | 12:1 | 10:1 |
| 35 | 10:1 | 8:1 |
| 30 | 8:1 | 7:1 |

Note: The required length of barrier and flare rate for each location will be determined by the designer and will be shown on the tabulation sheets and remarks column.

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**D. Length of Need.** Figure 12.3 illustrates the variables that should be considered in designing a roadside barrier to shield a condition effectively. The primary variables are the Runout Length, $L_R$, and the Lateral Extent of The Obstruction, $L_A$.

The Runout Length, $L_R$, as presented in Table 12.8, is the theoretical distance needed for a vehicle that has left the roadway to come to a stop. It is measured from the upstream extent of the obstruction, along the roadway, to the point at which a vehicle is assumed to leave the roadway. These distances have been further modified to reduce the length of barrier on low volume facilities.

The Lateral Extent, $L_A$, is the distance from the edge of through traveled way to the far side of the obstruction if it is a fixed object or to the outside edge of the clear zone, $L_C$, if it is an embankment or a fixed object that extends beyond the clear zone. Selection of an appropriate $L_A$ distance is a critical part of the design process.

Once $L_R$ and $L_A$ have been selected, the length of barrier required at a specific location depends upon the tangent length of barrier upstream from the obstruction ($L_1$), its lateral distance from the edge of through traveled way ($L_2$) and the flare rate (a:b) specified for the installation.

The tangent length of the barrier immediately upstream from the obstruction ($L_1$) is a variable length selected by the designer. If a semi-rigid barrier is connected to a rigid barrier, the tangent length should be at least as long as the transition section to reduce the possibility of pocketing at the transition and to increase the likelihood of smooth redirection if the guide rail is impacted immediately adjacent to the rigid barrier.

The final variable to be selected by the designer to calculate the required length of guide rail at a specific location is the flare rate (see Table 12.7).

Once the appropriate variables have been selected, the required length of need, X, in advance of the obstruction can be calculated with the following equation:

$$X = \frac{L_A + (b/a)(L_1) - L_2}{b/a + (L_A / L_R)}$$

Note that for a parallel installation, i.e., no flare rate, the above equation reduces to:

$$X = \frac{L_A - L_2}{(L_A / L_R)}$$

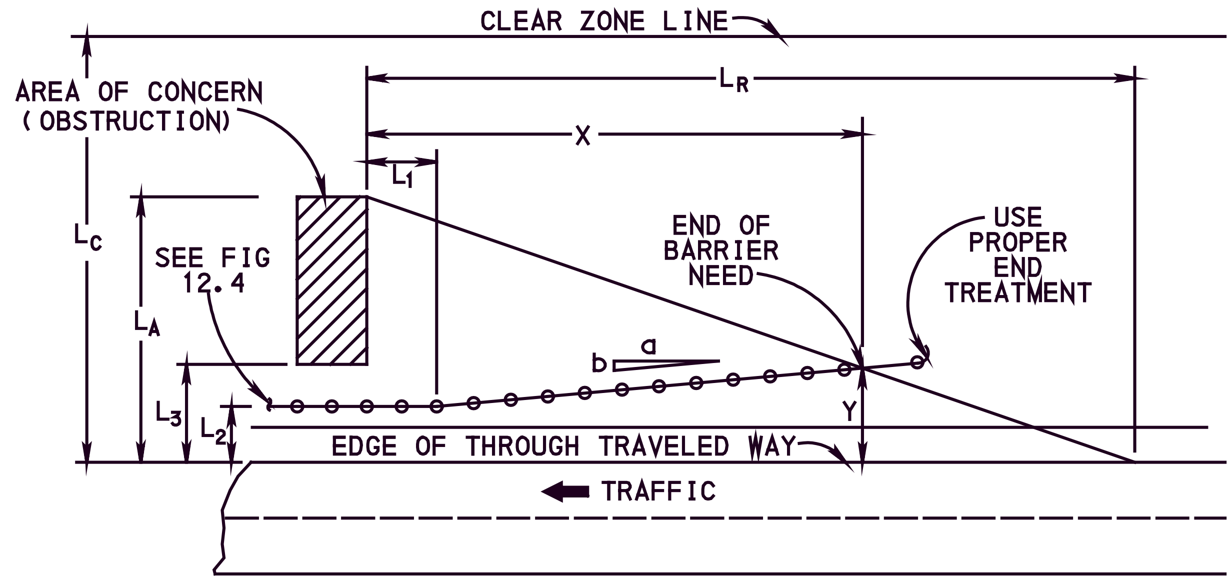
The lateral offset, Y, from the edge of traveled way to the beginning of the length of need can be calculated using the following equation:

$$Y = L_A - \frac{L_A}{L_R}(X)$$

Figure 12.4 illustrates the layout variables of an approach barrier for opposing traffic. The length of need, X, is determined in the same manner as previously described, but all lateral dimensions are measured from the left edge of traveled way of the opposing traffic, i.e., from the centerline for a two-lane roadway. If there is a two-way divided roadway, the edge of traveled way for the opposing traffic would be the edge of the driving lane on the median side. There are three ranges of clear zone width, $L_C$, that deserve special attention for an approach barrier for opposing traffic:

**1.** If the barrier is beyond the appropriate clear zone, no additional barrier and no crashworthy end treatment is required.

**2.** If the barrier is within the appropriate clear zone but the area of concern is beyond it, no additional barrier is required; however, a crashworthy end treatment should be used.




Where:

- X = DISTANCE FROM OBSTRUCTION TO END OF BARRIER NEED.
- Y = DISTANCE FROM EDGE OF THROUGH TRAVELED WAY TO END OF BARRIER NEED.
- $L_A$ = DISTANCE FROM EDGE OF THROUGH TRAVELED WAY TO LATERAL EXTENT OF OBSTRUCTION.
- $L_1$ = TANGENT LENGTH OF BARRIER UPSTREAM FROM OBSTRUCTION.
- $L_2$ = DISTANCE FROM EDGE OF THROUGH TRAVELED WAY TO BARRIER.
- $L_3$ = DISTANCE FROM EDGE OF THROUGH TRAVELED WAY TO OBSTRUCTION.
- $L_C$ = DISTANCE FROM EDGE OF THROUGH TRAVELED WAY TO THE OUTSIDE EDGE OF THE CLEAR ZONE.
- $L_R$ = THE THEORETICAL RUNOUT LENGTH NEEDED FOR A VEHICLE LEAVING THE ROADWAY TO STOP.
- a : b = FLARE RATE.

**FIGURE 12.3**
**APPROACH BARRIER LAYOUT**

## TABLE 12.8 (METRIC)
## DESIGN PARAMETERS FOR
## ROADSIDE BARRIER LAYOUT

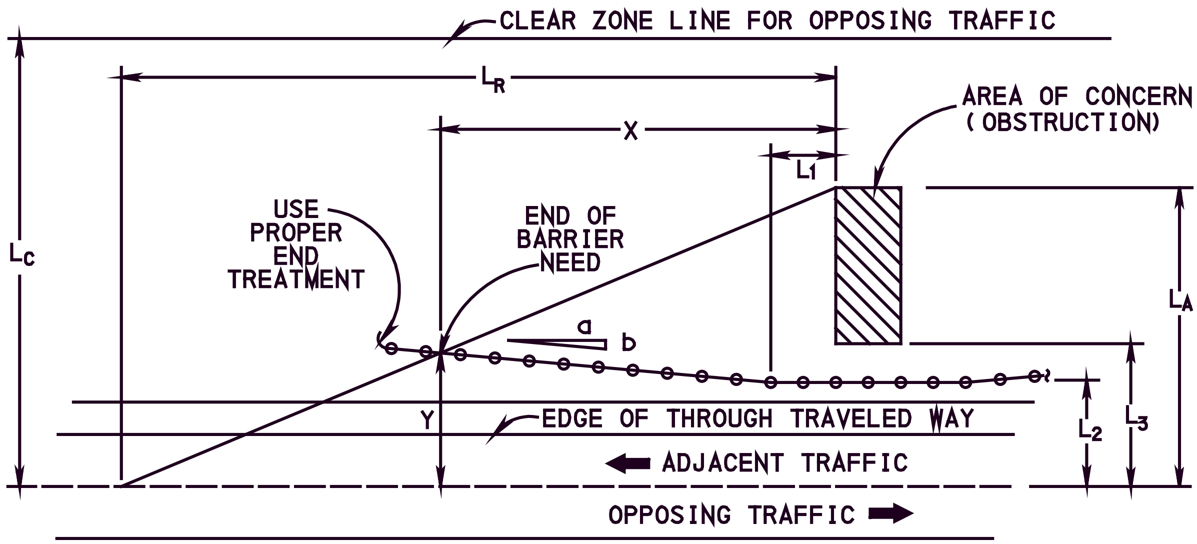
| **DESIGN SPEED (km/h)** | **DESIGN TRAFFIC VOLUME (ADT)** | | | |
|---|---|---|---|---|
| | **800 & UNDER** | **801 - 2000** | **2001 - 6000** | **OVER 6000** |
| | **$L_R$*** | **$L_R$*** | **$L_R$*** | **$L_R$*** |
| 110 | 110 | 120 | 135 | 145 |
| 100 | 100 | 105 | 120 | 130 |
| 90 | 85 | 95 | 105 | 110 |
| 80 | 75 | 80 | 90 | 100 |
| 70 | 60 | 65 | 75 | 80 |
| 60 | 50 | 55 | 60 | 70 |
| 50 | 40 | 45 | 50 | 50 |

*$L_R$ = RUNOUT LENGTH (IN METERS)

## TABLE 12.8 (ENGLISH)
## DESIGN PARAMETERS FOR
## ROADSIDE BARRIER LAYOUT

| **DESIGN SPEED (mph)** | **DESIGN TRAFFIC VOLUME (ADT)** | | | |
|---|---|---|---|---|
| | **800 & UNDER** | **801 - 2000** | **2001 - 6000** | **OVER 6000** |
| | **$L_R$*** | **$L_R$*** | **$L_R$*** | **$L_R$*** |
| 70 | 360 | 395 | 445 | 475 |
| 60 | 330 | 345 | 400 | 425 |
| 55 | 280 | 315 | 345 | 360 |
| 50 | 245 | 260 | 300 | 330 |
| 45 | 200 | 215 | 245 | 260 |
| 40 | 165 | 180 | 200 | 230 |
| 30 | 130 | 150 | 165 | 165 |

*$L_R$ = RUNOUT LENGTH (IN FEET)




Where: X = DISTANCE FROM OBSTRUCTION TO END OF BARRIER NEED.

Y = DISTANCE FROM EDGE OF THROUGH TRAVELED WAY TO END OF BARRIER NEED.

$L_A$ = DISTANCE FROM EDGE OF THROUGH TRAVELED WAY TO LATERAL EXTENT OF OBSTRUCTION.

$L_1$ = TANGENT LENGTH OF BARRIER UPSTREAM FROM OBSTRUCTION.

$L_2$ = DISTANCE FROM EDGE OF THROUGH TRAVELED WAY TO BARRIER.

$L_3$ = DISTANCE FROM EDGE OF THROUGH TRAVELED WAY TO OBSTRUCTION.

$L_C$ = DISTANCE FROM EDGE OF THROUGH TRAVELED WAY TO THE OUTSIDE EDGE OF THE CLEAR ZONE.

$L_R$ = THE THEORETICAL RUNOUT LENGTH NEEDED FOR A VEHICLE LEAVING THE ROADWAY TO STOP.

a : b = FLARE RATE.

**FIGURE 12.4**
**APPROACH BARRIER LAYOUT FOR OPPOSING TRAFFIC**

**3.** If the area of concern extends well beyond the appropriate clear zone (e.g., a river), the designer may choose to shield only that portion which lies within the clear zone, by setting $L_A$ equal to $L_C$ in Figure 12.4.

A traffic barrier should be set as far as possible from the edge of traveled way. The slopes between a barrier installation and the roadway should be 1V:10H or flatter (see Figure 12.5). The barrier may also be located on a 1V:6H slope or flatter 3.6 m (12 ft) from the hinge point such that an errant vehicle is in normal mode at the moment of contact.

Perhaps the most straightforward method to determine length of need is to scale the barrier layout directly on the plan sheets. By selecting an appropriate runout length and the lateral distance to be shielded, the designer can specify a guide rail installation (i.e., lateral offset and flare) that satisfies all placement criteria. This method is most appropriate for determining the length of barrier required to shield embankments or fixed objects on non-tangent sections of roadway. Examples of this technique are provided below in Section 12.4.E (see Figures 12.6 through 12.9).

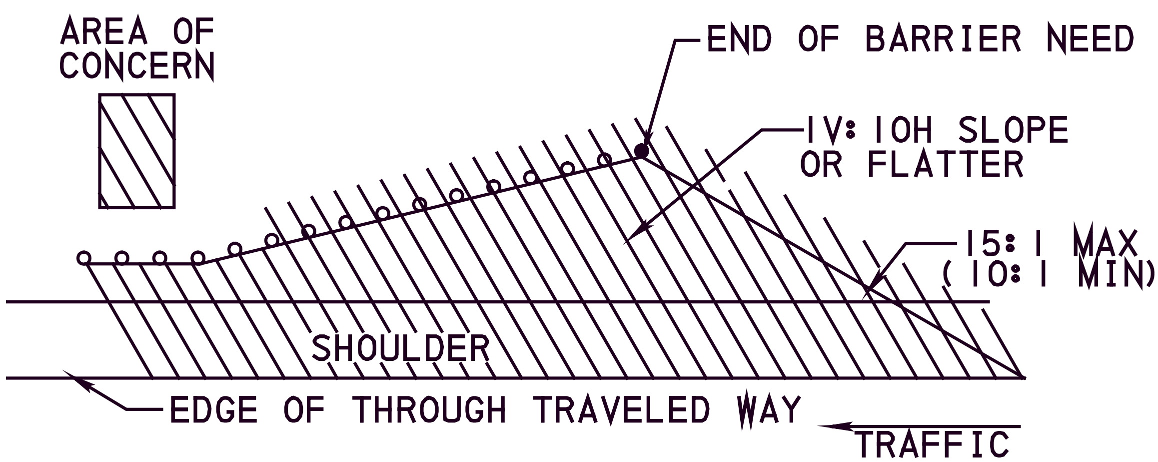



FIGURE 12.5
ROADSIDE SLOPES FOR APPROACH BARRIERS

**E. Example Problems.**

**METRIC EXAMPLE:**

GIVEN: ADT = 6200
Design Speed = 110 km/h
Embankment Slope = 1V:6H (right);
1V:10H (median)

SELECT: Clear Zone, $L_C$ = 9.0 m (for 1V:6H slope from Table 12.1)
Clear Zone = 9.0 m (for 1V:10H median slope from Table 12.1)
Lateral Extent of Area of Concern, $L_A$ = 9.0 m
Runout Length, $L_R$ = 145 m (from Table 12.8)
Transition, $L_1$ = 7.6 m
Barrier Offset, $L_2$ = 3.6 m (right)
= 2.4 m (median)
Flare Rate = 15:1 (from Table 12.7)

DISCUSSION:

For the right shoulder installation, the designer can scale 145 m back from the bridge rail end and 9.0 m laterally from the same point. The hypotenuse of this triangle approximates a vehicle's runout path. To shield the bridge end and the river to the edge of the clear zone, the barrier installation must intersect this line. Based on the variables selected, a barrier length of 45.9 m is required. If this were an existing bridge and the approach embankment slopes were 1V:2H, the barrier would have to be installed parallel to the shoulder to minimize earthwork and approximately 100 m would be needed to shield the same area. Calculations for the flared installation are as follows:

$$\text{Length of Need} = \frac{9.0 + (1/15)(7.6) - 3.6}{(1/15) + (9.0/145)} = 45.9 \text{ m}$$

Note that on the median side, the designer may shield the entire opening even though this distance exceeds the recommended clear zone for the 1V:10H slope. This emphasizes that the clear zone distance is not a precise number and that engineering judgment must be used in its application.

**ENGLISH EXAMPLE:**

GIVEN: ADT = 6200
Design Speed = 70 mph
Embankment Slope = 1V:6H (right);
1V:10H (median)

SELECT: Clear Zone, $L_C$ = 30 ft (for 1V:6H slope from Table 12.1)
Clear Zone = 30 ft (for 1V:10H median slope from Table 12.1)
Lateral Extent of Area of Concern, $L_A$ = 30 ft
Runout Length, $L_R$ = 475 ft (from Table 12.8)
Transition, $L_1$ = 25 ft
Barrier Offset, $L_2$ = 12 ft (right)
= 8 ft (median)
Flare Rate = 15:1 (from Table 12.7)

DISCUSSION:

For the right shoulder installation, the designer can scale 475 ft back from the bridge rail end and 30 ft laterally from the same point. The hypotenuse of this triangle approximates a vehicle's runout path. To shield the bridge end and the river to the edge of the clear zone, the barrier installation must intersect this line. Based on the variables selected, a barrier length of 151.5 ft is required. If this were an existing bridge and the approach embankment slopes were 1V:2H, the barrier would have to be installed parallel to the shoulder to minimize earthwork and approximately 328 ft would be needed to shield the same area. Calculations for the flared installation are as follows:

$$\text{Length of Need} = \frac{30 + (1/15)(25) - 12}{(1/15) + (30/475)} = 151.5 \text{ ft}$$

Note that on the median side, the designer may shield the entire opening even though this distance exceeds the recommended clear zone for the 1V:10H slope. This emphasizes that the clear zone distance is not a precise number and that engineering judgment must be used in its application.

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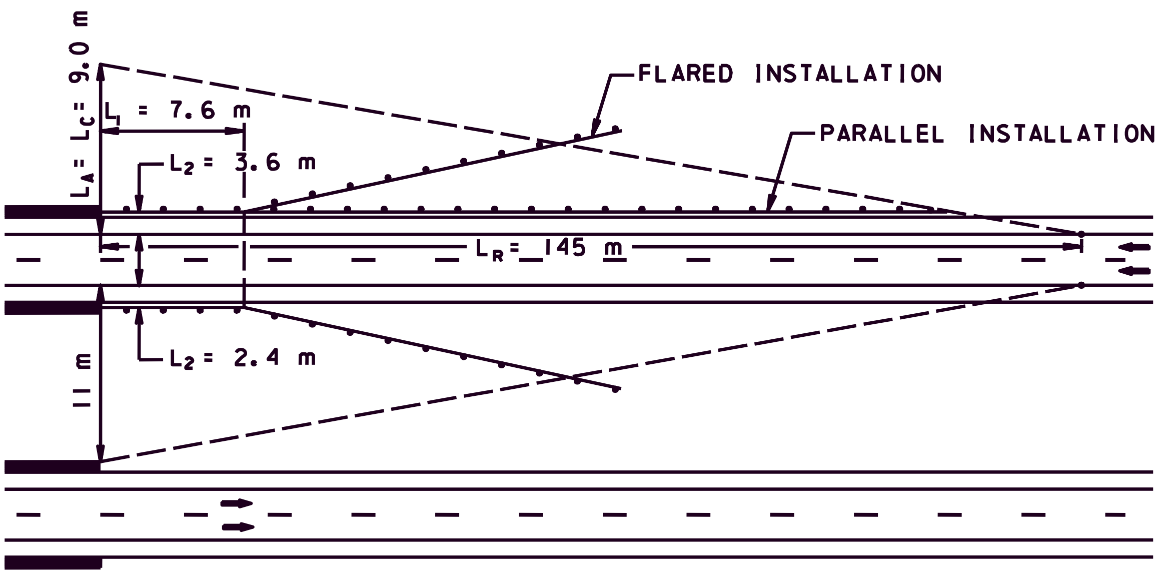


FIGURE 12.6 (METRIC)
EXAMPLE OF BARRIER DESIGN
FOR BRIDGE APPROACH

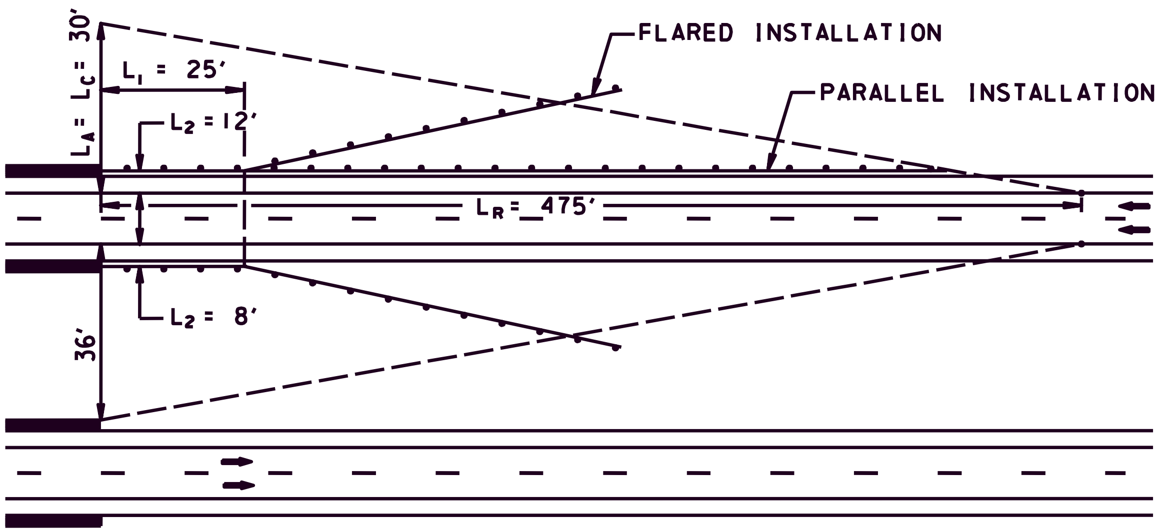


FIGURE 12.6 (ENGLISH)
EXAMPLE OF BARRIER DESIGN
FOR BRIDGE APPROACH

GIVEN: ADT = 850
Design Speed = 80 km/h (50 mph)
Embankment Slope = 1V:10H

SELECT: Clear Zone, $L_C$ = 4.5 m (15 ft) (from Table 12.1)
Runout Length, $L_R$ = 80 m (260 ft) (from Table 12.8)
Lateral Extent of Area of Concern, $L_A$ = 3.6 m (12 ft)
Transition, $L_1$ = 7.6 m (25 ft)
Barrier Offset, $L_2$ = 2.5 m (8.2 ft)
Flare Rate = 11:1 (from Table 12.7)

DISCUSSION:

If the bridge piers are the only fixed object within the clear zone, the barrier needed is a function of $L_A$, $L_1$, $L_R$ and the selected flare rate. However, if the bridge abutment also lies within the clear zone, the designer may elect to shield it as well, in which case an $L_A$ greater than 3.6 m (12 ft) would be used to determine the length of barrier needed in advance of the piers. The calculations for shielding only the piers are as follows:

$$\text{METRIC:} \quad \text{Length of Need} = \frac{3.6 + (1/11)(7.6) - 2.5}{(1/11) + (3.6/80)} = 13.2 \text{ m}$$

$$\text{ENGLISH:} \quad \text{Length of Need} = \frac{12 + (1/11)(25) - 8.2}{(1/11) + (12/260)} = 44.3 \text{ ft}$$

A semi-rigid rail system must be located far enough in front of the piers to permit deflection of the rail without the vehicle snagging on the piers; otherwise, a stiffened transition section must be used as in this example. Even if a fixed object is beyond the design deflection distance of a semi-rigid barrier, a vehicle with a high center of gravity may roll far enough to snag on the shielded object. If this is a major concern, a stiffer and/or higher barrier should be considered.

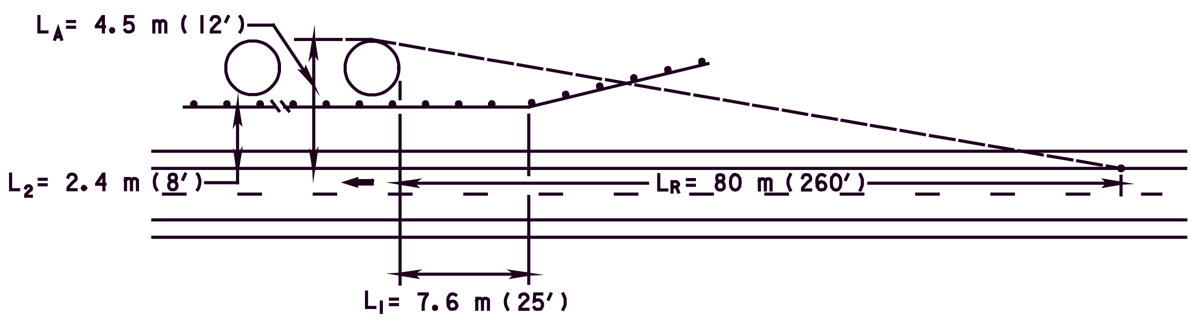


FIGURE 12.7
EXAMPLE OF BARRIER DESIGN FOR BRIDGE PIERS

GIVEN: ADT = 3000
Design Speed = 110 km/h (70 mph)
Embankment Slope at Beginning of $L_R$ = 1V:6H
Slope at $L_C$ is Critical, i.e., steeper than 1V:3H

SELECT: Clear Zone, $L_C$ = 9.0 m (30 ft) (from Table 12.1)
$L_A = L_C$
Runout Length, $L_R$ = 135 m (445 ft) (from Table 12.8)
Barrier Offset, $L_2$ = 2 m (6.6 ft)

DISCUSSION:

The area of concern begins at the top of the critical slope. Since the purpose of a barrier installation is to prevent a vehicle from reaching a non-traversable terrain feature or fixed object, the designer may elect to shield more of the slope by selecting a larger clear zone distance. It is often advantageous to review planned barrier lengths on-site just before installation to ensure adequate shielding.

The barrier may be introduced by anchoring it in a backslope, thus placing an end treatment that is not vulnerable to impact. This treatment effectively blocks off the entire embankment area. However, if no backslope exists or if it would require a significantly longer barrier installation to reach it without exceeding the recommended flare rate, a free-standing end treatment remains appropriate.

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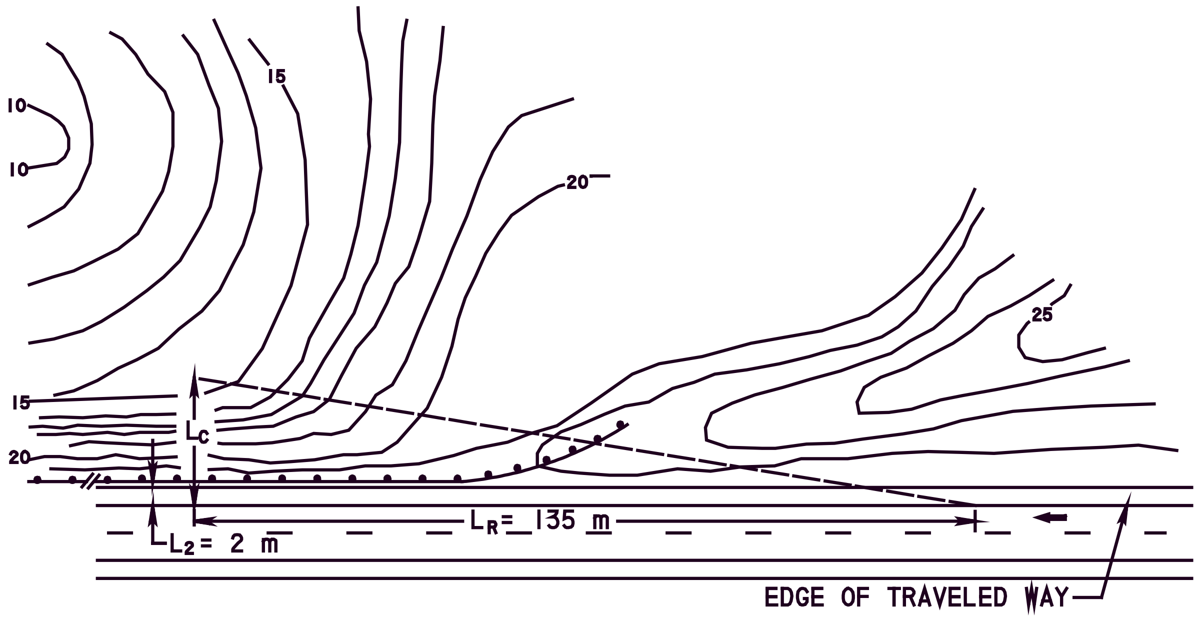



FIGURE 12.8 (METRIC)
EXAMPLE OF BARRIER DESIGN FOR
NONTRAVERSABLE EMBANKMENT

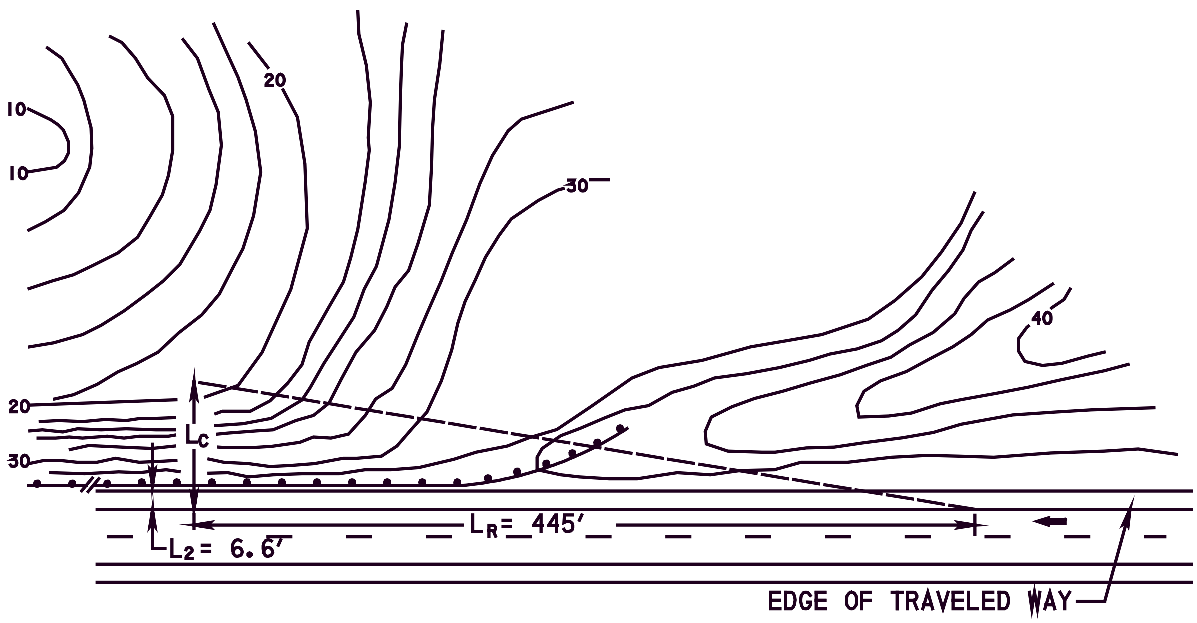



FIGURE 12.8 (ENGLISH)
EXAMPLE OF BARRIER DESIGN FOR
NONTRAVERSABLE EMBANKMENT

GIVEN: ADT = 650
Design Speed = 100 km/h (60 mph)
Embankment Slope = 1V:6H
Horizontal Curvature = 450 m radius (4°)

SELECT: Clear Zone, $L_C$ = 6.0 m (20 ft) (from Table 12.1)
Adjustment Factor for Curvature = 1.4 (1.4) (from Table 12.2)
Adjusted Clear Zone = (6.0)(1.4) = 8.4 m
(Adjusted Clear Zone = (20)(1.4) = 28 ft)
Runout Length, $L_R$ = Not Applicable (see DISCUSSION below)
Barrier Offset, $L_2$ = 1.2 m (4 ft)
Flare Rate = Not Applicable

DISCUSSION:

The length of need formula for a traffic barrier is directly applicable to straight highway alignment only. A vehicle leaving the roadway on the outside of a curve generally follows a tangential runout path if the area outside the roadway is flat and traversable. Thus, rather than using the theoretical $L_R$ distance to determine a barrier length of need, a line from the curve to the outside edge of the area of concern (or to the clear zone if the condition is continuous, such as the streambed shown in Figure 12.9) should be used to determine the appropriate length of barrier needed. The barrier length then becomes a function of the distance from the edge of the driving lane and can most readily be obtained graphically by scaling. A flare rate is not generally used along a horizontal curve.

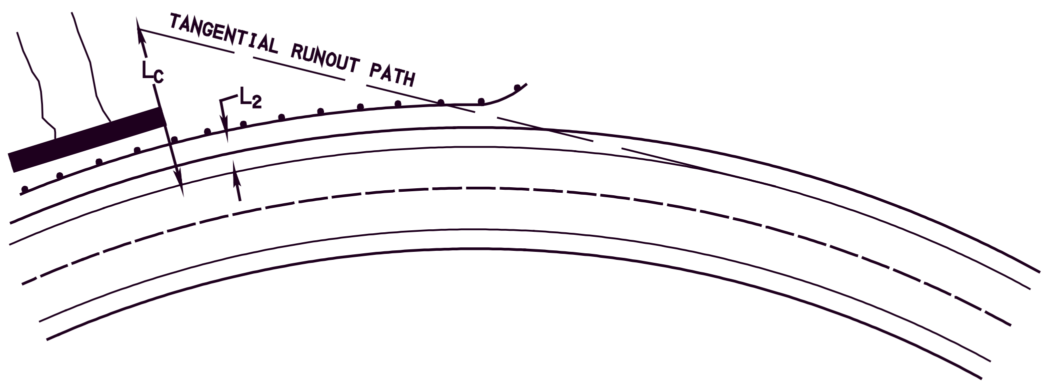



FIGURE 12.9
EXAMPLE OF BARRIER DESIGN FOR
FIXED OBJECT ON HORIZONTAL CURVE

## 12.5 MEDIAN BARRIER

**A. Median Barrier Guidelines.** Median barrier represents a longitudinal system used to prevent an errant vehicle from crossing the median of a divided highway. A median separates the traffic moving in opposite directions. However, median barriers, as discussed in this Chapter, are those designed to redirect vehicles striking either side of the barrier.

It is recognized that the increased use of median barriers has some disadvantages. The initial costs of installing a barrier can be significant. In addition, the installation of a barrier will generally increase the number of reported crashes as it reduces the recovery area available. As a result, there could be increased maintenance costs to repair the barrier as well as increased exposure to the maintenance crews completing the repairs. Another concern associated with the installation of a median barrier is that it will limit the options of maintenance and emergency service vehicles to cross the median. In snowy climates, a median barrier may also affect the ability to store snow in the median. There may be other environmental impacts depending on the grading required to install the barrier. For these reasons, a one-size-fits-all recommendation for the use of median barrier is not appropriate.

The need for median barriers is based on several factors including, but not limited to, median width, traffic volume and crash history. Figure 12.10 presents guidelines for median barriers based on two of these factors, median width and traffic volume. The guidelines presented in Figure 12.10 are for use on high speed, full access controlled roadways which have flat, traversable medians. A high-speed roadway is defined as having a posted speed limit of 70 km/h (45 mph) or greater.

Crash data indicating a high number of head-on and/or sideswipe crashes or substandard horizontal and/or vertical alignment may also be considered in evaluating the need for a median barrier.

These median barrier guidelines are to be considered an indicator that consideration should be given to utilizing the barrier. Satisfaction of these guidelines is not a guarantee that a barrier is needed. As such, these guidelines should be considered in the determination of the need for a barrier rather than absolute criteria.

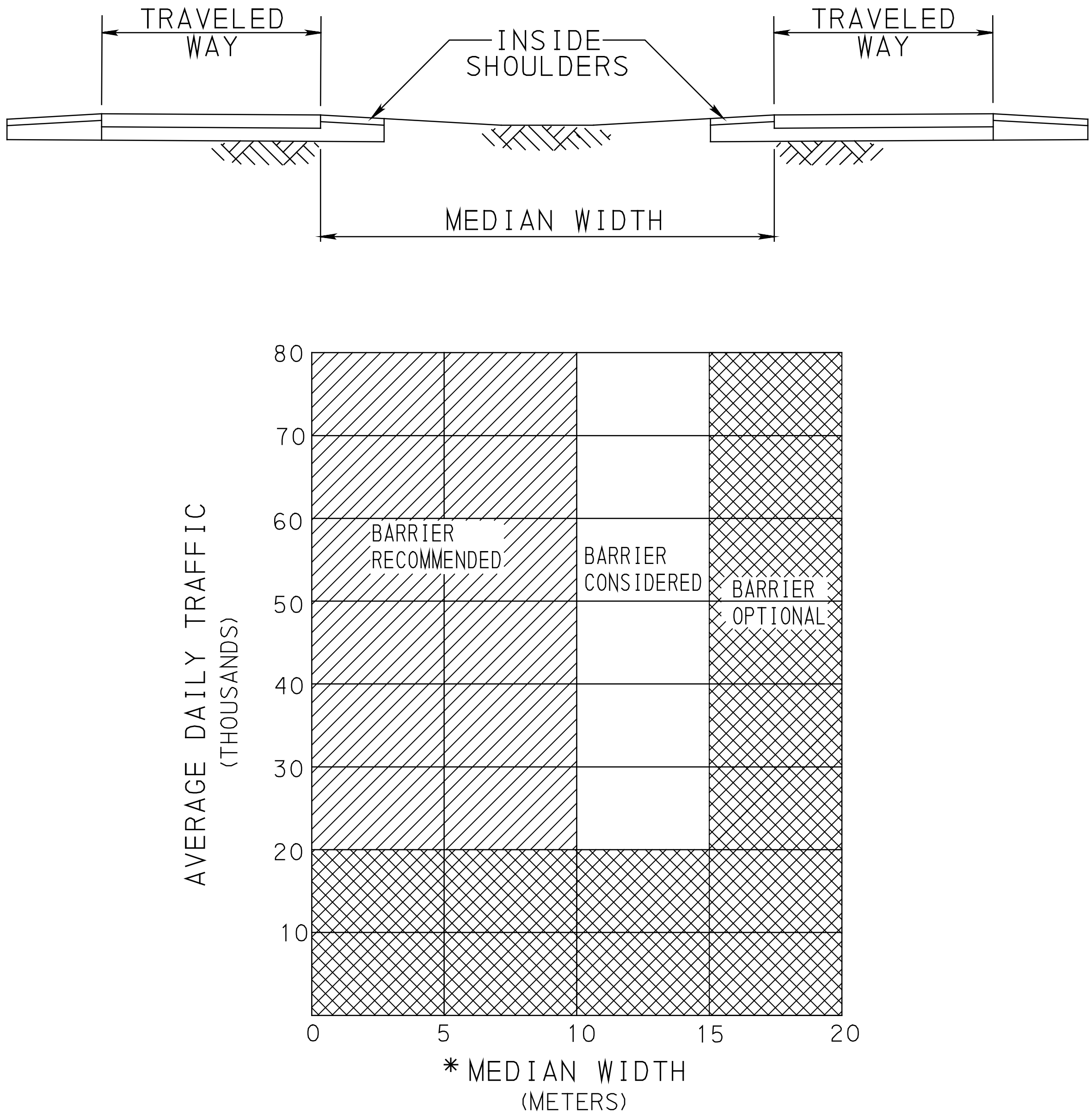
Specific median barrier guidelines for high-speed, divided highways are as follows:

**1.** New Roadways on New Alignment.

**a.** Median Widths Less Than or Equal to 10 m (30 ft). All new high-speed divided highways with a proposed median width of 10 m (30 ft) or less shall be designed and constructed with an approved median barrier system.

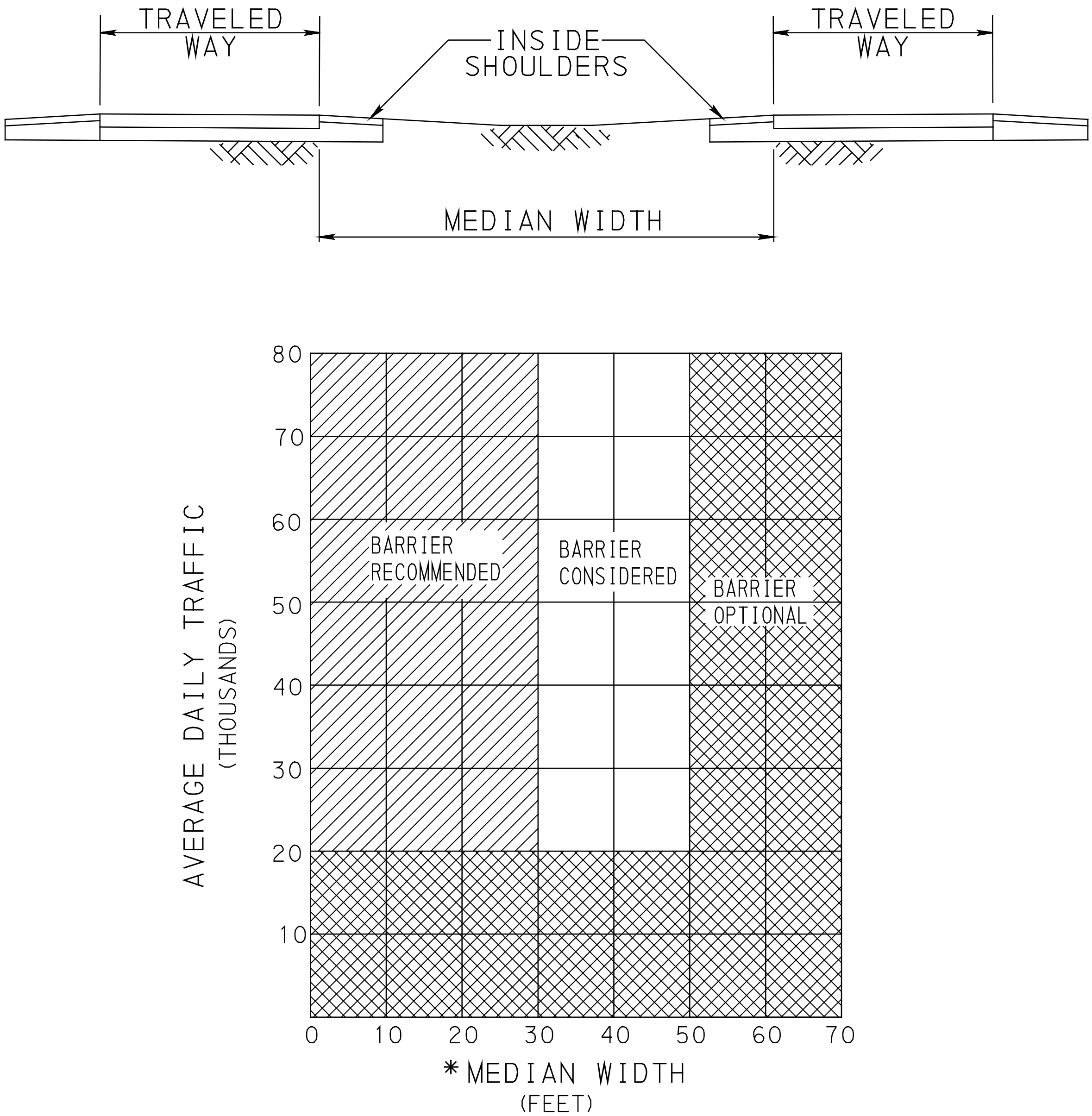
**b.** Median Widths Greater Than 10 m (30 ft) and Less Than 15 m (50 ft). All new high-speed divided highways with a proposed median greater than 10 m (30 ft) and less than 15 m (50 ft) shall be designed to allow for the future installation of a median barrier system by providing a 1.8 m (6 ft) level area in the median. The District Safety Review Committee shall review the proposed roadway horizontal and vertical alignment to determine if the median is traversable. If the design ADT is greater than 20,000 and if the median is traversable, then the designer shall consider placement of barrier, and the District Safety Review Committee would concur with the designer's decision.

**c.** Median Widths Greater Than or Equal to 15 m (50 ft). All new high-speed divided highways with a proposed median of 15 m (50 ft) or greater shall be designed to allow for the future installation of a median barrier system by providing a 1.8 m (6 ft) level area in the median.




* MEASURED FROM EDGE OF TRAVELED WAY TO EDGE OF TRAVELED WAY AND INCLUDES BOTH INSIDE SHOULDERS.

FIGURE 12.10 (METRIC)
MEDIAN BARRIER GUIDELINES ON HIGH-SPEED, FULLY CONTROLLED-ACCESS ROADWAYS




* MEASURED FROM EDGE OF TRAVELED WAY TO EDGE OF TRAVELED WAY AND INCLUDES BOTH INSIDE SHOULDERS.

FIGURE 12.10 (ENGLISH)
MEDIAN BARRIER GUIDELINES ON HIGH-SPEED, FULLY CONTROLLED-ACCESS ROADWAYS

**2.** Existing Roadways on Existing Alignment.

**a.** Median Widths Less Than 15 m (50 ft). All existing high-speed divided highways with an existing median of 15 m (50 ft) or less will be evaluated for the need for median barrier during the design of every highway improvement project. The District Safety Review Committee will review the existing horizontal and vertical alignment and existing median slopes to determine if the existing median is traversable. If the existing median is determined to be traversable, the District Safety Review Committee will review the roadway's existing horizontal and vertical alignment, crash history, traffic volumes, and vehicle classifications. From that review, the District Safety Review Committee will determine if a median barrier system is needed for the entire project or just certain curve or tangent sections of the roadway. The District Safety Review Committee should make its recommendations before Design Field View.

For projects not on the National Highway System (NHS), the District Executive will review the District Safety Review Committee recommendations and approve or disapprove the recommendations. For projects on the NHS with Federal Oversight (FO), the Federal Highway Administration (FHWA) will review the District Safety Review Committee recommendations and approve or disapprove the recommendations. For projects on the NHS with PENNDOT Oversight (PO), the District Executive will review the District Safety Review Committee recommendations and approve or disapprove the recommendations.

**b.** Median Widths Greater Than or Equal to 15 m (50 ft). All existing high-speed divided highways with an existing median of 15 m (50 ft) or greater will be evaluated for the need for median barrier during the design of every highway improvement project. The District Safety Review Committee will review the existing horizontal and vertical alignment and existing median slopes to determine if the existing median is traversable. If the existing median is determined to be traversable, the District Safety Review Committee will review the roadway's existing horizontal and vertical alignment, crash history, traffic volumes, and vehicle classifications. From that review, the District Safety Review Committee will determine if a median barrier system is needed for the entire project or just certain curve or tangent sections of the roadway. The District Safety Review Committee should make its recommendations before Design Field View.

For projects not on the NHS, the District Executive will review the District Safety Review Committee recommendations and approve or disapprove the recommendations. For projects on the NHS with Federal Oversight (FO), the Federal Highway Administration (FHWA) will review the District Safety Review Committee recommendations and approve or disapprove the recommendations. For projects on the NHS with PENNDOT Oversight (PO), the District Executive will review the District Safety Review Committee recommendations and approve or disapprove the recommendations.

For locations with median widths equal to or greater than 15 m (50 ft), a barrier is not normally considered except in special circumstances such as a location with a significant history of cross-median crashes.

Since these median barrier guidelines are based on average or normal conditions, they are not conclusive justification for the installation of a barrier at any particular location, nor are they a substitute for engineering judgment. The unique circumstances of each location and the amount of funds available will dictate if and when a barrier should be installed.

Median barriers are sometimes used on high-volume facilities, which do not have fully controlled access. As indicated in Figure 12.10, these median barrier guidelines were developed for use on high-speed, fully controlled-access roadways. Utilizing these median barrier guidelines on roadways that do not have full access control requires the need for engineering analysis and judgment, taking into consideration such items as, right-of-way constraints, property access needs, number of intersections and driveway openings, adjacent commercial development, sight distance at intersections, barrier end termination, etc.

The following median barriers are currently acceptable for use in Pennsylvania:

1. F-shape concrete median barrier (810 mm (32 in))
2. F-shape concrete tall barrier (1270 mm (50 in))
3. Steel-post W-beam with wood or plastic block
4. Other appropriate systems (e.g., high-tension cable median barrier---see Section 12.5.D)

The F-shape concrete median barrier has an overall height of 810 mm (32 in); this includes provision for a 75 mm (3 in) future pavement overlay, reducing the height to 735 mm (29 in) minimum. When total overlay depths are expected to exceed 75 mm (3 in) or when an 810 mm (32 in) height is considered inadequate, the total height of the concrete must be adjusted. This adjustment must be made above the slope breakpoint. The height extension may follow the slope of the upper face if the barrier is thick enough or adequately reinforced at the top, or the extension may be vertical. A height extension may also be considered for use as a screen to block headlight glare from opposing traffic lanes.

**B. Selection Guidelines.** The first decision to be made, when selecting an appropriate median barrier, concerns the level of performance needed.

In critical locations, where heavy vehicle containment is considered necessary, median barriers having significantly greater capabilities than commonly-used barriers (i.e., higher than 810 mm (32 in)) may be installed. Factors to consider in reaching a decision on special designs include:

1. High percentage or large average daily number of heavy vehicles.
2. Adverse geometrics (horizontal curvature).
3. Severe consequences of vehicular (or cargo) penetration into opposing traffic lanes.
4. Severe headlight glare from opposing traffic.

The following criteria shall be used for installation of median barrier:

**a.** Access Controlled Freeways. When median barrier is specified, the standard (F-shape) concrete median barrier should be used. Double-face strong post or weak post W-beam may be used. However, metal systems are not cost effective in the median.

**b.** Ramps. For opposing ramps where barrier protection is specified, use the same criteria as in the mainline.

**c.** Free Access Facilities. Careful consideration should be given to the installation of median barrier on four or more lane free access facilities. The intent of the median barrier is to prevent crossover type crashes and not to control turning movements. Problems are created at each intersection or median crossover since the median barrier is terminated at these points. An evaluation of the number of crossovers, crash history, alignment, sight distance, design speed, traffic volume and median width should be made prior to installations on these facilities.

**d.** Two or Three-Lane Facilities. For two-lane or three-lane, two-way highway facilities, the installation of median barrier is not required.

Special attention should be given to properly adjust the edge of traveled way grades on the median sides of superelevated sections to assure a barrier system can be utilized.

Generally, the type of median barrier used on the approaching roadway, adjacent to a structure, should also be carried across the structure.

Where median barrier is proposed on a facility which has existing barriers adjacent to the project, the existing type of barrier should be continued if the added length is about 300 m (1000 ft) or less and the median widths are similar.

Where left-hand turning lanes are provided, the barriers shall be terminated with impact attenuating devices or other safety measures in advance of the turning lanes based on the posted speed limit.

Other significant factors to consider in the lateral placement of a median barrier are the effect of the terrain between the edge of traveled way and the barrier, the flare rate at transition sections and the treatment of rigid objects in the median.

When it becomes necessary to flare a median barrier in order to shield a rigid object in a median, the flare rate should be gradual and within acceptable limits. For minimum flare rates, refer to Table 12.7.

**C. Median Barrier End Treatments.** Median barrier termination is ideally accomplished where the median is wide and exposure to the end is limited. Proper end treatments such as end transitions or impact attenuating devices, based on type of facility should be provided to reduce vehicle deceleration upon impact and provide protection against spearing. End treatments may be tapered, flared or both.

**1.** Tapered End Treatments. This type of end treatment is primarily intended to eliminate the spearing or high deceleration characteristics of blunt-ended terminals. However, since a tapered end treatment can cause an impacting vehicle to become airborne and/or overturn, its use should be limited to low-speed situations and/or locations where end-on impacts are unlikely. See Publication 72M, *Roadway Construction Standards*, Drawing RC-57M.

A typical end transition may be used for permanent barrier installations only when the last barrier section is located outside the required clear zone. A 20:1 sloped end transition is acceptable for permanent installations where the legal speed limit is 60 km/h (35 mph) or less; otherwise, use an impact attenuating device. When concrete barrier is terminated at the end of parallel ramps or T intersections, a 2.1 m (7 ft) end transition may be used where the legal speed is 60 km/h (35 mph) or less. For barrier installations, an impact attenuating device is not required if any of the following conditions are satisfied:

**a.** The barrier is extended at the proper flare rate until the end of the barrier system is located outside the required clear zone.

**b.** The barrier is extended at the proper flare rate until the end of the barrier system can be buried in a cut section.

**c.** The barrier is extended at the proper flare rate until the end of the barrier system is properly connected or overlapped with existing guide rail.

Refer to Table 12.7 for flare rate requirements of permanent concrete barrier installations.

**2.** Flared End Treatment. In this case, the barrier can be introduced far enough from the approaching traffic that no additional safety treatment is needed. The flare rate should meet the minimum criteria shown in Table 12.7.

**3.** Flared and Tapered End Treatment. By combining Items 1 and 2 above, a median barrier terminal can be located where it is unlikely to be hit and designed so any impacts that do occur do not result in severe crashes.

The most desirable median is one that is relatively flat and free of rigid objects where the barrier is normally placed at the center of the median. When the cross slope becomes steeper than 1V:10H in depressed or mounded medians, placement of the barrier depends on the rate and height of the slope and other geometric relationships between opposing traffic. Illustrations and suggestions on median barrier placement are found in the AASHTO Roadside Design Guide, Chapter 6.

For additional guidelines refer to Publication 72M, *Roadway Construction Standards*, Drawing RC-50M Series, for end transitions and to Section 12.9 for design guidelines and selection procedures for impact attenuating devices.

**D. High-Tension Cable Median Barrier.** There are several proprietary, high-tension cable barrier systems that have been developed and are increasing in use. These systems are installed with a significantly greater tension in the cables than generic three-cable systems installed previously throughout the Commonwealth. The deflection of these systems depends on the type of system and the post spacing. The high-tension systems also result in less damage to the barrier and in many cases, the cables remain at the proper height after an impact that damages several posts. The posts can be installed in concrete sleeves in the ground to facilitate removal and replacement.

The Department recommends four-cable barrier systems over three-cable barrier systems because the four-cable barrier systems have performed better in recent testing by FHWA. Four-cable barrier systems provide a wider safety net to accommodate most vehicle types and with respect to having at least two cables engage the vehicles. FHWA has noted that at least two cables engaging vehicles are desired for systems to perform well.

The Department recommends four-cable barrier systems to meet Test Level 4 (TL-4) criteria instead of Test Level 3 (TL-3) criteria, primarily to withstanding impacts by larger vehicles. For TL-3 criteria, the largest vehicle mass (2000 kg (4400 lb)) impacts the barrier at a speed of 100 km/h (62 mph) and at an angle of 25°. For TL-4 criteria, the largest vehicle mass (17,650 lb (8000 kg)) impacts the barrier at a speed of 80 km/h (50 mph) and at an angle of 15°. Test criteria are as set forth in NCHRP Report 350 and subsequent FHWA criteria adopted in the AASHTO publication *Manual for Assessing Safety Hardware (MASH)*.

When designs for a high-tension cable barrier system are being considered, consult and coordinate with the Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section. The Highway Design and Technology Section will provide assistance in evaluating design considerations for these systems and in addressing concerns raised by using these systems.

Table 12.9 presents design/location guidelines for high-tension cable barrier systems to be installed in medians.

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# TABLE 12.9
# DESIGN/LOCATION GUIDELINES
# FOR HIGH-TENSION CABLE BARRIER SYSTEMS
# INSTALLED IN MEDIANS

| FEATURE | GUIDELINE |
|---|---|
| Crash Requirements<br>(NCHRP Report 350) | • Cable Barriers: Test Level 4 (TL-4), minimum<br>• End Anchor Terminals: Test Level 3 (TL-3), minimum |
| Number of Cables | • 4 cables, minimum |
| Post Spacing (maximum) | • 3.0 m (10 ft) |
| Median Width (minimum) | • Slopes 6:1 to 10:1 - 10.8 m (36 ft)<br>• Slopes 10:1 or Flatter - 7.2 m (24 ft) |
| Median Slope | 6:1 or flatter<br>For median slopes 4:1 to 6:1, consult with Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section |
| Deflection | • Barrier placement location needs to account for the deflection limits of the system used.<br>• Deflections from a hit in any direction should not encroach into a travel lane.<br>• Do not specify deflection distances greater than 2.4 m (8 ft). |
| Barrier Placement (Swale Line) | • Slopes 6:1 to 10:1 - Not within 2.4 m (8 ft) of swale line<br>• Slopes 10:1 or Flatter - Not within 0.6 m (2 ft) of swale line<br>• Do not locate posts or end anchors in saturated soils. |
| Barrier Placement (Shoulder versus Center) | • For slopes greater than 6:1, install two systems in median.<br>• For 6:1 slopes or flatter, install one system in median.<br>• Place high-tension cable barrier systems a minimum of 3.0 m (10 ft) and preferably 3.6 m (12 ft) or more from the edge of traveled way.<br>• For additional guidance, see the AASHTO Roadside Design Guide, Section 6.6 (Placement Recommendations). |
| Maximum Distance Between Anchors | Varies by manufacturer and system |
| Transitions to Existing Barrier Systems | If encountered, needs to be addressed. Examples include bridge piers, sign structures, concrete median barrier, W-beam guide rail, dual structures with barrier dikes, etc. Consult with the Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section for guidance. |
| Soil Properties | Contractor to provide for a design to account for the anticipated soil type and to be sealed by a Professional Engineer (P.E.) licensed in Pennsylvania.<br><br>Soil properties for the design of the end anchors must be part of the contract documents. Existing geotechnical reports from the original construction project are to be made available for the installation contractor to review. In locations where complete geotechnical reports are not available, the supplied soil properties should include AASHTO Soil Classifications, moisture content; for cohesionless soils, the friction angle, density, and strength; for cohesive soils, the consistency and undrained shear strength. Cone penetrometer testing is one acceptable method to determine soil strength properties. Depth of soils information to 1500 mm (60 in) is recommended. |

**E. Gate Barrier Systems.** An emergency opening may be required, for example, to route traffic around a crash that requires the roadway to be temporarily closed. Proprietary devices have been developed and tested that can be used to provide a temporary opening in conjunction with a concrete safety-shaped median barrier. These gate barrier systems include:

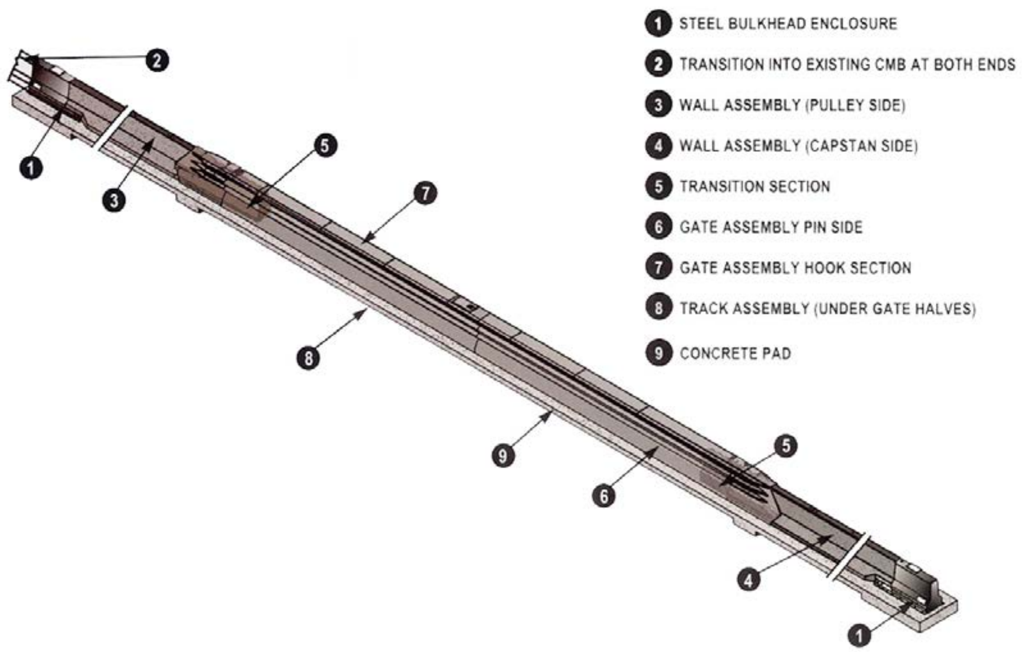
- The BarrierGate
- The ArmorGuard Gate
- The Vulcan Gate

**1. The BarrierGate.** The BarrierGate (NCHRP 350 approved, TL-3, FHWA Acceptance Letter B-25) is a proprietary longitudinal nongating barrier which opens to provide a 12.2 m or 7.9 m (40 ft or 26 ft) wide opening for controlled access through barrier openings.

The outermost ends of the gate assembly are equipped with transition assemblies that attach to custom concrete median barrier (CMB) sections.

The movement of the gate assemblies is directed by track assemblies anchored to a concrete foundation and guide rail assemblies anchored to the tops of the concrete transition assemblies.

The BarrierGate is a proprietary system, and as such, must be purchased or obtained through competitive bidding with an equally suitable alternate steel barrier system such as the ArmorGuard Gate and the Vulcan Gate.



**2. The ArmorGuard Gate.** The ArmorGuard Gate (NCHRP 350 approved, TL-3, FHWA Acceptance Letter B-87) is a proprietary longitudinal nongating barrier specifically designed to span a permanent opening in a concrete median barrier ranging from 8 m (26 ft) to 16 m (52 ft) long. The ArmorGuard Gate is a heavily reinforced steel barrier that is designed for emergency openings. The typical length of each gate section is 4 m (13 ft) and the effective overall height is 830 mm (33 in). The ArmorGuard Gate is 710 mm (28 in) wide at its base.

The ArmorGuard Gate is a proprietary system, and as such, must be purchased or obtained through competitive bidding with an equally suitable alternate steel barrier system such as the BarrierGate and the Vulcan Gate.

**3. The Vulcan Gate.** The Vulcan Gate (NCHRP 350 approved, TL-3, FHWA Acceptance Letter B-134C) is a proprietary longitudinal nongating barrier specifically designed to provide an emergency opening in a concrete median barrier. The median openings range from 8.28 m (27.17 ft) for a two-section Vulcan Gate (V2000) to 24.70 m (81.04 ft) for a six-section Vulcan Gate (V6000).

A typical Vulcan Gate system is comprised of existing Vulcan segments, two tested and accepted transitions to concrete median barrier, and two hinge segments. The hinges may also be used in a run of Vulcan barrier to create a gate opening.

The Vulcan Gate is a proprietary system, and as such, must be purchased or obtained through competitive bidding with an equally suitable alternate steel barrier system such as the BarrierGate and the ArmorGuard Gate.

## 12.6 TALL BARRIER

The primary use of tall barrier (glare screen) is to improve night visibility by reducing or eliminating glare from opposing headlights. At the same time it provides a greater level of performance for heavy vehicle containment. It may also be used in construction zones and in non-median locations such as between two-way frontage roads and freeways, and between highways and railroad tracks.

At the present time, there are no specific nationally recognized requirements established for the installation of glare screen. In the absence of such requirements, the following factors should be considered when assessing the need for a glare screen system:

**1.** Median width and crash experience.
**2.** Roadway curvature (horizontal and vertical).
**3.** Traffic volumes and vehicle characteristics.
**4.** Topographic characteristics.
**5.** Grades.
**6.** Number of lanes.
**7.** Horizontal sight distance.
**8.** Aesthetics.

In addition to the above factors, consideration should be given to determine whether the glare screen system should be a "closed" system that establishes a solid barrier between opposing traffic or an "open" system that provides unobstructed lateral vision.

Acceptable types of glare screen systems in Pennsylvania are concrete and plastic paddles or modular systems as shown in Figure 12.11. The concrete glare screen system details are shown in Publication 72M, *Roadway Construction Standards*. The plastic paddle or modular glare screen systems are acceptable for use as a retrofit on top of existing concrete median barrier or new 810 mm (32 in) barrier via special provisions based on the manufacturers' specifications and construction methods. Either system shall be provided by an approved manufacturer as listed in Publication 35, *Approved Construction Materials* (Bulletin 15).

A description for each system is as follows:

**1.** Concrete Glare Screen System. A concrete glare screen system represents a "closed" system using an F-shape concrete median barrier whose height is extended vertically to create an effective glare screen. Methods of construction include monolithic cast-in-place or slip-form or precast as shown on the Standard Drawings.

**2.** Plastic Paddle Glare Screen System. A plastic paddle glare screen system represents an "open" system using plastic paddles or modular systems anchored in an upright position on top of F-shape barrier or other conventional types of median devices and deployed parallel to the roadway in louver fashion resembling a picket fence.

A glare screen system for narrow medians may obstruct sight distance on curves to the left. Therefore, spacing or width of glare screen elements must be adjusted in proportion to the radius and calculations should be made to ensure that the glare screen does not reduce the sight distance needed for safe stopping. Glare screen should not be used where its installation would reduce the sight distance to less than safe stopping sight distance. The accepted design cutoff angle for glare screen should be 20° for tangent sections and 20° plus the quantity 1750 divided by the radius in meters for non-tangent sections (20° plus the degree of curvature for non-tangent sections).

Other types of glare screen systems of fabric and metal designs are undergoing research and development and may be considered on an experimental basis.

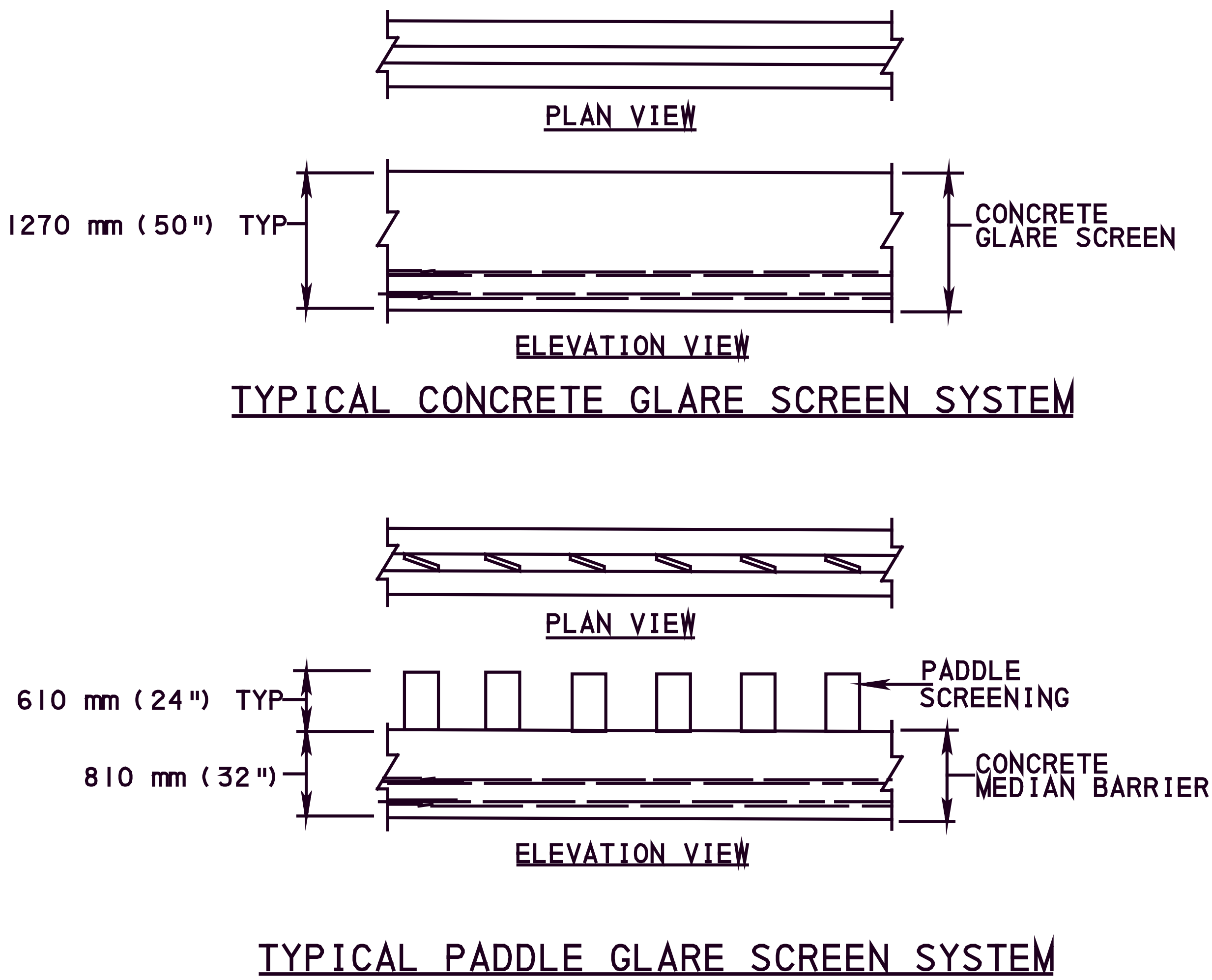



FIGURE 12.11
GLARE SCREEN SYSTEMS

## 12.7 SINGLE FACE CONCRETE BARRIER

Single face concrete barrier represents a rigid longitudinal barrier system used for the protection of piers and other roadside obstructions. The need for single face barrier shall be determined from Table 12.5, Figures 12.3 and 12.4 or Table 12.8 and the details shall conform to the Standard Drawings.

In special cases, single face barrier may be considered as a roadside (shoulder) barrier on projects where the minimum unobstructed distance (see Table 12.3) behind the guide rail is not available or on projects with a maintenance or design problem. Stability for single face barrier without back support is significantly affected by a reduction of the base width and additional base restraint is required to support the barrier in place. Emphasis should be placed on minimizing the number of such installations to only those that can be justified giving consideration to the social, environmental and economic factors as well as protective aspects.

Single face concrete barrier is **ONLY** appropriate for temporary barrier or roadside (shoulder) barrier when the barrier has full back support as shown in Publication 72M, *Roadway Construction Standards*.

Single face concrete barrier without full back support may be used if it is part of a moment slab. Design details for moment slabs are to be shown in the project plans following the guidance and details in BD-627M and Publication 15M, *Design Manual Part 4*.

Proper end treatments shall be provided as indicated on the Standard Drawings. Where single face barriers adjoin existing barrier systems, they shall be properly connected or overlapped in accordance with the Standard Drawings. All connection details not addressed by the Standard Drawings should be approved by the Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section, prior to inclusion in the project plans. For federally-funded projects, approval by the Federal Highway Administration (FHWA) is also required.

## 12.8 SHOULDER TREATMENTS

**A. Rumble Strips.** Rumble strips are depressed corrugations which provide an audible alert to motorists who drift off the travel lane. This audible warning provides an opportunity for errant drivers to react and make steering corrections that are needed to return to the travel way.

Rumble strips provide low-cost safety benefits and are to be included for both bituminous and concrete shoulders on new construction, reconstruction or resurfacing projects as indicated in Publication 72M, *Roadway Construction Standards*.

**1.** Limited Access Highways (Interstates and Expressways/Freeways). Provide shoulder rumble strips on each right and left shoulder which meet the following conditions:

- **a.** Right shoulders with a minimum paved width of 2.4 m (8 ft).
- **b.** Left (median) shoulders with a minimum paved width of 1.2 m (4 ft).

Installing rumble strips on bituminous paved shoulders requires an ID-2, ID-3, or Superpave HMA surface with BCBC base or better. Type 1-SP, Type 6-SP, and Type 7 shoulders should be specified in the design phase.

Shoulder rumble strips do not have to be part of a construction or restoration project. They can be installed via projects initiated exclusively for this purpose.

Shoulders should be in sufficiently good condition, as determined by the District, to effectively retrofit shoulder rumble strips without raveling or deteriorating. Otherwise, upgrade the shoulders prior to constructing shoulder rumble strips.

Do not install shoulder rumble strips on bridge decks, across transverse joints on concrete shoulders or across longitudinal joints.

Coordinate the construction of shoulder rumble strips with all necessary project phases. Do not construct the rumble strips until all construction phases, which utilize the shoulder to maintain traffic or construction vehicles/equipment, are complete.

**2.** Free Access Highways. Rumble strips for free access highways should be considered on a project by project basis and indicated on the construction plans. Rural and urban restoration (3R and reconstruction) projects should be evaluated.

Installing rumble strips on bituminous pavement requires an ID-2, ID-3, or Superpave HMA surface with BCBC base or better.

The following types of longitudinal rumble strips should be considered only on non-Interstate and non-expressway undivided two-lane or four-lane rural and urban roadways:

**a.** Shoulder Rumble Strips. Installed to reduce the number of single vehicle, run-off-the-road crashes.

**b.** Bicycle Tolerable Shoulder Rumble Strips. Installed in place of shoulder rumble strips that can pose problems for bicyclists who utilize paved shoulders for travel.

**c.** Centerline Rumble Strips. Installed to reduce the number of head-on and opposing crashes.

**d.** Edgeline Rumble Strips. Installed in lieu of shoulder rumble strips when the travel lane and shoulders are both of sufficient width.

For additional guidance on selecting longitudinal rumble strips, refer to Publication 46, *Traffic Engineering Manual*.

**B. Safety Edge$_{\mathbf{SM}}$**. The Safety Edge is a simple but extremely effective solution that can help save lives by allowing drivers who drift off highways to return to the road safely. Instead of a vertical drop-off, the Safety Edge consolidates the edge of the pavement to a 30° taper (with a 26° to 40° construction tolerance). Research has shown this is the optimum angle to reduce or eliminate tire scrubbing and allow drivers to re-enter the roadway safely. The Safety Edge provides a strong, durable transition for all vehicles. Even at higher speeds, vehicles can return to the paved road smoothly and easily. By including the Safety Edge detail while paving, this countermeasure can be implemented system-wide at a very low cost. The Safety Edge also provides a more durable pavement edge that prevents edge raveling. FHWA's goal is to accelerate the use of the Safety Edge technology, working with States to develop specifications and adopt this pavement edge treatment as a standard practice on all new and resurfacing bituminous pavement projects.

The Safety Edge is a proven technology with the following primary benefits:

- Reduces crashes and saves lives by mitigating pavement edge drop-off
- Is a low-cost, systematic improvement applied during paving
- Improves durability by reducing edge raveling
- Reduces tort liability

The Safety Edge is formed during a bituminous paving operation using a special removable wedge shaped shoe or end gate attached to the paver. See Publication 72M, *Roadway Construction Standards*, RC-25M for Safety Edge details.

The Safety Edge is to be used as a standard pavement edge treatment on the outside edge of bituminous pavements and shoulders for both wearing and binder courses having a depth of 1.5 in and greater. The total depth of the Safety Edge should not be more than 5 in.

The Safety Edge should not be included in urban typology projects where curb and sidewalk are encountered and it should not be used for base, leveling, or scratch courses at this time.

The Safety Edge is considered incidental to the paving course being placed and will result in an approximate 1% increase in the HMA/WMA material quantity. For tonnage items the 1% increase must be added to the project quantities.

The Safety Edge must be added to projects that meet the above guidelines via special provision N-a13401-A. The special provision specifies an **adjustable** Safety Edge device to prevent roll up of the edge. Fixed devices extrude the edge at a 30° angle, but after rolling, the angle of the edge may not meet the 40° maximum angle requirement. All pilot projects that used adjustable devices met the edge angle criteria.

No special preparation of the shoulder is required when placing the edge only on the final wearing course. However, preparation of the granular shoulder prior to placement is incidental to the paving items for wearing and binder courses. The incidental preparation work should be minor. Keep in mind that the asphalt material is incidental to the paving item. Thus, if more extensive prep work is required to prepare the shoulder area to address washouts or large drop-offs, the designer should include a separate item in the contract or work with County Maintenance Organizations to prepare the shoulders in advance of the project.

Shoulder backup is still to be placed with the Safety Edge as in the past with the traditional vertical edge.

The Safety Edge is not to be used as a longitudinal joint (i.e. lane to lane). A vertical or notched wedge joint for longitudinal joints is used as per Publication 408, Section 409.

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## 12.9 IMPACT ATTENUATING DEVICES

**A. Introduction.** Barrier end treatments and crash cushions are protective systems that prevent errant vehicles from impacting fixed objects by either gradually decelerating the vehicle to a stop when hit head-on, or by redirecting it away from the object for glancing impacts. These devices are used to shield barrier ends and other rigid objects that cannot be removed, relocated or made breakaway. Crash cushions and barrier end treatments are not intended to reduce crashes but rather to lessen their severity.

The intended function of all types of impact attenuating devices is to dissipate the energy of the vehicle either partially during a side-on impact or fully in the case of a head-on impact. This is accomplished through the principle of mechanics: "the change in kinetic energy is equal to the work done on the system." Some devices dissipate energy by crushing the elements of the system; others by putting the components of the attenuating system into motion. A third type operates on a combination of these two principles.

National Cooperative Highway Research Program (NCHRP) Report No. 350, *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, has previously contained the recommendations for testing and evaluating the performance of safety devices. The Federal Highway Administration adopted NCHRP Report 350 in the July 16, 1993 Federal Register. This document superseded the previous NCHRP Report 230 which was published in 1980.

**NCHRP 350** provides a wider range of test procedures to permit safety performance evaluations for a wider range of barriers, terminals, crash cushions, breakaway support structures and utility poles, truck-mounted attenuators, and work zone traffic control devices. Six Test Levels (1-6) are described in this report with full-scale vehicle crash testing. The nominal speed for Test Level 1 is 50 km/h (31 mph), 70 km/h (44 mph) for Test Level 2 and 100 km/h (62 mph) for Test Levels 3 through 6. Test Level 3 is the basic level required by the Federal Highway Administration for use on high-speed roadways on the National Highway System. In special conditions where containment of single-unit trucks, tractor trailers and tank trailers is necessary, the criteria for Test Levels 4, 5 and 6 are used respectively.

In 2009, AASHTO published the *Manual for Assessing Safety Hardware* (MASH). MASH is an update to and supersedes NCHRP Report 350 for the purposes of evaluating new safety hardware devices. MASH does not supersede any guidelines for the design of roadside safety hardware contained within the AASHTO Roadside Design Guide. MASH was developed through NCHRP Project 22-14(02), *Improvement of Procedures for the Safety-Performance Evaluation of Roadside Features*.

The purpose of MASH is to present uniform guidelines for the crash testing of both permanent and temporary highway safety features and evaluation criteria to assess test results. MASH also includes guidelines for the in-service evaluation of safety features. These guidelines and criteria incorporate current technology and the collective judgment and expertise of professionals in the field of roadside safety design. They provide: (1) a basis on which researchers and user agencies can compare the impact performance merits of candidate safety features, (2) guidance for developers of new safety features, and (3) a basis on which user agencies can formulate performance specifications for safety features. The need for updated crash test criteria was based primarily on changes in the vehicle fleet.

An implementation plan for MASH was adopted jointly by AASHTO and FHWA. The plan states that all highway safety hardware accepted prior to the adoption of MASH - using criteria contained in NCHRP Report 350 - may remain in place and may continue to be manufactured and installed. In addition, highway safety hardware accepted using NCHRP Report 350 criteria is not required to be retested using MASH criteria. However, new highway safety hardware not previously evaluated must utilize MASH for testing and evaluation.

Implementation of MASH on the NHS, as described in a FHWA memorandum November 20, 2009, will be as follows:

- The AASHTO Technical Committee on Roadside Safety is responsible for developing and maintaining the evaluation criteria as adopted by AASHTO. FHWA shall continue its role in the review and acceptance of highway safety hardware.

- All highway safety hardware accepted prior to adoption of MASH using criteria contained in NCHRP Report 350 may remain in place and may continue to be manufactured and installed.

- Highway safety hardware accepted using NCHRP Report 350 criteria is not required to be retested using MASH criteria.

- If highway safety hardware that has been accepted by FHWA using criteria contained in NCHRP Report 350 fails testing using MASH criteria, AASHTO and FHWA will jointly review the test results and determine a course of action.

- Upon adoption of MASH by AASHTO, any new highway safety hardware not previously evaluated shall utilize MASH for evaluation and testing.

- Any new or revised highway safety hardware under development at the time the MASH is adopted may continue to be tested using the criteria in NCHRP Report 350. However, FHWA will not issue acceptance letters for new or revised highway safety hardware tested using NCHRP Report 350 criteria after January 1, 2011.

- Highway safety hardware installed on new construction and reconstruction projects shall be those accepted under NCHRP Report 350 or MASH.

- Agencies are encouraged to upgrade existing highway safety hardware that has not been accepted under NCHRP Report 350 or MASH:

  - During reconstruction projects,
  - During 3R projects, or
  - When the system is damaged beyond repair.

- Highway safety hardware not accepted under NCHRP Report 350 or MASH with no suitable alternatives available may remain in place and may continue to be installed.

Updates to existing highway safety hardware are to be addressed as part of the Department's Interstate and Expressway Pavement Preservation Guidelines and Non-Expressway Pavement Preservation (NEPP) Guidelines for Federal Aid and State Projects. These guidelines are described in Publication 242, *Pavement Policy Manual*, Appendix G.

The best choice a designer can make is to eliminate the need for barrier. Roadside barrier and terminals must be selected, installed, and maintained in such a manner that a motorist striking it at any speed or angle has the best chance for survival. Terminal selection must be a deliberate design decision based on site conditions and on the known performance characteristics of the various terminals.

**B. Terminal Characteristics.** Crashworthy terminals are classified as non-gating or gating by design. A non-gating system will gradually stop or redirect a vehicle away from a fixed object, while a gating terminal allows a vehicle to pass through after impact when the tension in the system is released.

Non-gating terminals are the high type crash cushions used to terminate median barriers for bidirectional traffic, gore areas and other narrow or wide obstructions. Crash cushion systems such as sand barrels or water filled are gating terminals that can be used to shield a narrow or wide obstruction. However, they are not designed to redirect vehicles for side impacts.

**All of the W-beam guide rail terminals discussed in Section 12.9, except for the anchored backslope terminal, are gating terminals.** That means simply that all of them, when struck at or near the nose at an angle of 15° or greater, will yield readily, allowing a vehicle to continue into the area immediately behind and beyond the terminal. Thus, for angle hits of 15° or higher at or near the first post, all W-beam terminals perform about the same and most impacting vehicles will travel behind and beyond the terminal.

W-beam guide rail terminals have also been classified as either tangent designs (installed parallel to the roadway edge) or flared designs (flared away from the roadway). Experience has shown, however, that even "tangent" terminals are best installed with a 0.3 m or 0.6 m (1 ft or 2 ft) offset from the line of barrier proper (over the entire terminal length) to minimize nuisance hits. Typical flared terminals generally require a 1.2 m (4 ft) offset from the barrier itself, although some designs have been successfully tested with lesser offsets. The actual offset distance of a terminal may have a significant effect on site grading requirements as discussed later in more detail. However, the most significant difference in terminal performance is whether or not a terminal is likely to slow an impacting vehicle appreciably in near end-on crashes.

Most gating terminals for W-beam guide rail have been designed and developed to dissipate significant amounts of the kinetic energy in a head-on crash and are considered to be **energy-absorbing designs**. In high-speed, head on impacts on the terminal nose, energy-absorbing terminals have demonstrated their ability to stop impacting vehicles safely in relatively short distances (usually 15 m (50 ft) or less depending on type of terminal). Some gating terminals for W-beam guide rail are classified as **non-energy absorbing designs** and will allow an unbraked vehicle to travel over 45 m (150 ft) behind and parallel to the guardrail installation or along the top of the barrier when struck head-on at high speeds.

The decision to use an energy-absorbing terminal versus a non-energy absorbing terminal should be based on the likelihood of a near end-on impact and the nature of the recovery area immediately behind and beyond the terminal. **If the barrier length of need was properly determined, it is unlikely that a vehicle will reach the primary shielded object after an end-on impact regardless of the terminal type selected. However, if the terrain beyond the terminal end and immediately behind the barrier is not safely traversable, an energy-absorbing terminal is recommended.**

**C. Site Grading Requirements.** Grading in the area of the terminal is an important consideration regardless of the specific terminal type used. The grading must be considered from three perspectives: ***advance grading***, ***adjacent grading*** and ***runout distance grading***. Proper grading in **advance** of the terminal is needed to be sure the vehicle is stable at the point of initial contact. Proper grading **adjacent** to the terminal is needed to be sure the vehicle remains stable while in physical contact with the terminal. Finally, proper ***runout distance grading*** immediately downstream and behind the terminal is needed to be sure the vehicle remains stable after it clears the terminal and comes to a stop. This runout distance, not to be confused with the runout length needed to calculate barrier length of need, is especially important for near end-on hits into non-energy absorbing terminals.

**1.** Advance Grading. ***Advance grading*** must be applied to the terrain over which a vehicle may travel before contact with a barrier terminal. For W-beam terminals, this area should be no steeper than 1V:10H to ensure that a vehicle is stable at the moment of impact and that its suspension is neither extended nor compressed. When grading platforms are built, they must be smoothly transitioned to existing sideslopes so that the entire roadside approach to the barrier remains traversable as well as the area immediately behind it. In many instances, it will be more cost-effective to extend the barrier itself so its terminal can be installed without the need for additional earthwork or to use a terminal that requires less flare.

**2.** Adjacent Grading. ***Adjacent grading*** refers to the area on which the terminal is installed and the area immediately behind it. Ideally, this area should be essentially flat so the terrain itself does not exacerbate vehicle roll, pitch or yaw upon impact with the terminal. For impacts into the side of a terminal where redirection is expected (from the third post back for current W-beam terminals), the terminal posts should have at least 0.6 m (2 ft) of soil support behind them. For near head-on impacts, a relatively flat area should extend 1.5 m (5 ft) behind the terminal nose in a direction away from the roadway so a motorist striking the terminal with the left front of a vehicle will not have reached a high roll angle prior to impact. These recommended dimensions are shown in Figures 8-2 and 8-3 in the AASHTO Roadside Design Guide. If a grading platform was constructed, the departure end of this platform must be gradually blended into the (usually) steeper sideslopes behind the barrier. From a practical standpoint, a recoverable slope of 1V:4H behind the terminal may be a practical compromise, and in some cases a traversable slope as steep as 1V:3H may be acceptable. While such grading should be possible on freeways and many other high-speed arterial highways, it may not be cost-effective on roadways with limited rights-of-way and reduced clear zones. In these locations, the area immediately behind the terminal should be at least similar in nature to the roadside immediately upstream from the terminal.

**3.** Runout Distance Grading. ***Runout distance grading*** refers to the area into which an impacting vehicle may travel after breaking through a gating terminal. The physical extent of the area needed will vary depending on vehicle size and impact speed, impact angle, driver reaction, terrain character, and terminal type.

**While it is desirable to have a long recovery area available immediately behind the barrier, practical considerations will often dictate a much smaller area. As recommended in Section 8.3.3.3 of the AASHTO Roadside Design Guide, the minimum recovery area behind and beyond all W-beam terminals should be an area approximately 23 m (75 ft) long and 6 m (20 ft) wide.** Note that if the roadside in advance of the terminal does not have a 6 m (20 ft) wide recovery area, it is not intended that additional clear zone be provided behind the terminal, but the recovery area should at least be consistent with that available elsewhere along the road. In many cases, it may not be practical to provide even a minimum runout area due to physical constraints such as restricted rights-of-way or environmental concerns.

**D. Crashworthy End Treatments / Crash Cushions.** Crashworthy end treatments/crash cushions acceptable for use in Pennsylvania are listed below by type for a particular application. They are categorized by type as follows:

- Type I - Anchored Backslope Terminal
- Type II - Energy Absorbing Terminals
- Type III - Non-Energy Absorbing Terminals
- Type IV - Gating Systems Used Where Two-Way Traffic Is Present
- Type V - Non-Gating Terminals Used Where Two-Way Traffic Is Present
- Type VI - Gating, Non-Redirective Crash Cushion Systems
- Miscellaneous Systems

Publication 408, *Specifications*, and special provisions, as well as Publication 35, *Approved Construction Materials* (Bulletin 15), indicate a list of approved devices as follows:

- Publication 408, *Specifications*, Section 619 - Permanent Impact Attenuating Devices

- Publication 408, *Specifications*, Section 696 - Temporary Impact Attenuating Devices (This work is the furnishing, placing and removing of temporary impact attenuating devices for maintenance and protection of traffic during construction.)

- Publication 408, *Specifications*, Section 697 - Reset Temporary Impact Attenuating Devices (This work is the resetting of a temporary impact attenuating device from one construction area to another within the project limits.)

Table 12.10 shows the approved impact attenuating devices, Type I through Type VI. As listed in Publication 35, *Approved Construction Materials* (Bulletin 15), some devices may be used as either permanent or temporary devices and they are as follows: Type IV, Type V - Standard, and Type VI.

Conversely, the Type V Low Maintenance/Self Restoring systems **are only to be used in permanent locations** where there are high traffic volumes and there is high potential for being impacted. Although the Type V-Low Maintenance/Self Restoring systems are designed to accept a second hit without repair (in most cases), the Department does not have enough experience with a second hit or with the service life capabilities of these systems. Type V-Low Maintenance/Self Restoring systems could be used in a long-term work zone with unique setting conditions, but they cost twice as much as a Type V-Standard device and are not considered the best choice.

A proprietary system may be justified based on unique and special highway conditions. Prior approval must be acquired to use proprietary items. Refer to Publication 51, *Bid Package Preparation and Policies Manual*, for guidance.

**1. Type I - Anchored Backslope Terminal.**

**a.** Description. This terminal is constructed by attaching the W-beam guide rail to a concrete anchor or a post anchor buried into the backslope while retaining its full height relative to the edge of traveled way.

A W-beam guide rail that can be terminated in a backslope is a preferred end treatment because it eliminates any possibility of a true end-on hit. However, an effective installation must satisfy several design criteria.

First and foremost of these must be the steepness of the slope into which the W-beam is anchored. The ideal slope is one that is nearly vertical, in which case the slope in effect becomes an extension of the barrier and a motorist cannot physically get behind the terminal. In such a case, the barrier can be brought into the backslope as soon as practical using the maximum flare rate appropriate for the design speed of the highway.

If the backslope is significantly flatter than 1V:1H, a buried-in-backslope design behaves essentially like a turned-down terminal and can be overridden. In these instances, the full design length of need of the barrier must be provided and there should be a minimum distance behind the rail that is 23 m (75 ft) long and 6 m (20 ft) wide that is both free of fixed objects and reasonably traversable, just as with all other W-beam terminals. Note that if the roadside in advance of the terminal does not have a 6 m (20 ft) wide recovery area, it is not intended that additional clear zone be provided behind the terminal, but the recovery area should at least be consistent with that available elsewhere along the road. **For the anchored backslope terminal, the length of need begins at the point where the W-beam remains at full height in relation to the roadway shoulder, usually at the point where the barrier crosses the ditch line. If the backslope continues under and in front of the flared W-beam, the rail height is effectively reduced and the slope forms a ramp that could allow a vehicle to override the rail instead of being redirected.**

The anchored backslope terminal has been successfully tested over 1V:10H, 1V:6H, and 1V:4H foreslopes. In each case, the height of the W-beam rail was held constant in relation to the roadway shoulder elevation until the rail crossed the ditch bottom. When the distance from the ground to the bottom of the W-beam exceeds approximately 450 mm (18 in), a W-beam rubbing rail must be added to minimize wheel snagging on the support posts. On high-speed routes with a design speed above 70 km/h (45 mph), the W-beam height, even across a 1V:10H slope, should match the roadway grade.

**b.** Application. The most desirable method to terminate guide rail is to bury the end in a backslope where it cannot be hit end on. This system should also be used even when the barrier system's Length of Need (LON) would normally end downstream of a backslope if the backslope is within 60 m (200 ft) and there is not a large available runout area (60 m × 15 m (200 ft × 50 ft)) beyond the terminal. Standard details for the backslope end treatment are shown in Publication 72M, *Roadway Construction Standards*, Drawing RC-54M.

**2. Type II - Energy Absorbing Terminals.**

**a.** Description. Energy absorbing terminals may be categorized as flared or tangent. Flared terminals are preferred because they are installed 1.2 m (4 ft) away from the edge of shoulder at the approach end. Both types require level (1V:10H) terrain in front of the system and 1.0 m (3 ft) behind since they are gating systems. Tangent terminals are used when the area required for flared terminals is not available and they are installed parallel to the shoulder with 0.3 m (1 ft) to 0.6 m (2 ft) offset at the nose. They will redirect vehicles for side angle impacts beyond the third post.

Energy absorbing terminals have been designed and developed to dissipate significant amounts of the kinetic energy in a head-on crash. In high-speed, head on impacts on the terminal nose, energy-absorbing terminals have demonstrated their ability to stop impacting vehicles safely in relatively short distances (usually 15 m (50 ft) or less depending on type of terminal). In contrast, non-energy absorbing terminals will allow an unbraked vehicle to travel over 45 m (150 ft) behind and parallel to the guide rail installation or along the top of the barrier when struck head-on at high speeds.

If the barrier length of need was properly determined, it is unlikely that a vehicle will reach the primary shielded object after an end-on impact regardless of the terminal type selected. However, if the terrain beyond the terminal end and immediately behind the barrier is not safely traversable, an energy-absorbing terminal is recommended.

**b.** Application. These end terminals are used on the approach end of single runs of Strong Post (Type 2-S) W-beam guide rail on either side of the roadway. They may also be used to terminate Weak Post (Type 2-W) guide rail with a 15.2 m (50 ft) transition of Strong Post guide rail between the Weak Post system and the terminal. See Section 12.4.D for appropriate length of need determination and Publication 72M, *Roadway Construction Standards,* Drawing RC-54M for site grading details.

**c.** Approved Systems. Type II approved energy absorbing terminals include:

Energy Absorbing Terminals (Flared):

- Flared Energy Absorbing Terminal (FLEAT-350)
- Flared Energy Absorbing Terminal (FLEAT-SP)
- X-Tension End Terminal (X-Tension)

Energy Absorbing Terminals (Tangent):

- Sequentially Kinking Terminal (SKT-350)
- Box Beam Bursting Energy Absorbing Terminal - Single-Sided Crash Cushion (BEAT-SSCC)
- Sequentially Kinking Terminal (SKT-SP)
- X-Tension End Terminal (X-Tension)

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**(1) FLEAT-350.** The FLEAT-350 (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-46) is a flared energy absorbing terminal system designed to terminate W-beam guide rail for unidirectional traffic. When impacted, the extruder head is driven along the rail, separating several weak posts from the rail. As the extruder head slides along the rail, it forces the rail through an opening that flattens and kinks the corrugations. The kinetic energy of an impacting vehicle is primarily absorbed in the flattening and bending of the rail.

The FLEAT-350 is 11.43 m (37.5 ft) long and is to be installed with a 1.2 m (4 ft) straight flare. The FLEAT was also tested with a 0.75 m (2.5 ft) flare and may be installed between 0.7 m (2.25 ft) and 1.2 m (4 ft) flare. However, the standard is 1.2 m (4 ft) with exceptions. The FLEAT-350 is a proprietary system and should be acquired on the basis of competitive bidding with the FLEAT-SP and X-Tension.

**(2) FLEAT-SP.** The FLEAT-SP (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-88B) is also a flared energy absorbing terminal system designed to terminate W-beam guide rail for unidirectional traffic. The FLEAT-SP is a two-post system and differs from the FLEAT-350 in the following ways:

- Post #1 has an enhanced upper and lower hinge.
- Post #2 has a hinged post with no ground strut.
- Post #3 and beyond may use generic standard W150 × 13.5 (W6 × 9) guide rail posts and standard W-beam rail sections.

When impacted, the vehicle extruder head is driven along the rail, separating several weak posts from the rail. As the extruder head slides along the rail, it forces the rail through an opening that flattens and kinks the corrugations. The kinetic energy of an impacting vehicle is primarily absorbed in the flattening and bending of the rail.

The FLEAT-SP is 11.43 m (37.5 ft) long and is to be installed with a 1.2 m (4 ft) straight flare. The FLEAT was also tested with a 0.75 m (2.5 ft) flare and may be installed between 0.7 m (2.25 ft) and 1.2 m (4 ft) flare. However, the standard is 1.2 m (4 ft) with exceptions. The FLEAT-SP is a proprietary system and should be acquired on the basis of competitive bidding with the FLEAT-350 and X-Tension.

**(3) X-Tension.** The X-Tension (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-102) is a flared energy absorbing terminal system and a tangent energy absorbing terminal system designed to terminate W-beam guide rail for unidirectional traffic. The X-Tension is capable of redirecting vehicles impacting from the length of need, which starts at the first post.

In all end on impacts, varying amounts of energy are dissipated depending on the length of time the vehicle remains in contact with the impact head. During end on impacts the head, rail one and the slider, telescope over rail two until rail two comes to rest in the back of the impact head. At this point, the V notch bolts joining rail one and two are sheared allowing the entire rail one, head, slider and rail two assembly to slide over rail three. As the head is pushed down the two cables, the cables are pulled through the brake bar in a torturous path, which dissipates energy.

The X-Tension complies with NCHRP 350 in the following ways:

- The tangent and flared configurations using either wood (CRT) or steel line posts (first two posts crimped near the ground line).
- The tangent and flared configurations use a small "kit" of key components that are used in conjunction with standard W-beam guide rail, wood or composite block-outs, steel line posts or CRT wood posts and standard guide rail component hardware to make up any of the noted configurations.
- The amount of offset for flared applications can be between the tangent position (no offset) and the fully flared (1.2 m (4 ft) offset) as tested.
- Recognition of the redirective capability of the system from the first post. Therefore, the system qualifies as a "Redirective, Non-Gating" Terminal under the definitions in NCHRP Report 350.

When impacted, the vehicle extruder head is driven along the rail, separating several weak posts from the rail. As the extruder head slides along the rail, it forces the rail through an opening that flattens and kinks the corrugations. The kinetic energy of an impacting vehicle is primarily absorbed in the flattening and bending of the rail.

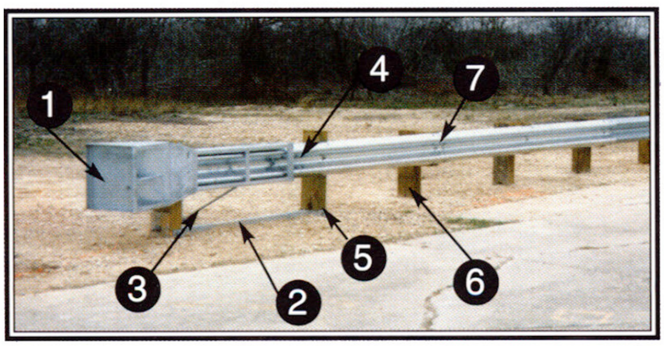
The X-Tension is 13.02 m (42.71 ft) long. The X-Tension is a proprietary system and should be acquired on the basis of competitive bidding with flared systems (FLEAT-SP, FLEAT-350) or with tangent systems (SKT-350, BEAT-SSCC, SKT-SP).

Flared Application:

Tangent Application:

**(4) SKT-350.** The SKT-350 (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-40) is a tangent energy absorbing terminal system. The SKT-350 is designed to be used on the approach of a run of strong post W-beam guide rail. On impact, the impact head is driven along the rail, separating several weak posts from the rail. As the impact head slides along the rail, it feeds the rail through an opening that sequentially kinks the corrugations. The kinetic energy of the impacting vehicle is primarily absorbed through the kinking of the rail. The SKT-350 is 15.2 m (50 ft) long and can be installed parallel to the roadway or with a straight taper of 25:1 or 50:1 to move the nose 0.3 m or 0.6 m (1 ft or 2 ft) away from the edge of the shoulder. The SKT-350 is capable of redirecting 820 kg to 2000 kg (1800 lb to 4400 lb) vehicles when impacting the system at an angle beyond the third post.

The SKT-350 is a proprietary system and should be acquired on the basis of competitive bidding with other equally suitable tangent energy absorbing terminal systems such as the BEAT-SSCC, the SKT-SP, and the X-Tension.




1. **Impact Head**
2. **Ground Strut**
3. **Cable Anchor**
4. **Cable Anchor Bracket**
5. **Foundation Tub Sleeve**
6. **Timber Post & Block**
7. **W-Beam Rail**

**(5) BEAT-SSCC.** The BEAT-SSCC (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-69B) is a tangent energy absorbing terminal system. The BEAT-SSCC attaches directly to rigid barrier, bridge abutments, and bridge rails and serves as both a transition and an end treatment. The BEAT-SSCC comes available with surface mounted posts or ground mounted posts; the ground mounted design does not need a concrete pad to be built.

The BEAT-SSCC is comprised of the following main components: (1) an impact head assembly; (2) a Stage 1 energy absorber (152 mm × 152 mm × 3.2 mm (6 in × 6 in × 1/8 in) box beam rail); (3) a Stage 2 energy absorber (152 mm × 152 mm × 4.8 mm (6 in × 6 in × 3/8 in) box beam rail); (4) eight breakaway steel posts; and (5) a fabricated end section for transitioning the BEAT-SSCC to a F-shaped concrete barrier.

The shortest length of the BEAT-SSCC is 8.5 m (28 ft). For sites needing additional length of need, the BEAT-SSCC is available in lengths of 9.8 m (32 ft), 11.0 m (36 ft), 12.2 m (40 ft) and 13.4 m (44 ft).

The BEAT-SSCC is a proprietary system and should be acquired on the basis of competitive bidding with other equally suitable tangent energy absorbing terminal systems such as the SKT-350, the SKT-SP, and the X-Tension.

**(6) SKT-SP.** The SKT-SP (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-61A) is a tangent energy absorbing terminal system. The SKT-SP is designed to be used on the approach of a run of strong post W-beam guide rail. The SKT-SP is a two-post system and differs from the SKT-350 in the following ways:

- Post #1 has an enhanced upper and lower hinge.
- Post #2 has a hinged post with no ground strut.
- Post #3 and beyond may use generic standard W150 × 13.5 (W6 × 9) guide rail posts and standard W-beam rail sections.

On impact, the impact head is driven along the rail, separating several weak posts from the rail. As the impact head slides along the rail, it feeds the rail through an opening that sequentially kinks the corrugations. The kinetic energy of the impacting vehicle is primarily absorbed through the kinking of the rail. The SKT-SP is 11.43 m (37.5 ft) long and can be installed parallel to the roadway or with a straight taper of 25:1 or 50:1 to move the nose 0.3 m or 0.6 m (1 ft or 2 ft) away from the edge of the shoulder. The SKT-SP is capable of redirecting 820 kg to 2000 kg (1800 lb to 4400 lb) vehicles when impacting the system at an angle beyond the third post.

The SKT-SP is a proprietary system and should be acquired on the basis of competitive bidding with other equally suitable tangent energy absorbing terminal systems such as the BEAT-SSCC, and the X-Tension.

**3. Type III - Non-Energy Absorbing Terminals.**

**a.** Description. Non-energy absorbing terminals will allow an unbraked vehicle to travel over 45 m (150 ft) behind and parallel to the guide rail installation or along the top of the barrier when struck head-on at high speeds.

**b.** Application. These end terminals are used on the approach end of single runs of Strong Post (Type 2-S) W-beam guide rail on either side of the roadway. They can also be used to terminate Weak Post (Type 2-W) guide rail with a 15.2 m (50 ft) transition of Strong Post guide rail between the terminals and the Weak Post system. See Section 12.4.D for appropriate length of need determination and RC-54M for site grading details.

**c.** Approved Systems. The Type III approved flared non-energy absorbing terminal is:

- Slotted Rail Terminal (SRT-350)

**(1) SRT-350.** The SRT-350 (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-51) is a flared non-energy absorbing terminal system. The SRT-350 is a proprietary gating system intended to be used as a guide rail end treatment. The design of the SRT-350 consists of an 11.4 m (37.5 ft) straight flare with the first post offset 1.2 m (4 ft) from the downstream guide rail. The two anchor posts are steel Hinged Breakaway (HBA) posts while the remaining posts are standard 1830 mm (6 ft) long CRT posts. The HBA posts include the use of 102 mm × 152 mm × 5 mm (4 in × 6 in × 3/16 in) soil tubes in lieu of W150 × 13 (W6 × 8.5) steel stub posts, and two parallel ground struts between post No. 1 and post No. 2. The rail to the post attachment hole at post No. 1 is slotted to the end of the beam element. A total of five CRT posts and two HBA posts are used.

The SRT may be used to terminate Weak Post guide rail with a 15.2 m (50 ft) section of Strong Post guide rail between the Weak Post System and the end treatment.

The SRT-350 is a unidirectional end treatment. Since the SRT-350 is proprietary, it should be acquired on the basis of competitive bidding if other equally suitable flared non-energy absorbing terminal systems become available.

**4. Type IV - Gating Systems Used Where Two-Way Traffic Is Present**

**a.** Description. These systems use a variety of methods to dissipate the kinetic energy of an impacting vehicle in head-on crashes, arresting the vehicle in a controlled manner such that the risk of serious injuries to the occupants is minimized.

**b.** Application. These systems can be used to terminate W-beam guide rail, concrete median barrier, and double-faced W-beam median barrier. They are typically used in roadway medians that are 3.0 m (10 ft) wide or more, but also have application in shoulder and gore areas and on point hazards such as bridge piers. Redirection of the impacted vehicle begins at different points along each of the devices, but impacting vehicles will pass through the device on side angle impacts at the approach end. Approved terminal to barrier connections as required are incidental to each system. These systems can be installed in permanent locations or temporary in work zones.

**c.** Approved Systems. Type IV approved terminals include:

- Crash-Cushion Attenuating Terminal (CAT-350)
- Brakemaster 350
- Advanced Dynamic Impact Extension Module (ADIEM)
- Flared Energy Absorbing Terminal - Median Terminal (FLEAT-MT)

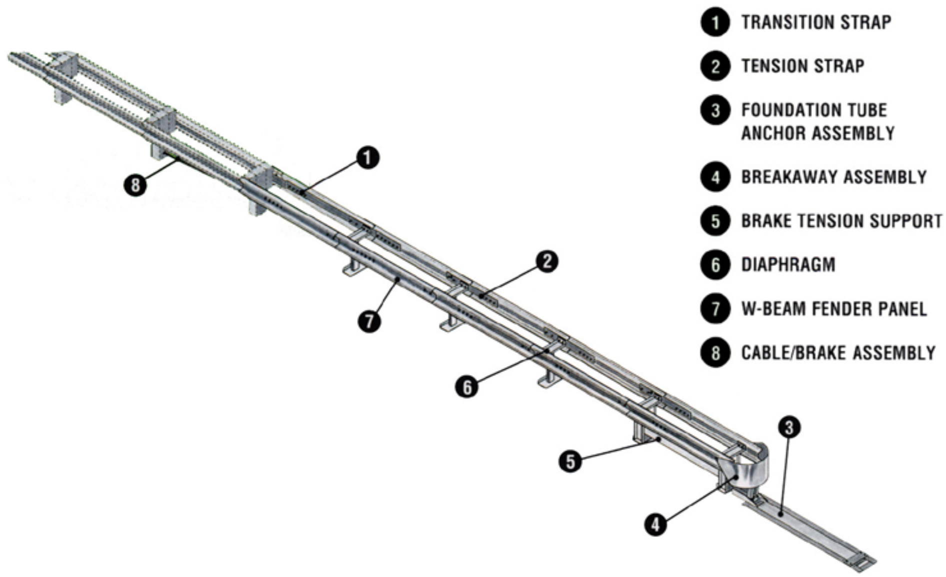
**(1) Crash Cushion/Attenuating Terminal (CAT-350).** The CAT-350 is a proprietary system (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-33) and is both a bidirectional and a unidirectional energy absorbing crash cushion and end treatment. The system can be used to protect motorists from barriers in the median or on the shoulder, or to shield fixed objects. The CAT-350 is considered gating, however, redirection begins at post number 4 from the approach end. The CAT-350 should not be used in narrow medians less than 3.0 m (10 ft).

The CAT-350 is a cable-anchored, three-stage system utilizing a soft nose piece, slotted 2.75 mm (12 gage) and 3.51 mm (10 gage) W-beam rails and breakaway wooden posts. The CAT-350 functions by first folding up the soft nose which creates a buffer. The rails are then activated and begin to translate by shearing out tabs of steel between adjacent slots in the guide rail until the vehicle has been decelerated. Since the CAT-350 is a proprietary system, it should be acquired on the basis of competitive bidding with other equally suitable systems such as the Brakemaster 350.

A tail-end section is required to attach the CAT-350 to the existing barrier or fixed object and it is incidental to the CAT-350 system.

**(2) Brakemaster 350.** The Brakemaster 350 (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-41) is a proprietary gating system that offers an alternative for low frequency impact applications. The unit is designed to protect a variety of narrow fixed objects in low frequency impact areas in wide medians such as double-sided guide rail ends, bridge pillars, and lighting or sign supports. It may also be used to terminate W-beam guide rail on the shoulders. The Brakemaster 350 should not be used in narrow medians less than 3.0 m (10 ft).

The Brakemaster 350 consists of a framework of W-beam steel guide rail panels which move rearward when hit head-on. A special braking mechanism provides frictional resistance, which brings an impacting vehicle to a complete stop. A tail end section is required to attach the Brakemaster 350 to the barrier or fixed objects and it is incidental to the Brakemaster 350. Since the Brakemaster 350 is a proprietary system, it should be acquired on the basis of competitive bidding with other equally suitable systems such as the CAT-350.



**(3) Advanced Dynamic Impact Extension Module (ADIEM).** The ADIEM (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-38) is a proprietary end treatment and crash cushion for portable and permanent concrete barriers, bridge parapet rail, etc. The ADIEM attaches directly to concrete barrier and it is installed with pins on a smooth surface in the same plane as the barrier on soil, asphalt or concrete. For this system, redirection begins 4.2 m (14 ft) from the approach end. For temporary or construction zone applications, the system may be relocated as the work zone changes, and from project to project.

The energy absorption elements of the ADIEM are lightly reinforced, ultra low strength perlite concrete modules. The ADIEM dissipates the energy of an impact as the light weight modules are crushed. Clean up and restoration of the system to full service requires replacement of the damaged modules and minor sweep up of debris.

**(4) Flared Energy Absorbing Terminal - Median Terminal (FLEAT-MT).** The FLEAT-MT (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-46D) is a proprietary end treatment for use in wide medians. The components of the original roadside FLEAT are combined with a couple of small additional components to create the FLEAT-MT. The FLEAT-MT attaches directly to median double-sided W-beam guide rail and can be used with wood or steel breakaway posts.

Two impact heads are required. One of the impact heads is at the fourth post in from the end of the barrier and fits over the backside W-beam rail element. The other impact head fits over the end of the traffic-side rail element ahead of the first and is offset from the face of the median barrier proper in a straight flare.

The front single-sided section of the FLEAT-MT is similar to the FLEAT-350 and functions the same. Depending on the severity of the impact, the vehicle may be stopped before reaching the second impact head at the fourth post. If the end-on impact is severe enough, the vehicle will activate the second impact head. This impact head will then begin to slide down the rail sequentially kinking the backside rail.

**5. Type V - Non-Gating Terminals Used Where Two-Way Traffic Is Present.**

**a.** Description. These systems use a variety of methods to dissipate the kinetic energy of an impacting vehicle in head-on crashes, arresting the vehicle in a controlled manner such that the risk of serious injuries to the occupants is minimized. The redirection point of these devices begins at the approach end of the device, i.e., they are non-gating.

**b.** Application. These systems can be used to terminate concrete median barrier, double-faced W-beam median barrier, and other obstructions. They are typically used in narrow or wide roadway medians, but also have application in shoulder and gore areas and on point hazards such as bridge piers and other wide obstructions. Approved terminal to barrier connections as required for reverse direction impacts, are incidental to each system. These systems can be installed in permanent locations or temporary in work zones. In the PS&E package, include a special provision to indicate what width "W" is to be protected by the Type V impact attenuating device. For maximum values for "W," refer to Table 12.10 in the column for "ADDITIONAL INFO".

**c.** Approved Systems. Type V approved terminals include:

- Standard
  - QuadGuard
  - TRACC
  - TAU-II
  - QUEST

- Low Maintenance/Self Restoring
  - QuadGuard Elite
  - REACT 350
  - REACT 350 (60")
  - SCI100GM and SCI70GM
  - QuadGuard LMC

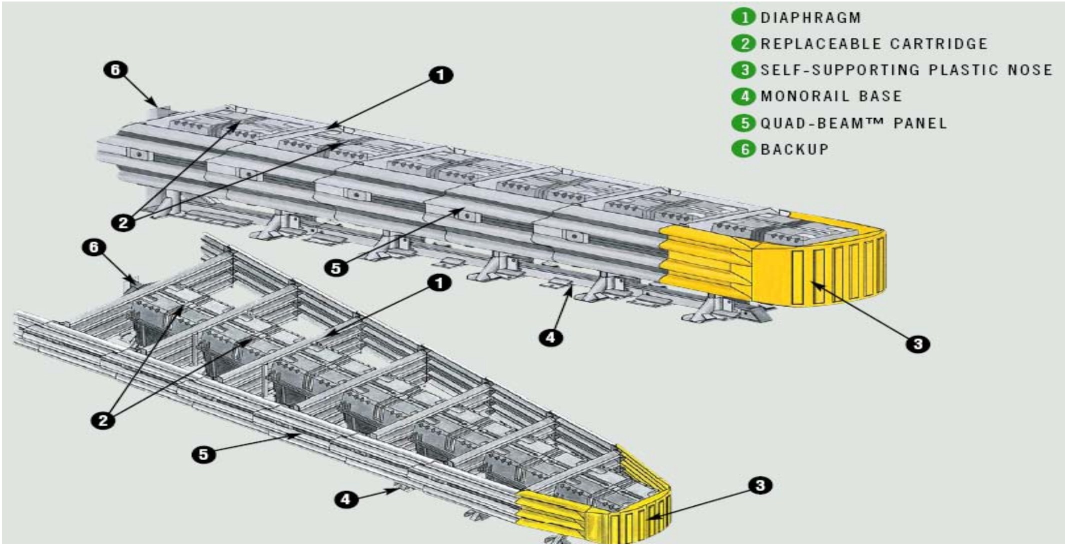
Type V Low Maintenance/Self Restoring crash cushions either suffer very little, if any damage, upon impact and are easily pulled back into their full operating condition, or they partially rebound after an impact and may only need an inspection to ensure that no parts have been damaged, misaligned, etc. Although some attenuators can still function and save lives after being struck once, no device is completely maintenance free.

**(1) QuadGuard.** The QuadGuard (NCHRP 350 approved, TL-2 and TL-3) is a proprietary system and can be used for unidirectional or bidirectional traffic. The QuadGuard is a nongating system and is intended for use to terminate roadside barrier of various types and other obstructions up to 2.3 m (90 in) wide. When used for bidirectional traffic, FHWA approved transitions are required in the event of a reverse direction impact at the rear of the system.

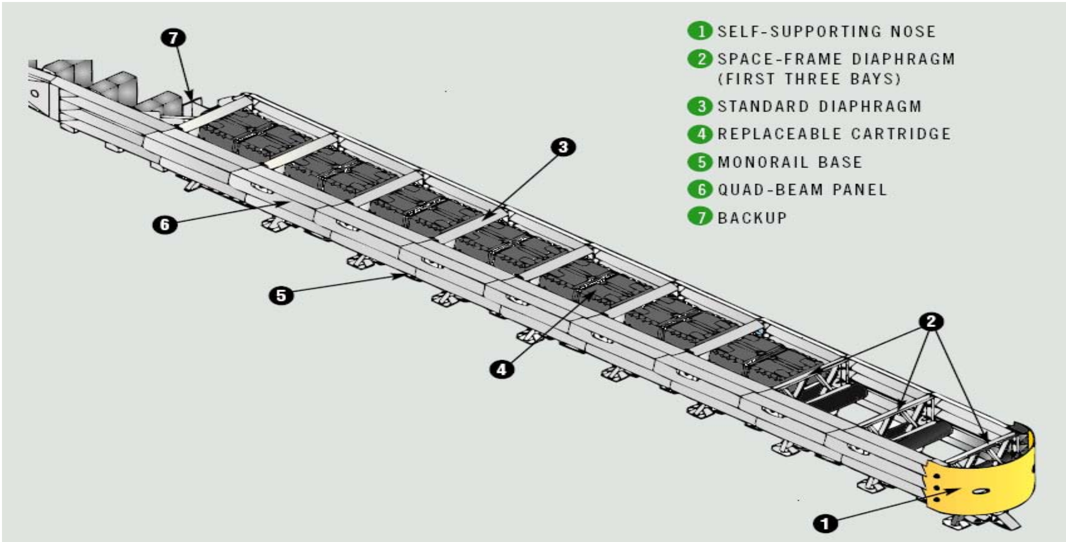
The Standard Quadguard system (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-35) uses crushable energy absorbing cartridges surrounded by diaphragms. The Quadguard HS (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-35E) is also a proprietary system for design speeds up to 113 km/h (70 mph). The Quadguard HS features space-frame diaphragms that are used in the first three bays of the system, which do not contain a cartridge. A 3-bay QuadGuard system (NCHRP 350 approved, TL-2, FHWA Acceptance Letter CC-35C) is also available. If any of these QuadGuard systems is impacted and the cartridges are damaged, they have to be replaced.

Since the QuadGuard is proprietary, it should be acquired on the basis of competitive bidding with other equally suitable systems such as the TRACC, the TAU-II and the QUEST.

**QuadGuard:**




**QuadGuard HS:**



**(2) TRACC.** The TRACC system (NCHRP 350 approved, TL-2 and TL-3, FHWA Acceptance Letter CC-54) can be used for unidirectional or bidirectional traffic. The TRACC is a redirective, nongating system and is intended for use to terminate median barrier. When used for bidirectional traffic, an FHWA approved transition is required in the event of a reverse direction impact at the rear of the system and is incidental to the TRACC system.

The TRACC can be installed on a 150 mm (6 in) thick reinforced concrete base and anchored with twenty-seven 190 mm (7.5 in) long steel anchor studs 16 mm (0.63 in) in diameter. The TRACC can also be used as a temporary crash cushion resting on 200 mm (8 in) of asphalt (or 150 mm (6 in) of asphalt over 150 mm (6 in) of compacted subbase) if anchored with twenty-seven 460 mm (18 in) long Grade 5 threaded studs set in drilled holes using a polyester resin meeting ACI 349 requirements.

Since its original approval based on the NCHRP 350 guidelines, the manufacturer has modified its design into three other products. The first product, SHORTRACC (NCHRP 350 approved, TL-2, FHWA Acceptance Letter CC-54A), is similar to the TL-3 TRACC, with the second and third stages of the TL-3 TRACC shortened for the TL-2 design. The second product, WIDETRACC (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-54D), is available in varying lengths, widths, and test levels. The WIDETRACC can be custom designed for any appropriate wide application. The third product, FASTRACC (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-54H), is longer than the TL-3 TRACC because of the addition of a set of standard two-bay side panels on each side of the system supported by two additional sliding frames which ride along a lengthened base assembly.

The TRACC is a proprietary system and, as such, must be purchased or obtained through competitive bidding with equally suitable alternate systems such as the standard QuadGuard, the TAU-II and the QUEST.



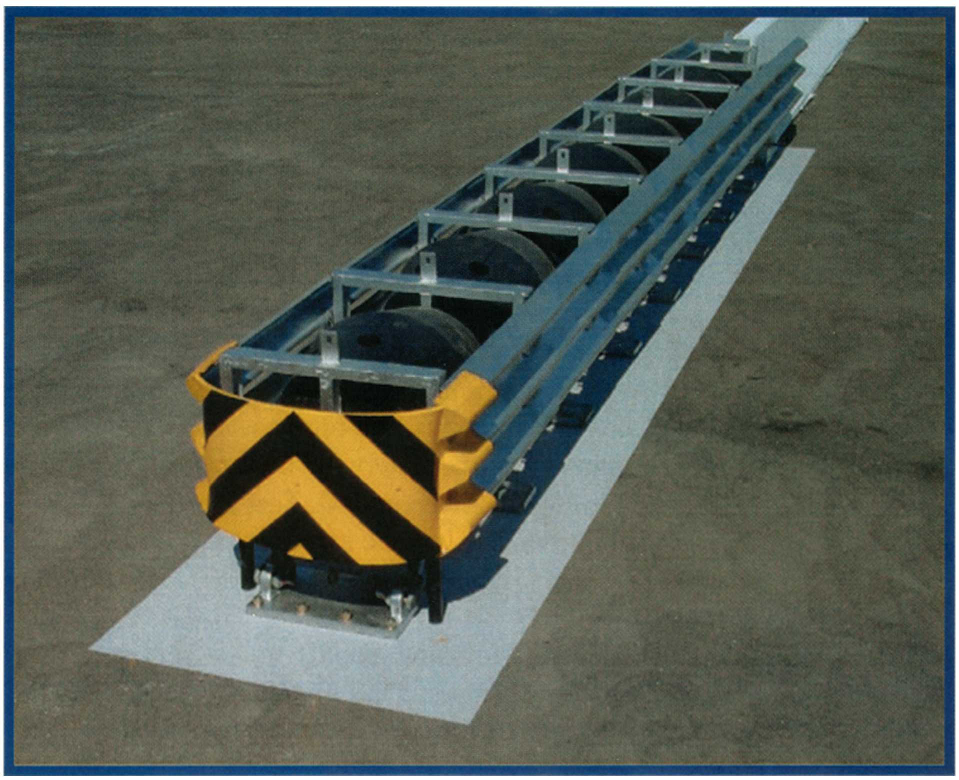
WIDETRACC™

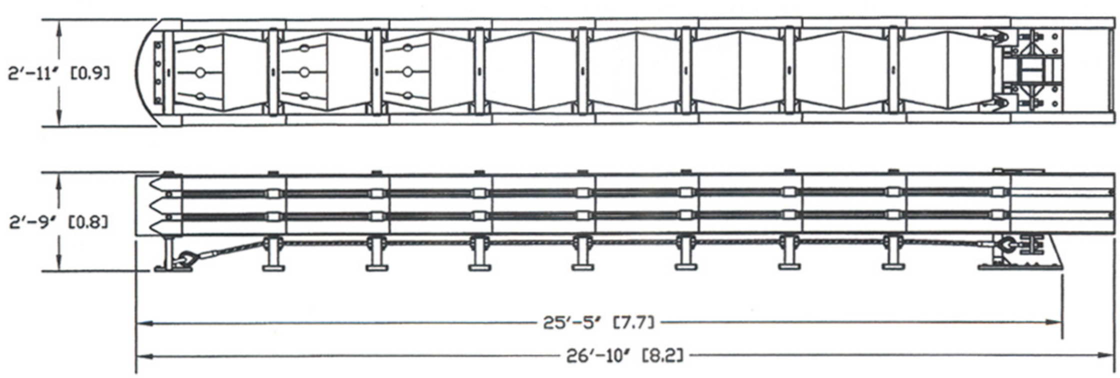

FASTRACC™

**(3) TAU-II.** The TAU-II (NCHRP 350 Approved, TL-2 and TL-3, FHWA Acceptance Letter CC-75) is a redirective, non-gating crash cushion system for edge of road and narrow median applications. The TAU-II is designed for attachment to permanent or portable concrete barrier.

An eight-bay system (approximately 8 m (26 ft) in length) met NCHRP 350's requirements for Test Level 3 (TL-3). A four-bay system (approximately 4.3 m (14 ft) in length) met NCHRP 350's requirements for Test Level 2 (TL-2). Both systems of TAU-II consist of galvanized steel elements in accordance with ASTM standards and plastic components made of high molecular weight polyethylene.

The TAU-II is a proprietary system and, as such, must be purchased or obtained through competitive bidding with equally suitable alternate systems such as the standard QuadGuard, the TRACC and the QUEST.






**TAU-II™ Redirective, Non-Gating Crash Cushion**
**(Plan and Elevation Views—8 Bay (100 km/h) System**

**(4) QUEST.** The QUEST (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-87) is a proprietary system and can be used for unidirectional or bidirectional traffic. The QUEST is a nongating system and is intended for use to terminate concrete median barrier or W-beam guide rail. When used for bidirectional traffic, FHWA approved transitions are required in the event of a reverse direction impact at the rear of the system.

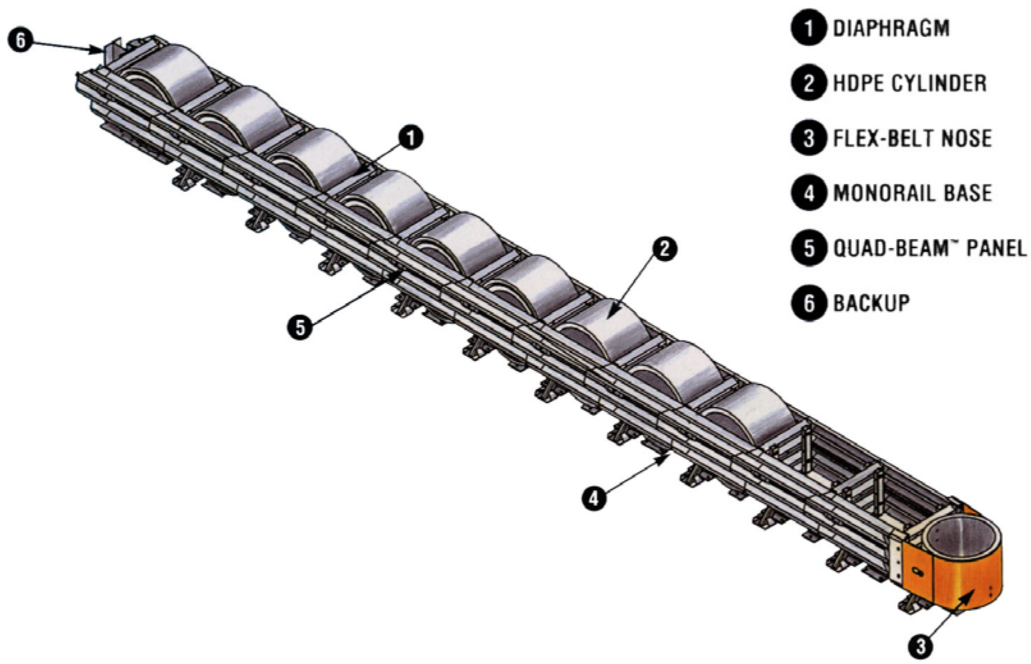
The main components of the QUEST include a ground-anchored backup assembly, two ground-anchored front anchors, two front rails, two rear rails, nose, trigger assembly, sled, diaphragm, bridge and panel assemblies. All components are galvanized to resist corrosion in accordance with ASTM standards. The series of W-beam panels are supported by the diaphragms with a trigger mechanism at the nose which, when hit, releases a "front assembly" to absorb the energy of impact. The system can be preassembled and moved to the installation site or can be assembled on-site.

The QUEST is a proprietary system and, as such, must be purchased or obtained through competitive bidding with equally suitable alternate systems such as the standard QuadGuard and the TRACC.

**(5) QuadGuard Elite.** The QuadGuard Elite (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-57) is a proprietary system and can be used for unidirectional or bidirectional traffic. The QuadGuard Elite is a nongating system and is intended for use to terminate roadside barrier of various types and other obstructions up to 2.3 m (90 in) wide. When used for bidirectional traffic, a FHWA approved transition is required in the event of a reverse direction impact at the rear of the system and is incidental to the QuadGuard Elite.

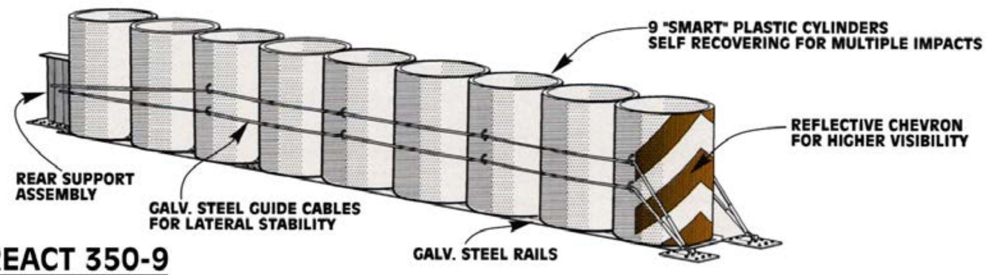
The QuadGuard Elite is a low maintenance/self restoring crash cushion that uses self-restoring high density plastic cylinders in place of crushable cartridges used in the standard QuadGuard. However, many of the components are identical to those used in the standard or LMC systems.

The QuadGuard Elite is a proprietary system and, as such, must be purchased or obtained through competitive bidding with equally suitable alternate systems such as the REACT 350 and the SCI100GM.

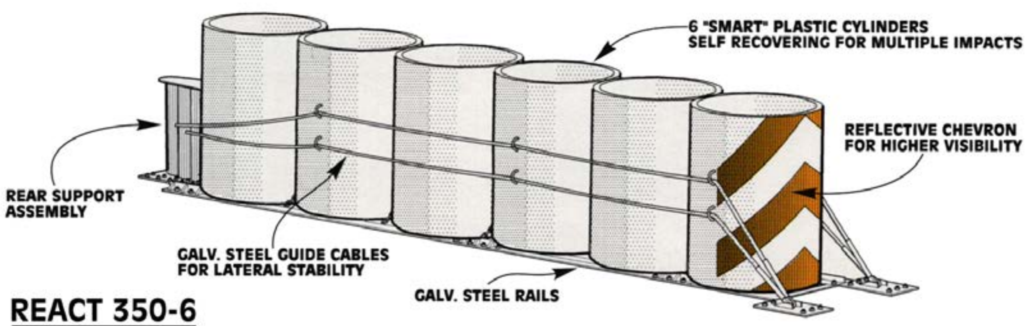


**(6) REACT 350.** The REACT 350 (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-26B) is a proprietary, non-gating crash cushion designed to terminate concrete median barrier and other narrow fixed objects from 0.9 m (3 ft) to 1.5 m (5 ft) wide. This system is designed in three different performance levels: REACT 350-9, REACT 350-6 and REACT 350-4. Each level corresponds to a different test speed. The REACT 350 is self restoring, at least to 90% according to the manufacturer.

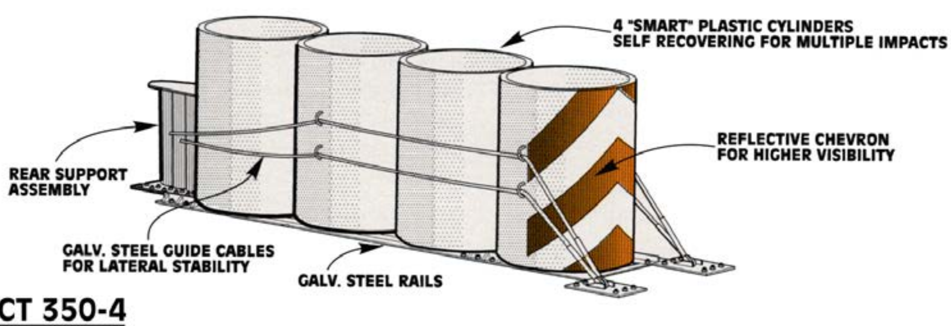
The REACT 350 is composed of high molecular weight and high density polyethylene cylinders of varying wall thickness. Each cylinder is 910 mm (36 in) in diameter and 1220 mm (48 in) high. Two 25.4 mm (1 in) cables are located on each side of the attenuator to provide redirection in side impacts. These cables are connected to anchor plates at the front of the REACT 350 and to a backup assembly at the rear of the unit. The REACT 350 unit rests on a steel support structure and is stiffened laterally at the back of three chain assemblies attached to rods in the support structure on each side and to steel plates located between cylinders. When used for bidirectional traffic, FHWA approved transitions are required in the event of a reverse direction impact at the rear of the system.




REACT 350-9




REACT 350-6



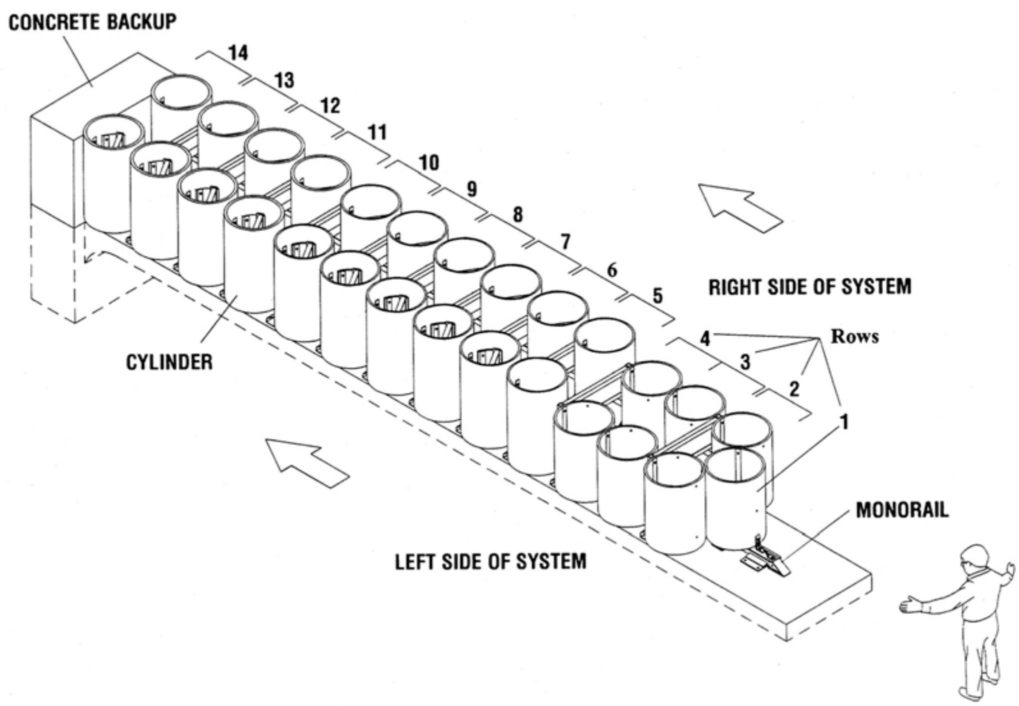

REACT 350-4

**(7) REACT 350 (60").** The REACT 350 (60") (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-73) is a redirective, non-gating, low maintenance/self restoring crash cushion. This system is capable of shielding hazards up to 1.5 m (5 ft) wide.

The REACT 350 (60") consists of 27 cylinders in 14 rows attached to a monorail via diaphragms. After a design impact as described in NCHRP 350, the system has the ability to recover a major portion of its shape, position and energy absorbing capability.

The REACT 350 (60") utilizes various cylinder wall thicknesses to accommodate both light cars and heavier, high center-of-gravity vehicles. The system can be mounted to a new or existing concrete backup.

Since the REACT 350 and REACT 350 (60") are proprietary, it should be acquired on the basis of competitive bidding with other equally suitable systems such as the QuadGuard Elite and the SCI100GM.

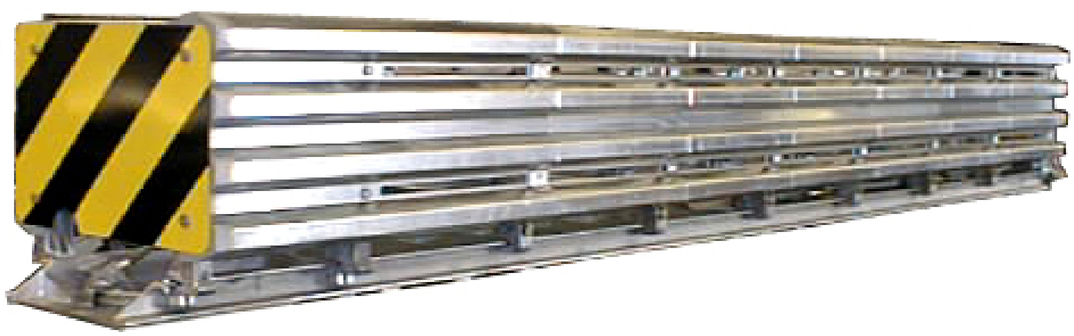


**(8) SCI100GM and SCI70GM.** The SCI100GM system (NCHRP 350 Approved, TL-3, FHWA Acceptance Letter CC-85) and SCI70GM (NCHRP 350 Approved, TL-2, FHWA Acceptance Letter CC-85A) can be used for unidirectional or bidirectional traffic. The SCI100GM and SCI70GM are redirective, nongating systems and are intended for use to terminate median barrier. When used for bidirectional traffic, an FHWA approved transition is required in the event of a reverse direction impact at the rear of the system and is incidental to the SCI100GM and SCI70GM systems.

These redirective, non-gating crash cushions are 850 mm (34 in) high, with a length of 6550 mm (21.5 ft) for the SCI100GM and a length of 4118 mm (13.5 ft) long for the SCI70GM. Their main components include base and side frame assemblies fabricated of mild steel tubing, a front sled assembly, and a series of 10-gauge galvanized Grade 60 steel side panels mounted to collapsing steel frames and a shock arresting cylinder. A 28.6 mm (1.125 in) diameter steel cable is attached to the front sled assembly and is then routed around a front sheave to dual sheave assemblies located at the back of the attenuator (one at either end of the shock arresting cylinder). The SCI70GM is three bays shorter than the SCI100GM and the cylinder stroke was reduced accordingly. The units telescope backward upon frontal impact and generate stopping force from a combination of friction between the cable and the non-rotating sheaves, acceleration of the attenuator's masses, crush factors in the body and frame of the vehicle, and the variable resistance created by the shock arresting cylinder as it compresses between the rear sheave assemblies by the tensioned cable. The base unit is anchored to the mounting substrate with 48 bolts for the SCI100GM and 34 bolts for the SCI70GM. Testing was performed on a unit mounted on a concrete pad with galvanize Grad B7 all-thread rods 19 mm (0.75 in) in diameter and 178 mm (7 in) long. These rods were inserted into 22.2 mm (0.875 in) diameter holes and set with epoxy.

The transition designs are acceptable when the SCI100GM or SCI70GM is connected to a solid concrete barrier or backup. When attached to W-beam or Thrie-beam median barrier, that barrier must include an acceptable transition design, such as RC-50M, to redirect vehicles impacting from the backside and to prevent their snagging on the back corner of the attenuator.

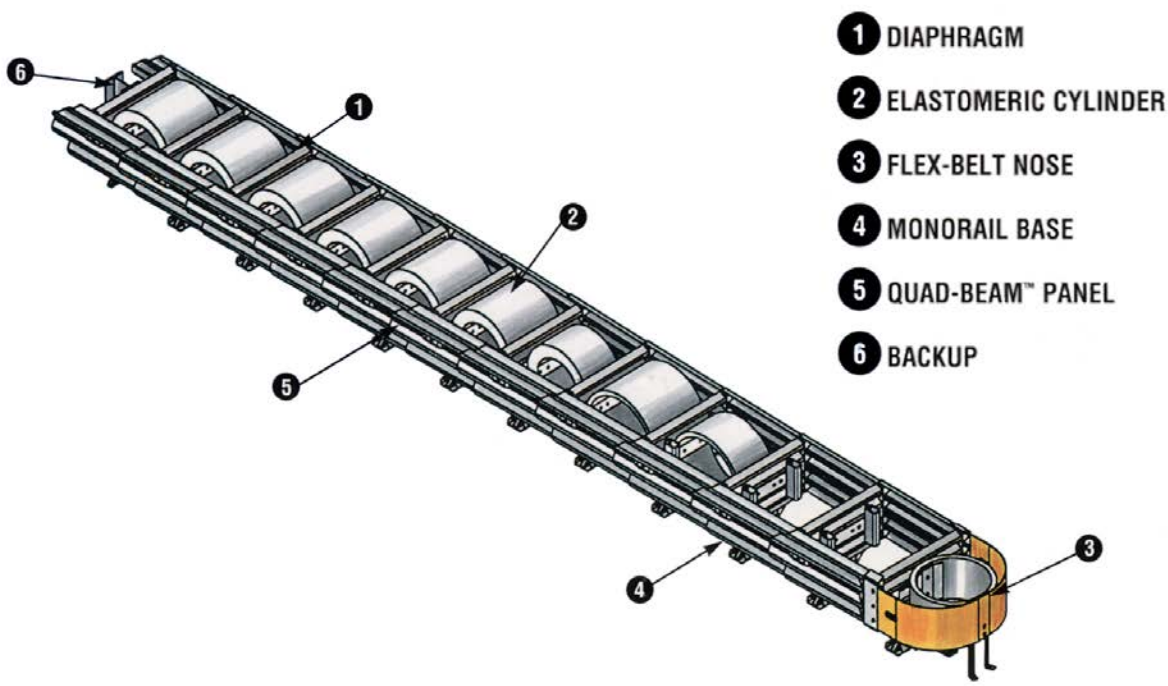
The SCI100GM and SCI70GM are proprietary systems and, as such, must be purchased or obtained through competitive bidding with equally suitable alternate systems such as the QuadGuard Elite and the REACT 350.



**(9) QuadGuard LMC.** The QuadGuard LMC (NCHRP 350 approved, TL-3, FHWA Acceptance Letter CC-43) is a proprietary system and can be used for unidirectional or bidirectional traffic. The QuadGuard LMC is a nongating system and is intended for use to terminate roadside barrier of various types and other obstructions up to 2.3 m (90 in) wide. When used for bidirectional traffic, an FHWA approved transition is required in the event of a reverse direction impact at the rear of the system and is incidental to the QuadGuard LMC system.

The QuadGuard LMC is a low maintenance crash cushion that uses self-restoring elastomeric cylinders in place of crushable cartridges used in the standard QuadGuard. However, several parts are identical to those used in the standard or wide systems. It is recommended for use in potentially high frequency impact areas.

The QuadGuard LMC is a proprietary system and, as such, must be purchased or obtained through competitive bidding with equally suitable alternate systems such as the REACT 350 and the SCI100GM.



**6. Type VI – Gating, Non-Redirective Crash Cushion Systems.**

**a.** Description. These systems include a group of unrestrained barrels partially filled with sand and a crash cushion system filled with water. The energy of an impacting vehicle is dissipated by a transfer of the vehicle's momentum to the mass of the sand barrels or water-filled crash cushions. These systems can be used to shield a narrow or wide obstruction. However, they are not designed to redirect vehicles for side impacts.

**b.** Application. Appropriate arrangements of sand filled barrels may be used to shield barrier walls up to 4.0 m (13 ft) wide, gore areas and other fixed objects in low frequency impact areas. Sand barrels are not designed to redirect vehicles for side impacts; consequently, modules near the rear of the array should be carefully placed to minimize the likelihood of a motorist striking the corner of the object being shielded.

Recommended locations of the water filled crash cushion system (ABSORB 350) are gore areas, ramps and other locations where penetration of an errant vehicle is not likely to cause a crash in opposing traffic lanes, or impacts with workers behind the barrier. This device should only be used in locations where non-redirection is appropriate and is not to be used in medians with opposing traffic unless the device is located outside the clear zone for both directions. Vehicle penetration is likely to occur for angle hits from the nose to near the mid-point of the array, and penetration/override of the system is possible for high-speed, high angle impacts near the rear of the device. Also note that proper anti-freezing agents must be used when the ABSORB 350 is used in areas where low temperature can be anticipated.

**c.** Approved Systems. Proprietary Type VI (NCHRP 350 approved, TL-3) crash cushion systems include:

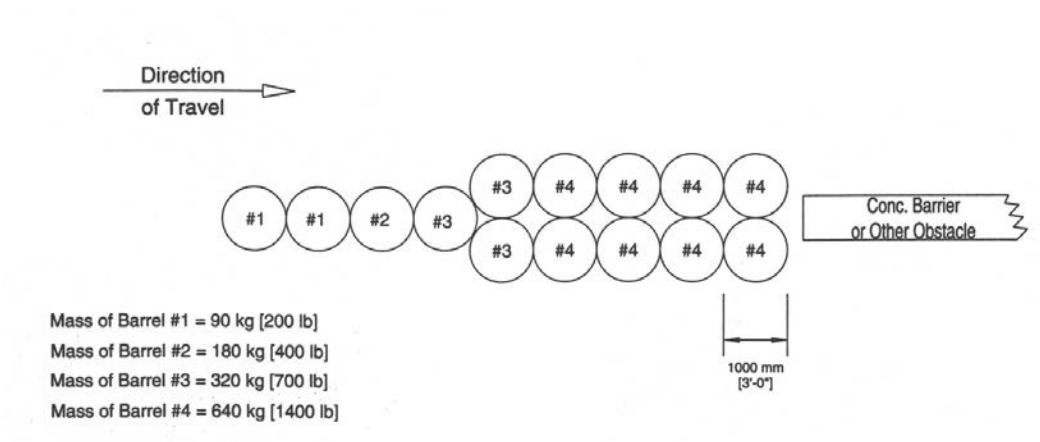
- Sand Filled
  - Energite III Module (FHWA Acceptance Letter CC-29)
  - Fitch Universal Module (FHWA Acceptance Letter CC-28)
  - Traffix (FHWA Acceptance Letter CC-52)

- Water Filled
  - ABSORB 350

**(1) Energite III Module.**
**(2) Fitch Universal Module.**
**(3) Traffix.**

Although there are differences in the parts that comprise the individual modules of each system, the overall size and weight of the modules are very similar. Module size has been standardized at 914 mm (36 in) diameter. Standard module weights are 100 kg (220 lb), 200 kg (440 lb), 300 kg (660 lb), 650 kg (1435 lb) and 950 kg (2100 lb). No back-up structure or wall is required for these devices since the force that a vehicle exerts on the individual modules is not transmitted through the cushion. These systems are intended to protect wide fixed objects in low frequency impact areas.

Since these sand filled crash cushion systems are proprietary, they should be acquired on the basis of competitive bidding with other equally suitable alternate, non-redirective (Type VI) systems such as water filled crash cushions (ABSORB 350).




**(4) ABSORB 350.** The ABSORB 350 (NCHRP approved, TL-2 and TL-3, FHWA Acceptance Letter CC-66A and CC-66) is a non-redirective, gating water filled crash cushion primarily intended to shield the approach ends of temporary concrete barrier in general and Quick Change Median Barrier (QMB) segments in particular. The water filled crash cushion may also be used to shield permanent concrete barrier at appropriate locations.

The ABSORB 350 system consists of a nosepiece assembly followed by five, eight or nine element assemblies, and a transition/attachment assembly. Two types of element assemblies must be alternated when installed. Both types are made from low-density polyethylene and have internal structural components and connection hardware fashioned from ASTM A-36 mild steel. These elements are 800 mm (32 in) tall and 610 mm (24 in) wide. When empty, the elements assemblies weigh 48 kg (106 lb) each. When filled with approximately 300 L (79 gal) of water, they weigh 315 kg (694 lb). The first element in an array must be kept empty to ensure proper performance. All other elements must be filled with water. The eight-element and nine-element TL-3 designs are 8.2 m (27 ft) long and 9.2 m (30 ft) long, respectively; the five-element TL-2 design is 5.2 m (17 ft) long.

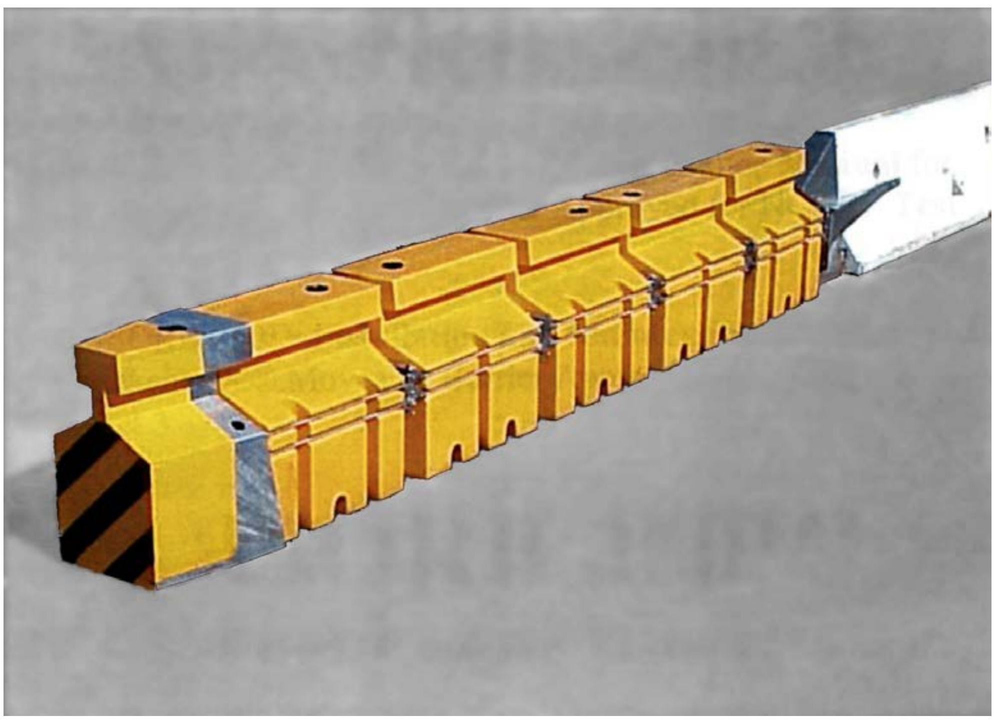
The ABSORB 350 TL-3 designs may be considered for use on the NHS as follows:

- Quick-Change Moveable Median Barrier (QMB). The TL-3 design consists of the nosepiece assembly, eight ABSORB 350 elements and the leading top edge of the first QMB unit tapered as shown on the installation manual.

- F-Shape Median Barrier (Permanent and Temporary). The TL-3 design consists of the nosepiece assembly, nine ABSORB 350 elements and the special attachments/transition assembly (for attachment to standard concrete barrier). The F-shape barrier sections must have a minimum length of 3.6 m (12 ft) to use the ABSORB 350.

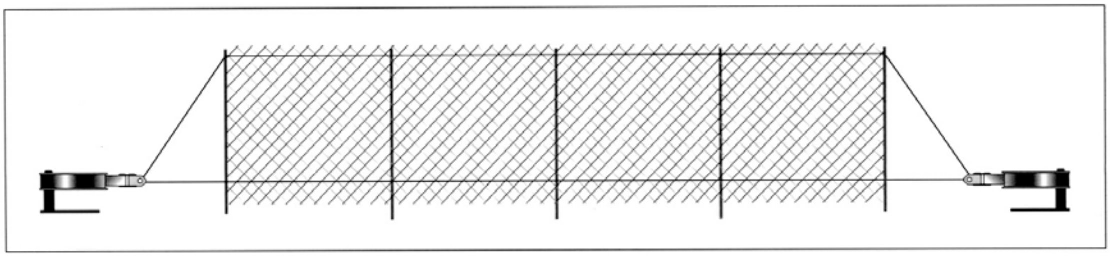
The ABSORB 350 TL-2 design consists of the nosepiece assembly, five ABSORB 350 elements and a special attachment/transition assembly (for attachment to standard concrete barrier). The TL-2 design is acceptable for use on the NHS for speeds less than 70 km/h (45 mph). When attached to QMB barrier, the first QMB unit must be tapered as noted above.

The ABSORB 350 is a proprietary system, and as such, must be purchased or obtained through competitive bidding with an equally suitable alternate, non-redirective (Type VI) system such as sand barrels.

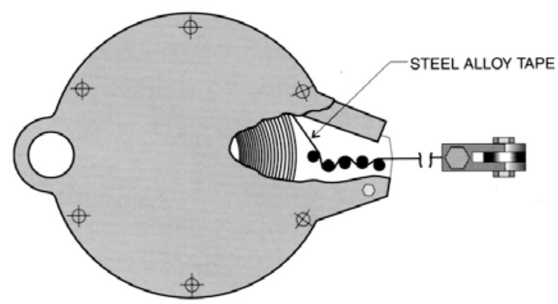


**7. Miscellaneous Systems.** The DRAGNET (NCHRP 350 approved, FHWA Acceptance Letter B-15) is not normally used except in special conditions. The DRAGNET system is an arresting type of attenuator that provides a safe, controlled stop with a minimum of damage to the impacting vehicle, regardless of speed or vehicle size. The DRAGNET system, with its ability to span any road width, is ideal for utilization in work zones.

The DRAGNET should be used under unique circumstances on a case by case basis, since it is proprietary and a sole source item.



The **DRAGNET VEHICLE ARRESTING BARRIER**, (or "VAB") consists of a net with a continuous cable running through the top and bottom, both ends of which are attached to customized "enegry absorbers". These energy absorbers contain a spool of coiled steel alloy tape. The tape is lead through a series of offset steel pins contained in the energy absorbers. As the net is hit, the metal tape is pulled through the pins, constantly bending and straightening the tape.




**ENERGY ABSORBER**

This metal deformation causes the smooth, safe deceleration of the vehicle. By changing the gauge of the metal tape and configuration of the pins, a barrier can be designed to handle any situation from an 1,800 pound car to an 80,000 pound tractor trailer.

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**E. Design Considerations and Criteria.** Common applications of end treatments and crash cushions include roadside and median installations to terminate barriers for protection of potential impacts with fixed "point" objects. Obstacles such as bridge abutments, bridge piers, fixed-base overhead sign bridge supports and other obstacles of similar geometry (short in the longitudinal direction) represent examples where crash cushions can be effectively used to reduce a potential serious impact.

Impact attenuating devices are designed to restrain vehicle impacts under what may be termed "normally expected impact modes". That is, the vehicle is expected to be in stable on-the-surface mode at impact although obviously out of the normal travel lane. They are designed to mechanically restrain an impacting vehicle through a force line at expected bumper height when the vehicle is in a wheels-on-the-ground mode.

The approach to impact attenuating devices needs to be level (1V:10H or flatter). Also the area behind the terminal should be free of significant fixed objects for those systems that are designed to move laterally. If a clear runout path is not attainable, this area should be at least similar in character to upstream, unshielded roadside areas.

Refer to Table 12.10 for design guidelines for impact attenuating devices. Further discussion of this criteria can be found in the AASHTO Roadside Design Guide, Chapter 8.

**F. Approval Policy.** There are several levels of consideration for the approval of impact attenuating devices on Department projects. Currently, all of the systems listed above have been accepted based on crash testing as per NCHRP Report 350 or MASH. As outlined in Section 12.9.A, all new installations of impact attenuating devices must meet the criteria of NCHRP Report 350 or MASH. The following steps in sequence shall ensure uniform application of these safety devices, how to handle requests to the Department and provide a means for quality control statewide.

**1.** New Products:

**a.** The Department has a formal Product Evaluation (PE) system to coordinate the review of new products. Any new system or major change to an already accepted system should be processed through the PE system (Master Policy Statement #418).

**b.** The Product Evaluation Review Board has the authority to make judgment on the acceptability of a particular system or material. This shall be accomplished through coordination with respective personnel from the Bureaus of Project Delivery and Maintenance and Operations, as well as by the review of appropriate crash data and FHWA status reports.

**c.** Once a product or system is found acceptable, a generic specification or special provision shall be developed to control its use on Department projects. The provisions will have enough latitude to allow for site considerations, such as width and length or the number of bays or barrels. Approved systems shall be listed in Publication 35, *Approved Construction Materials* (Bulletin 15).

**2.** Project Application. Inclusion in a particular project shall be based on the use of the specification including specific site conditions. The manufacturer shall be required to provide shop drawings and, if necessary, design calculations for approval for each site on a project-by-project basis. Concept approval shall be given at the Final Design Office Meeting. For permanent impact attenuating devices, final review shall be made by the District office based on the manufacturer's pre-approved shop drawings by the Bureau of Project Delivery.

# TABLE 12.10
# DESIGN GUIDELINES FOR IMPACT ATTENUATING DEVICES

| | SYSTEM | TERMINAL | CRUSH CUSHION | ENERGY ABSORBING | NON-ENERGY ABSORBING | NONGATING | GATING | UNIDIRECTIONAL | BIDIRECTIONAL | IF BIDIRECTIONAL MINIMUM MEDIAN WIDTH | TRANSITIONS TO: SEE TRANSITION CODES BELOW | | | | ADDITIONAL INFO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | STRONG POST W BEAM | WEAK POST W BEAM | CMB (F-SHAPE) | DOUBLE FACED W BEAM | |
| Type I | ANCHORED BACKSLOPE | **X** | | **X** | | **X** | | **X** | | | 1A | N/A | N/A | N/A | SEE RC-54M FOR DETAILS |
| Type II | FLEAT-350 | **X** | | **X** | | | **X** | **X** | | | 1A | 3C | N/A | N/A | REDIRECTION BEGINS BEYOND POST #3<br>L = 11.43 m (37.5 ft) |
| | FLEAT-SP | **X** | | **X** | | | **X** | **X** | | | 1A | 3C | N/A | N/A | REDIRECTION BEGINS BEYOND POST #3<br>L = 11.43 m (37.5 ft) |
| | X-Tension | **X** | | **X** | | **X** | | **X** | **X** | 0.67 m (2.2 ft) | 1A | 3C | N/A | N/A | REDIRECTION BEGINS BEYOND POST #1<br>L = 13.17 m (43.21 ft) |
| | ET-PLUS with SYTP | **X** | | **X** | | | **X** | **X** | | | 1A | 3C | N/A | N/A | REDIRECTION BEGINS AT POST #3<br>FROM THE APPROACH END<br>L = 15.24 m (50 ft) |
| | SKT-350 | **X** | | **X** | | | **X** | **X** | | | 1A | 3C | N/A | N/A | REDIRECTION BEGINS BEYOND POST #3<br>L = 15.24 m (50 ft) |
| | BEAT-SSCC | **X** | | **X** | | | **X** | **X** | | | N/A | N/A | 1A | N/A | REDIRECTION BEGINS AT POST #3<br>FROM THE APPROACH END<br>L = 8.5 m (28 ft) to 13.4 m (44 ft) |
| | SKT-SP | **X** | | **X** | | | **X** | **X** | | | 1A | 3C | N/A | N/A | REDIRECTION BEGINS BEYOND POST #3<br>L = 11.43 m (37.5 ft) |
| Type III | SRT-350 | **X** | | | **X** | | **X** | **X** | | | 1A | 3C | N/A | N/A | REDIRECTION BEGINS BEYOND POST #3<br>L = 11.43 m (37.5 ft) |
| Type IV | CAT-350 | **X** | **X** | **X** | | | **X** | **X** | **X** | 3.0 m (10 ft) | N/A | N/A | 3B | 2D | REDIRECTION BEGINS AT POST #4<br>FROM THE APPROACH END<br>L = 9.6 m (31.5 ft) + Transition |
| | Brakemaster 350 | **X** | **X** | **X** | | | **X** | **X** | **X** | 3.0 m (10 ft) | N/A | N/A | 2D | 2D | REDIRECTION BEGINS BEYOND POST #3<br>L = 9.6 m (31.5 ft) |
| | ADIEM | **X** | **X** | **X** | | | **X** | **X** | **X** | 3.0 m (10 ft) | N/A | N/A | 1A | 2D | REDIRECTION BEGINS 4.2 m (14 ft)<br>FROM THE APPROACH END<br>L = 9.14 m (30 ft) + Connection |
| | FLEAT-MT | **X** | | **X** | | | **X** | **X** | **X** | 3.6 m (12 ft) | N/A | N/A | 2D | 2D | REDIRECTION BEGINS BEYOND POST #3<br>L = 11.43 m (37.5 ft) |

## TABLE 12.10 (CONTINUED)
## DESIGN GUIDELINES FOR IMPACT ATTENUATING DEVICES

| | SYSTEM | TERMINAL | CRUSH CUSHION | ENERGY ABSORBING | NON-ENERGY ABSORBING | NONGATING | GATING | UNIDIRECTIONAL | BIDIRECTIONAL | IF BIDIRECTIONAL MINIMUM MEDIAN WIDTH | TRANSITIONS TO: SEE TRANSITION CODES BELOW | | | | ADDITIONAL INFO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | STRONG POST W BEAM | WEAK POST W BEAM | CMB (F-SHAPE) | DOUBLEFACED W BEAM | |
| Type V- Standard | QuadGuard | | X | X | | X | | X | X | 0.6 m (2 ft) | N/A | N/A | 2D | 2D | ALSO AVAILABLE FOR TL-1 AND TL-2<br>L = 6.3 m (20.75 ft) + Transition<br>W = 0.6 m (2 ft) |
| Type V- Standard | TRACC | | X | X | | X | | X | X | 0.6 m (2 ft) | N/A | N/A | 2D | 2D | ALSO AVAILABLE FOR TL-2<br>L = 6.5 m (21.25 ft) + Transition<br>W = 0.6 m (2 ft) |
| Type V- Standard | SHORTRACC | | X | X | | X | | X | X | 0.6 m (2 ft) | N/A | N/A | 2D | 2D | L = 4.33 m (14.21 ft) + Transition<br>W = 0.6 m (2 ft) |
| Type V- Standard | WIDETRACC | | X | X | | X | | X | X | 1.47 m (4.83 ft) | N/A | N/A | 2D | 2D | L = 6.5 m (21.25 ft) + Transition<br>W = 1.47 m (4.83 ft)<br>Can be customized to protect any width |
| Type V- Standard | FASTRACC | | X | X | | X | | X | X | 0.6 m (2 ft) | N/A | N/A | 2D | 2D | L = 7.924 m (26 ft) + Transition<br>W = 0.6 m (2 ft) |
| Type V- Standard | TAU-II | | X | X | | X | | X | X | 0.6 m (2 ft) | N/A | N/A | 2D | 2D | ALSO AVAILABLE FOR TL-2<br>L = 7.7 m (25.42 ft) + Transition<br>W = 0.6 m (2 ft) |
| Type V- Standard | QUEST | | X | X | | X | | X | X | 0.6 m (2 ft) | N/A | N/A | 2D | 2D | ALSO AVAILABLE FOR TL-2<br>L = 5.74 m (18.75 ft) + Transition<br>Can be customized to protect widths up to 0.9 m (3 ft) |
| Type V - Low Maintenance / Self Restoring | QuadGuard Elite | | X | X | | X | | X | X | 0.6 m (2 ft) | N/A | N/A | 2D | 2D | ALSO AVAILABLE FOR TL-2<br>L = 10.8 m (36 ft) + Transition<br>W = 0.6 m (2 ft)<br>Can be customized to protect widths up to 2.3 m (90 in) |
| Type V - Low Maintenance / Self Restoring | REACT 350 | | X | X | | X | | X | X | 0.9 m (3 ft) | N/A | N/A | 2D | 2D | ALSO AVAILABLE FOR TL-1 AND TL-2<br>W = 0.9 m (3 ft)<br>L = 9.4 m (31 ft) + Transition |
| Type V - Low Maintenance / Self Restoring | REACT 350 (60") | | X | X | | X | | X | X | 1.5m (5 ft) | N/A | N/A | N/A | N/A | L = 8.9 m (29 ft) + Transition<br>Attached to a 1.5 m (5 ft) wide reinforced and anchored concrete backup. |
| Type V - Low Maintenance / Self Restoring | SCI100GM<br>SCI70GM | | X | X | | X | | X | X | 0.6 m (2.0 ft) | N/A | N/A | 2D | 2D | SCI100GM: L = 6.6 m (21.5 ft) + Transition<br>SCI70GM: L = 4.1 m (13.5 ft) + Transition<br>W = 0.6 m (2 ft) |
| Type V - Low Maintenance / Self Restoring | QuadGuard LMC | | X | X | | X | | X | X | 0.9 m (3 ft) | N/A | N/A | 2D | 2D | L = 9.8 m (32 ft) + Transition<br>W = 0.9 m to 2.3 m (3 ft to 7.5 ft) |

## TABLE 12.10 (CONTINUED)
## DESIGN GUIDELINES FOR IMPACT ATTENUATING DEVICES

| | SYSTEM | TERMINAL | CRUSH CUSHION | ENERGY ABSORBING | NON-ENERGY ABSORBING | NONGATING | GATING | UNIDIRECTIONAL | BIDIRECTIONAL | IF BIDIRECTIONAL MINIMUM MEDIAN WIDTH | TRANSITIONS TO: SEE TRANSITION CODES BELOW | | | | ADDITIONAL INFO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | STRONG POST W BEAM | WEAK POST W BEAM | CMB (F-SHAPE) | DOUBLEFACED W BEAM | |
| Type VI | Energite III | | **X** | **X** | | | **X** | **X** | **X** | 2.0 m (6.5 ft) | N/A | N/A | 1B | 1B | CUSTOM DESIGNS USED ESPECIALLY FOR WIDE HAZARDS (i.e., GREATER THAN 2.4 m (8 ft) WIDE) |
| | Fitch Universal | | **X** | **X** | | | **X** | **X** | **X** | 2.0 m (6.5 ft) | N/A | N/A | 1B | 1B | CUSTOM DESIGNS USED ESPECIALLY FOR WIDE HAZARDS (i.e., GREATER THAN 2.4 m (8 ft) WIDE) |
| | Traffix | | **X** | **X** | | | **X** | **X** | **X** | 2.0 m (6.5 ft) | N/A | N/A | 1B | 1B | CUSTOM DESIGNS USED ESPECIALLY FOR WIDE HAZARDS (i.e., GREATER THAN 2.4 m (8 ft) WIDE) |
| | ABSORB 350 | | **X** | **X** | | | **X** | **X** | **X** | 0.6 m (2.0 ft) | N/A | N/A | 2D | 2D | CUSTOM DESIGNS USED ESPECIALLY FOR WIDE HAZARDS (i.e., GREATER THAN 2.4 m (8 ft) WIDE) |

TRANSITION CODES

1. NO ADDITIONAL PARTS NEEDED
   - A. Attaches Directly to system.
   - B. System is placed in front of hazard offset for bidirectional traffic.

**L = System Length**
**W = System Width**

2. TRANSITION PIECE REQUIRED OR DESIRABLE
   - A. THREE-to-W Transition
   - B. End shoe
   - C. NJ offset panel
   - D. FHWA approved transitions

3. TRANSITION SECTION
   - A. 3810 mm (12 ft, 6 in) section of strong post W-beam guide rail
   - B. Any federally approved transition section from W-beam guide rail to CMB or concrete wall
   - C. 15.2 m (50 ft) sections of 2-S guide rail
   - D. 3810 mm (12 ft, 6 in) section of double-faced guide rail

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## 12.10 TEMPORARY BARRIERS

**A. Introduction.** Temporary barriers are devices designed to help prevent penetration by vehicles while minimizing injuries to vehicle occupants, and to protect workers, bicyclists, and pedestrians.

The four primary functions of temporary barriers are to:

- Keep vehicular traffic from entering work areas, such as excavations or material storage sites;
- Separate workers, bicyclists, and pedestrians from motor vehicle traffic;
- Separate opposing directions of vehicular traffic; and
- Separate vehicular traffic, bicyclists, and pedestrians from the work area such as false work for bridges and other exposed objects.

If temporary barriers are used to channelize vehicular traffic, standard delineations, pavement markings, or channelizing devices should supplement temporary barrier for improved daytime and nighttime visibility. The delineation color is to match the applicable pavement marking color.

Temporary barriers, including their end treatments, are to be crashworthy. To mitigate the effect of striking the upstream end of a temporary traffic barrier, install the end by flaring until the end is outside the acceptable clear zone or by providing crashworthy end treatments.

Use of longitudinal temporary barriers should be based on an engineering analysis. A number of factors such as traffic volume, traffic operating speed, offset, and duration affect barrier need within work zones. However, improper use of temporary barriers can provide a false sense of security for both the motorist and the worker. Therefore, care must be taken in their design, installation, and maintenance.

Several designs for temporary barriers are available that may be appropriate for work-zone applications. Although no consensus on specific warrants exists, barriers are usually justified for bridge widening; shielding of roadside structures; roadway widening (especially with edge dropoffs); and for separating two-lane, two-way traffic on one roadway of a normally widened facility.

The material and construction requirements for temporary barriers are described in:

- Publication 408, *Specifications*, Section 627 - Temporary Barrier
- Publication 408, *Specifications*, Section 628 - Reset Temporary Barrier

Publication 35, *Approved Construction Materials* (Bulletin 15), lists the approved temporary barriers, including:

- Precast Concrete Barriers and Glare Screens
- Steel Barriers
- Water-Filled Barriers

The approved temporary barriers listed in Bulletin 15 are further categorized for use by Test Level. As discussed previously in Section 12.9.A, the nominal speed for Test Level 2 (TL-2) is 70 km/h (44 mph) and 100 km/h (62 mph) for Test Levels 3 through 6 (TL-3 through TL-6).

Each of the approved temporary barriers listed in Bulletin 15 is described by name, type, material, tested height, tested deflection, and reference number (FHWA Acceptance Letter). The deflection distances shown resulted from controlled crash tests at a 25 degree impact angle. The severe impact angle crash test may not be representative of actual field conditions during construction.

Additional information is found below about temporary barriers approved for use on PennDOT projects.

**B. Temporary Barrier - Concrete.**

**1. PennDOT F-Shape Temporary Concrete Barrier.** The PennDOT F-Shape Temporary Concrete Barrier (NCHRP 350 approved, TL-3, FHWA Acceptance Letter B-79) is an 860 mm (34 in) high modified F-shape portable barrier in segment lengths of 3.6 m (12 ft). The use of a 127 mm (5 in) vertical reveal in lieu of the standard 76 mm (3 in) dimension increases the total barrier height to the 860 mm (34 in) noted above and raises the slope break-point to 300 mm (12 in). The base width is 610 mm (24 in) and the barrier tapers to a 230 mm (9 in) top width.

The connection between segments is a 300 mm (12 in) long × 690 mm (27 in) high × 13 mm (0.5 in) thick steel plate that fits loosely into a vertical slot formed into the end of each segment. The segments are tightly butted together during installation.

The design deflection distance of PennDOT's F-Shape Temporary Concrete Barrier was reported to be 2.555 m (8.4 ft).

When this barrier is used as a permanent barrier, the lower 50 mm (2 in) of the base will be set into the roadway surface, thereby resulting in a barrier having the standard F-shape profile that can be expected to have little or no deflection under normal impacts.

**2. Other Temporary Concrete Barriers.** Bulletin 15 lists other approved temporary concrete barrier systems (NCHRP 350 approved, TL-3) that may be used on PennDOT projects. The listing in Bulletin 15 includes the systems' names, tested heights, tested deflections, and reference numbers (FHWA Acceptance Letters).

**3. Single Face Concrete Barrier.** Single face concrete barrier is never appropriate for temporary barrier or roadside (shoulder) barrier unless the barrier has full back support as shown in Publication 72M, *Roadway Construction Standards*.

Single face concrete barrier may be used if it is part of a moment slab. Design details should be approved by the Department prior to inclusion in the project plans.

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**C. Temporary Barrier - Steel.**

**1. Vulcan Barrier System.** The Vulcan Barrier System (NCHRP 350 approved, TL-3, FHWA Acceptance Letter B-134) is a proprietary, longitudinal, nongating barrier for use as a temporary barrier (portable longitudinal barrier) in work zones. Each segment has a nominal length (pin to pin) of 4115 mm (13.5 ft), a height of 813 mm (32 in) and a width of 546 mm (21.5 in). The mass (weight) of each segment is approximately 395 kg (871 lb). The upper portion incorporates standard thrie-beam guide rail panels, and the bottom incorporates sheet metal rub rails.

Five steel bulkheads tie the sides of the Vulcan together. The end bulkheads incorporate vertically aligned holes to facilitate pinning Vulcan segments together. The center bulkhead incorporates a lifting table for assembly and transport. A stiffener plate also runs the length of each segment. Vulcan sections are pinned together using 51 mm (2 in) diameter steel connecting pins. When installed in straight configurations, an optional steel space can be installed in the connecting joint to reduce lateral deflection. The Vulcan's end bulkheads can also be used to connect an appropriate crash cushion to a Vulcan installation.

In its unanchored configuration, at least 23 segments of Vulcan (92 m (302 ft) must be attached to each end of unanchored Vulcan barriers to establish a "beginning of length of need" (BLON) point and to limit the barrier's dynamic deflection within the length of need to that noted in the crash test. For an installation of the Vulcan in an unanchored configuration, the minimum length is 64 sections. The freestanding, unshielded end of this design is not crashworthy and requires either shielding with a suitable anchored impact attenuator for uni-directional applications or introduction outside the appropriate clear zone. Anticipated lateral deflection of the Vulcan for anchored and unanchored configurations must be communicated to end users so effective field installations can be designed.

The moveable Vulcan Barrier System, as described above, had a design deflection distance of 1.8 m (6 ft).

Two other Vulcan Barrier Systems approved for use as temporary barrier are: (1) moveable Vulcan System Minimum Deflection System (NCHRP 350 approved, TL-3, FHWA Acceptance Letter B-134C) with a deflection distance of 300 mm (12 in); and (2) Vulcan System (NCHRP 350 approved, TL-4, FHWA Acceptance Letter B-134D) with a deflection distance of 1.143 m (3.75 ft).

**2. Zoneguard.** The Zoneguard (NCHRP 350 approved, TL-3, FHWA Acceptance Letter B-176A) is a proprietary longitudinal nongating barrier for use as a temporary barrier (portable longitudinal barrier) in work zones. The Zoneguard portable longitudinal barrier system is comprised of 4.2 mm thick (8 gage, 0.165 in thick), ASTM A36 pressed, galvanized steel panels assembled in 15.24 m (50 ft) long sections. Each section is 820 mm (2.69 ft) high with a base width of 700 mm (2.3 ft) and a top beam width of 157 mm (0.52 ft). The Zoneguard has a step 150 mm (0.5 ft) wide on each side just above surface level, which slopes upward to meet the upper beam section. Each section has a mass (weight) of approximately 1406 kg (3097 lb). The base of each 15.24 m (50 ft) long section has twelve rubber feet, 700 mm × 165 mm × 13 mm (2.30 ft × 0.54 ft × 0.043 ft), which are fixed using an adhesive compound.

The complete barrier test installations were each nominally 820 mm (2.69 ft) high, 700 mm (2.3 ft) wide, and 76.2 m (250 ft) long. Tests were conducted for two different anchoring patterns: (1) the standard arrangement which includes anchoring at each end of the barrier and (2) the minimum deflection arrangement which includes anchoring every 10.2 m (33.3 ft) along the barrier. The standard arrangement is anchored at points 500 mm (1.64 ft) and 5.1 m (16.67 ft) from each end on both sides for a total of four anchors per end. These anchors were 38 mm (1.5 in) diameter ASTM 1018 smooth rod, 305 mm (12 in) long and installed 200 mm (8 in) deep into concrete. The minimum deflection Zoneguard arrangement is identical to the standard arrangement described above apart from the addition of the intermediate threaded resin anchors placed in both sides of the "foot" section on 10.2 m (33.3 ft) centers. Alternate anchor designs certified by the manufacturer may be used to provide equal or greater anchorage strength to that provided for the test installations.

When used across a bridge joint, it should be noted that the Zoneguard can accommodate 250 mm (10 in) of movement.

Standard 15.24 m (50 ft) Zoneguard units can be installed on curves down to 244 m (800 ft) radius. Special units can be provided for tighter curves, as well as flared sections. A 13 mm (0.5 in) thick rubber pad on the foot section allows for water drainage off the road surface.

The Zoneguard had a design deflection distance of 1.93 m (6.33 ft) for the standard arrangement and 0.41 m (1.33 ft) for the minimum deflection arrangement. The recorded deflections were the maximum dynamic deflections of the top of the barrier.

**3. BarrierGuard 800.** The BarrierGuard 800 (NCHRP 350 approved, TL-3, FHWA Acceptance Letter B-131) is a proprietary, longitudinal, nongating barrier for use as a temporary barrier (portable longitudinal barrier) in work zones. The BarrierGuard 800 is constructed from 5 mm (0.2 in) thick A36 galvanized steel panels assembled in 12 m (40 ft) segments. Each segment is 800 mm (31.5 in) high with a base width of 540 mm (21.5 in) and a top width of 230 mm (9 in). The BarrierGuard 800 has a sloped face with a "step" 255 mm (10 in) above the ground. Each segment weighs approximately 1080 kg (2380 lb). The system is anchored at each end and at a point approximately 6 m (1.8 ft) in from each end with a total of sixteen 24 mm (0.95 in) diameter by 460 mm (18 in) long threaded steel rods (4 rods at each anchor location) in a minimum of 75 mm (3 in) of asphaltic concrete over at least 200 mm (8 in) of compacted dense graded aggregate. Alternative designs certified by the manufacturer to provide anchorage equal to or better than the tested design may also be used.

The BarrierGuard 800 described above should account for a design deflection distance of 1.5 m (4.9 ft).

A second system, the BarrierGuard 800 - Minimum Deflection System (NCHRP 350 approved, TL-4, FHWA Acceptance Letter B-158), is a modification of the previously approved BarrierGuard 800 system and is designed to minimize the dynamic deflection of the system. Minimum Deflection systems are valuable in application where there is only limited space available, such as bridge deck repairs/replacement projects. To achieve this reduction in deflection, the BarrierGuard 800 - Minimum Deflection System incorporates the following modifications to the standard BarrierGuard 800:

- The barrier is anchored every 6 m (20 ft) with either joint anchors or intermediate anchors.
- The system consists of either 6 m (20 ft) or 12 m (40ft) BarrierGuard 800 sections.
- The barrier sections are fitted with a T-top attachment to aid in the redirection and stability of the vehicle after impact. The T-top measures 473 mm (15 5/8 in) wide and 121 mm (4 3/4 in) tall. The effective width of the top section with the T-top installed is 474 mm (18 5/8 in). With the T-top installed the barrier height is 921 mm (36 in) and the mass of each 6 m (20 ft) BarrierGuard 800 section is approximately 135 kg/m (90 lb/ft) or 800 kg (1800 lb). The mass of a similar 12 m (40 ft) section is approximately 135 kg/m (90 lb/ft) or 1600 kg (3600 lb).

The BarrierGuard 800 - Minimum Deflection System should account for a design deflection distance of 305 mm (12 in).

**4. Mobile Barrier Trailer.** The Mobile Barrier Trailer (MBT-1) (NCHRP 350 approved, TL-3, FHWA Acceptance Letter B-178) is an integrated, rigid wall, semi-trailer that is used in conjunction with standard semi-tractors to provide mobile, improved, safety, and work environments for personnel at applicable maintenance, construction, and security sites. It is an extended, mobile, longitudinal barrier that provides a physical and visual wall between passing traffic and the maintenance and construction personnel. With an integrated crash attenuator at the rear, a semi-tractor at the front, and a rigid wall on the side toward passing traffic, the MBT will provide approximately 30.5 m (100 ft) of barrier and protected work area.

The basic trailer is comprised of two platforms and up to three wall sections. The platforms are each 6.4 m (21 ft) in overall length, 2.54 m (100 in) wide and 1.22 m (4 ft) high (riding approximately 1.52 m (5 ft) high with 305 mm (12 in) of ground clearance). The wall sections are each 6.10 m (20 ft) long, 610 mm (24 in) wide, and 1.22 m (4 ft) high (riding approximately 1.52 m (5 ft) high with 305 mm (12 in) of ground clearance). A homogenous 6.4 mm (0.25 in) steel plate is welded to cover the outer side of each wall section. Each wall section abuts up against another of the platforms and is built the same to take an impact from either direction. There are no snag points at the seams. The outer 6.4 mm (0.25 in) plate and associated welds are ground beveled to transition from one to the other.

The MBT, as described above, had a design deflection distance of 0.61 m (2 ft).

**D. Temporary Barrier - Water-Filled.**

**1. Guardian Safety Barrier.** The Guardian Safety Barrier (NCHRP 350 approved, TL-3, FHWA Acceptance Letter B-34E) is a proprietary, longitudinal, nongating barrier for use as a temporary barrier (portable longitudinal barrier) in work zones. The barrier is made of plastic and is fitted with steel tubing.

The Guardian Safety Barrier should account for a design deflection distance of 1.98 m (6.5 ft).

The TL-3 version of the Guardian Safety Barrier requires a specially-made highway kit to be installed according to the manufacturer's drawings and specifications.

**2. Triton Barrier System.** The Triton Barrier System (NCHRP 350 approved, TL-3, FHWA Acceptance Letter B-179 and TL-2, FHWA Acceptance Letter B-21) are proprietary, longitudinal, nongating, water-filled barriers for use as temporary barrier (portable longitudinal barrier) in work zones.

The Triton barrier consists of 1981 mm (78 in) long by 813 mm (32.25 in) high by 533 mm (21.5 in) wide segments of lightweight polyethylene plastic shells designed to accept water ballast. The plastic barrier shell is supplemented by an internal steel framework to provide additional rigidity during handling and impacts. There is also a cable along the top connecting the joints between barrier segments. This cable provides the barrier's tensile capacity during impacts. The barrier is molded in a shape that interacts with an impacting vehicle to reduce its roll, pitch, and yaw.

The exterior dimensions of the Trition Barrier System are the same for TL-2 and TL-3. However, the interior U-bolts at the ends of each module are double-nutted to the interior steel framework in the TL-3 units. Each module is set on two 178 mm (7 in) high plastic pedestals to raise its center of gravity in order to meet TL-3 evaluation criteria. These pedestals are strapped to each individual unit and are also tethered together (in groups of ten) with a braided polyester cord to reduce debris scatter following an impact.

The Triton Barrier System should account for a design deflection distance of 2.7 m (8.9 ft) at TL-2 and over 3.0 m (10 ft) at TL-3.

**3. Yodock Model 2001 Barrier System.** The Yodock Model 2001 Barrier System (NCHRP 350 approved, TL-3, FHWA Acceptance Letter B-97) and Model 2001M Barrier System (NCHRP 350 approved, TL-2, FHWA Acceptance Letter B-97) are proprietary, longitudinal, nongating, water-filled barriers for use as temporary barrier (portable longitudinal barrier) in work zones.

The Yodock Model 2001 Barrier System is 1170 mm (46 in) tall, 610 mm (24 in) wide at the base, and 280 mm (11 in) wide at the top. The individual units are connected at the ends with polyethylene couplers and along the sides by 89 mm × 89 mm × 6.4 mm (3.5 in × 3.5 in × 0.25 in) structural steel tubes supported by steel brackets which extend through two forklift holes in each unit. The steel side tubes are 1830 mm (6 ft) long and spliced with 280 mm (11 in) 64 mm × 64 mm × 6.4 mm (2.5 in × 2.5 in × 0.25 in) steel tubes using two 19 mm (0.75 in) × 114 mm (2.25 in) long Grade 8 hex head bolts. The centerline height of the rails is 706 mm (27 in). Dynamic deflection was reported to be 4.28 m (14.0 ft) for TL-3.

The Yodock Model 2001M Barrier is similar to the Yodock Model 2001 Barrier System, except that it is 813 mm (32 in) tall, 457 mm (18 in) wide at the base, and 203 mm (8 in) wide at the top. Also, the centerline height of the steel rails is 596 mm (23.5 in). Dynamic deflection was reported to be 3.68 m (12.1 ft) for TL-2.

**4. Sentry Water-Cable Barrier System.** The Sentry Water-Cable Barrier System (NCHRP 350 approved, TL-3, FHWA Acceptance Letter B-196) is a proprietary, longitudinal, nongating, water-filled barrier for use as a temporary barrier (portable longitudinal barrier) in work zones. The Sentry Water-Cable Barrier was designed without the need for an external attached structure to meet TL-2 and TL-3 barrier performance. A second design objective was to produce a product with minimal lateral deflection of the barrier. Each section is a freestanding longitudinal wall unit with an approximate width, height, and length of 635 mm × 1092 mm × 2032 mm (25 in × 46 in × 84 in), respectively.

Each section has eleven connecting lugs, five on one end, and six on the opposite end. The four upper lugs on each barrier section contain one each independent corrosion resistant steel wire rope molded into the Sentry Water-Cable Barrier. The four wire rope pieces in each section act similarly to a cable barrier when impacted. A 31.8 mm (1.25 in) diameter steel T-pin drops through the 38.1 mm (1.5 in) diameter holes in the lugs, linking the sections together. The shell of each section is made up of high density polyethylene (HDPE).

Wall sections for the Sentry Water-Cable Barrier are set in position, connected by the T-pin and T-pin clip, and filled with water. The empty mass (weight) of each Sentry Water-Cable Barrier section is approximately 75 kg (165 lb). The mass (weight) of each Water-Cable Barrier section when filled with water is approximately 975 kg (2,150 lb). The Sentry Water-Cable Barrier does not use an external structure to achieve TL-2 or TL3 barrier performance, reducing the chance of improper assembly of the barrier.

The design deflection distance was reported as 2.74 m (9 ft) for TL-3 and 1.8 m (5 ft, 9 in) for TL-2.

**E. Lateral Placement of Temporary Barrier in a Dropoff Condition.**

**1.** Design Considerations. Work zones may have locations where dropoffs greater that 50 mm (2 in) in height are adjacent to an active travel lane. During the design and construction phases, work zone set-ups must be reviewed thoroughly for locations where temporary barrier may be placed between the active travel lane and the dropoffs.

For locations where temporary barrier is to be located beside dropoffs, three linear measurements are to be identified:

- Dropoff Height. The dropoff height is typically greater than 50 mm (2 in).

- Lateral Space (LS). The LS is the distance available behind the temporary barrier to accommodate barrier deflection.

- Barrier Deflection Distance (BDD). The BDD is equal to the tested deflection for the temporary barrier at the specified Test Level (e.g., TL-2, TL-3, TL-4). For the BDD of various PennDOT-approved temporary barriers, refer to Publication 35, *Approved Construction Materials* (Bulletin 15).

Figure 12.12 describes three dropoff conditions with lateral placement of temporary barrier:

- <u>Condition 1 - BDD ≤ LS</u>: This is a desirable condition for dropoff heights greater than 50 mm (2 in). The LS behind the temporary barrier is equal to or greater than the BDD for the selected temporary barrier.

- <u>Condition 2 - BDD > LS, Dropoff Height < 150 mm (6 in)</u>: This condition is only permissible when the dropoff is less than 150 mm (6 in) and the work zone set-up has been reviewed to maximize the LS.

- Condition 3 - BDD > LS, Dropoff Height ≥ 150 mm (6 in): Under this condition, the temporary barrier is to be stiffened with restraints. Methods to limit the BDD for temporary barriers must be approved by the Bureau of Project Delivery.

**2.** Plans and Proposal. In the instances where temporary barrier for dropoff conditions is to be included in the plans and proposal:

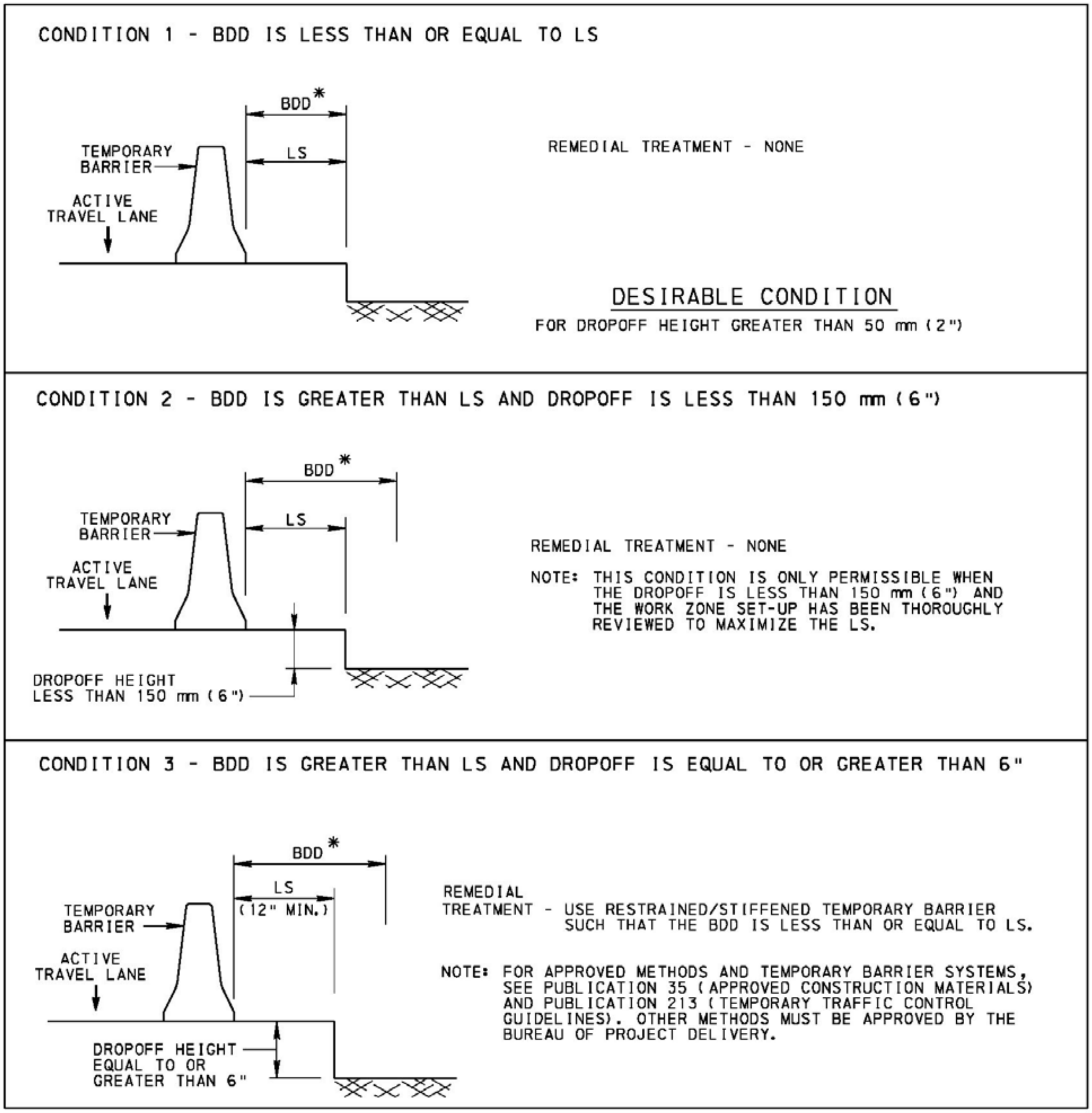
**a.** Identify the LS and the anticipated maximum dropoff height behind each run of temporary barrier.

**b.** Select a PennDOT-approved temporary barrier from one of the following categories:

- Test Level 3, BDD ≤ 0.6 m (2 ft)
- Test Level 3, BDD ≤ 1.5 m (5 ft)
- Test Level 3, BDD ≤ 2.7 m (9 ft)
- Test Level 3, BDD ≤ 4.6 m (15 ft)
- Test Level 2, BDD ≤ 2.7 m (9 ft)
- Test Level 2, BDD ≤ 4.6 m (15 ft)

Following are examples to clarify what PennDOT-approved temporary barriers may be selected.

## FIGURE 12.12
## LATERAL PLACEMENT OF TEMPORARY BARRIER IN A DROPOFF CONDITION




Where: BDD= BARRIER DEFLECTION DISTANCE
LS = LATERAL SPACE - DISTANCE AVAILABLE BEHIND TEMPORARY BARRIER TO ACCOMMODATE BARRIER DEFLECTION
* = For the deflection distance of various approved barriers, see Publication 35, *Approved Construction Materials* (Bulletin 15).

**EXAMPLE 1:** A temporary barrier is to be placed between an active travel lane and a dropoff condition. The following conditions through the work zone are anticipated:

GIVEN: Work Zone Posted Speed Limit = 80 km/h (50 mph)
Maximum Dropoff Height = 250 mm (10 in)
LS = 1.8 m (6 ft)

DISCUSSION:

The above example corresponds with Condition 1 in Figure 12.12, where the BDD is less than or equal to the LS and no remedial treatment is needed. Also, the work zone posted speed limit is greater than the nominal speed for Test Level 2 (70 km/h (44 mph)) but is less than the nominal speed for Test Level 3 (100 km/h (62 mph)).

Therefore, for this example, a PennDOT-approved temporary barrier may be selected from a category that satisfies Test Level 3 and has a BDD less than the LS of 1.8 m (6 ft). The applicable categories are:

- Test Level 3, BDD ≤ 0.6 m (2 ft)
- Test Level 3, BDD ≤ 1.5 m (5 ft)

**EXAMPLE 2:** A temporary barrier is to be placed between an active travel lane and a dropoff condition. The following conditions through the work zone are anticipated:

GIVEN: Work Zone Posted Speed Limit = 56 km/h (35 mph)
Maximum Dropoff Height = 125 mm (5 in)
LS = 3.0 m (10 ft)

DISCUSSION:

The above example corresponds with Condition 1 and Condition 2 in Figure 12.12. The BDD for some temporary barriers is less than or equal to the LS (Condition 1). The BDD for other temporary barriers is greater than the LS and has a dropoff less than 150 mm (6 in) (Condition 2). Also, the work zone posted speed limit is less than the nominal speed for Test Level 2 (70 km/h (44 mph)) and Test Level 3 (100 km/h (62 mph)).

Therefore, for this example, a PennDOT-approved temporary barrier may be selected from a category that satisfies Test Level 2 or Test Level 3 and has a BDD less than the LS of 3.0 m (10 ft) (Condition 1). The applicable categories are:

- Test Level 3, BDD ≤ 0.6 m (2 ft)
- Test Level 3, BDD ≤ 1.5 m (5 ft)
- Test Level 3, BDD ≤ 2.7 m (9 ft)
- Test Level 2, BDD ≤ 2.7 m (9 ft)

Because the dropoff is less than 150 mm (6 in) in this example, a PennDOT-approved temporary barrier may also be selected from a category that satisfies Test Level 2 or Test Level 3, and has a BDD greater than LS. The applicable categories are:

- Test Level 3, BDD ≤ 4.6 m (15 ft)
- Test Level 2, BDD ≤ 4.6 m (15 ft)

Temporary barrier selected from Condition 1 is the desirable condition, since the BDD is less than the LS. However, Condition 2 is permissible if the dropoff is less than 150 mm (6 in) and if the work zone set-up has been thoroughly reviewed to maximize the LS.

**<u>EXAMPLE 3</u>:** A temporary barrier is to be placed between an active travel lane and a dropoff condition. The following conditions through the work zone are anticipated:

GIVEN: Work Zone Posted Speed Limit = 80 km/h (50 mph)
Maximum Dropoff Height = 600 mm (24 in)
LS = 0.6 m (2 ft)

DISCUSSION:

The above example corresponds with Condition 3 in Figure 12.12, where the BDD is greater than the LS and the dropoff is greater than 150 mm (6 in). Also, the work zone posted speed limit is greater than the nominal speed for Test Level 2 (70 km/h (44 mph)) but is less than the nominal speed for Test Level 3 (100 km/h (62 mph)).

Therefore, for this example, a PennDOT-approved temporary barrier may be selected from a category that satisfies Test Level 3 and has a BDD less than the LS of 0.6 m (2 ft). If the BDD is greater than 0.6 m (2 ft), the temporary barrier must be stiffened. The applicable categories are:

- Test Level 3, BDD ≤ 0.6 m (2 ft)

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## 12.11 RAILING SYSTEM TEST LEVEL SELECTION FOR BRIDGES

The selection criteria presented herein is applicable to railings mounted on bridges.

Provide bridge railings that meet the requirements of Test Level 5 (TL-5) of NCHRP Report 350, unless another test level is authorized by the District Executive. The Typical Concrete Barrier (shown in Publication 218M, *Standards for Bridge Design*, Drawing BD-601M) provides a high level of safety and low maintenance cost. This barrier is considered the default bridge railing system unless the District Executive authorizes a different railing system due to environmental, public request, or other requirements.

Test Levels 4 and 6 (TL-4 and TL-6) may be authorized by the District Executive on a case-by-case basis. A copy of the Alternate Bridge Railing Test Level Authorization will be kept in the permanent bridge inspection file. TL-6 may be considered for locations where a history of, or the potential for, tanker-truck rollover exists.

TL-4 may be considered in the following cases:

- Case I - Where favorable conditions of alignment, grade and speed exist and, hence, the probability of severe crashes is minimal.
- Case II - Where the height required for railings satisfying TL-5 may hinder sight distance requirements.
- Case III - Along the sides of bridges with sidewalks not separated from traffic with a crashworthy traffic railing.

Other than situations where the smaller height of TL-4 barriers is required to alleviate sight distance problems, select the Test Level for railing systems using Table 12.11. The adjusted ADT to be used in this table is calculated as follows:

$$\text{Adjusted ADT} = K_c \times K_g \times K_s \times (\text{The estimated construction-year total ADT for the highway})$$

Where: $K_g$ = Correction factor for grade, see Figure 12.13.

$K_c$ = Correction factor for curvature, see Figure 12.13. The sharpest curvature on the bridge or the bridge approaches shall be used in determining $K_c$.

$K_s$ = Correction factor for drop-off distance and under-structure conditions, see Figure 12.14.

The estimated construction-year ADT may be limited to 10,000 vehicles per day per lane for design speeds of 80 km/h (50 mph) or greater.

**<u>EXAMPLE</u>:**
Select the railing test level for a bridge with the following characteristics:

GIVEN:
- Bridge is on a four-lane divided highway.
- Bridge is on a section of the highway that has a 3% grade.
- Bridge is on a curve that has a 4 degree curvature.
- Bridge crosses a river that has water 4500 mm (15 ft) deep. The bridge deck is 13 500 mm (45 ft) above water.
- Estimated construction year ADT = 9,250.
- Railing offset from the driving lanes is 1800 mm (6 ft).
- Percent trucks = 10%.
- Highway design speed = 80 km/h (50 mph).

SOLUTION:

From Figure 12.13:

$K_c$ = 2.0 for a 4 degree curvature
$K_g$ = 1.25 for a 3% grade

From Figure 12.14:
$K_s$ = 1.6 for a bridge deck 13 500 mm (45 ft) above water and using the curve for water > 10 ft deep

Adjusted ADT = 9,250 × 2 × 1.25 × 1.6 = 37,000 vpd < No. of lanes × 10,000 = 40,000 vpd – OK

Use Adjusted ADT = 37,000 vpd

From Table 12.11 for 80 km/h (50 mph) design speed:

- Go to the block of lines corresponding to 10% trucks.
- Chose the line for rail offset 900 mm to 2100 mm (3 ft to 7 ft). This range encompasses the 1800 mm (6 ft) given.
- Move horizontally to the area that corresponds to Divided highway.

→ TL-4 is allowed for Adjusted ADT up to 60,000.
→ TL-5 is required for Adjusted ADT > 60,000.

Therefore, for an Adjusted ADT = 37,000 vpd, TL-4 may be used if authorized by the District Executive.

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## TABLE 12.11
## RAILING SYSTEMS TEST LEVEL SELECTION CRITERIA

| Site Characteristics | | | | | Adjusted ADT Ranges for Railing Test Levels ($10^3$ vpd) | |
|---|---|---|---|---|---|---|
| | | | | | Highway Type | |
| Design Speed | | Truck percent | Rail Offset | | Divided or undivided with 5 or more lanes * | Undivided with 4 lanes or less |
| | | | | | TL-4 permitted for Adjusted ADT up to the number below, otherwise, TL-5 is required | TL-4 permitted for Adjusted ADT up to the number below, otherwise, TL-5 is required |
| (km/h) | (mph) | | (mm) | (ft) | | |
| 50 | 30 | 0 | 0-900 | 0-3 | ∞ | ∞ |
| 50 | 30 | 0 | 900-2100 | 3-7 | ∞ | ∞ |
| 50 | 30 | 0 | 2100-3600 | 7-12 | ∞ | ∞ |
| 50 | 30 | 0 | >3600 | >12 | ∞ | ∞ |
| 50 | 30 | 5 | 0-900 | 0-3 | ∞ | ∞ |
| 50 | 30 | 5 | 900-2100 | 3-7 | ∞ | ∞ |
| 50 | 30 | 5 | 2100-3600 | 7-12 | ∞ | ∞ |
| 50 | 30 | 5 | >3600 | >12 | ∞ | ∞ |
| 50 | 30 | 10 | 0-900 | 0-3 | 179 | 148 |
| 50 | 30 | 10 | 900-2100 | 3-7 | 258 | 228 |
| 50 | 30 | 10 | 2100-3600 | 7-12 | 404 | 365 |
| 50 | 30 | 10 | >3600 | >12 | ∞ | ∞ |
| 50 | 30 | 15 | 0-900 | 0-3 | 103 | 85 |
| 50 | 30 | 15 | 900-2100 | 3-7 | 147 | 129 |
| 50 | 30 | 15 | 2100-3600 | 7-12 | 229 | 205 |
| 50 | 30 | 15 | >3600 | >12 | 472 | 467 |
| 50 | 30 | 20 | 0-900 | 0-3 | 72 | 59 |
| 50 | 30 | 20 | 900-2100 | 3-7 | 102 | 90 |
| 50 | 30 | 20 | 2100-3600 | 7-12 | 159 | 143 |
| 50 | 30 | 20 | >3600 | >12 | 329 | 325 |
| 50 | 30 | 25 | 0-900 | 0-3 | 55 | 45 |
| 50 | 30 | 25 | 900-2100 | 3-7 | 79 | 69 |
| 50 | 30 | 25 | 2100-3600 | 7-12 | 122 | 110 |
| 50 | 30 | 25 | >3600 | >12 | 253 | 250 |

* For one way highways, use half the ADT shown for divided or undivided with 5 or more lanes.

## TABLE 12.11 (CONTINUED)
## RAILING SYSTEMS TEST LEVEL SELECTION CRITERIA

| Site Characteristics | | | | | Adjusted ADT Ranges for Railing Test Levels ($10^3$ vpd) | |
|---|---|---|---|---|---|---|
| | | | | | Highway Type | |
| Design Speed | | Truck percent | Rail Offset | | Divided or undivided with 5 or more lanes * | Undivided with 4 lanes or less |
| | | | | | TL-4 permitted for Adjusted ADT up to the number below, otherwise, TL-5 is required | TL-4 permitted for Adjusted ADT up to the number below, otherwise, TL-5 is required |
| (km/h) | (mph) | | (mm) | (ft) | | |
| 65 | 40 | 0 | 0-900 | 0-3 | ∞ | ∞ |
| 65 | 40 | 0 | 900-2100 | 3-7 | ∞ | ∞ |
| 65 | 40 | 0 | 2100-3600 | 7-12 | ∞ | ∞ |
| 65 | 40 | 0 | >3600 | >12 | ∞ | ∞ |
| 65 | 40 | 5 | 0-900 | 0-3 | 280 | 202 |
| 65 | 40 | 5 | 900-2100 | 3-7 | 335 | 254 |
| 65 | 40 | 5 | 2100-3600 | 7-12 | 452 | 367 |
| 65 | 40 | 5 | >3600 | >12 | ∞ | ∞ |
| 65 | 40 | 10 | 0-900 | 0-3 | 80 | 56 |
| 65 | 40 | 10 | 900-2100 | 3-7 | 90 | 69 |
| 65 | 40 | 10 | 2100-3600 | 7-12 | 132 | 102 |
| 65 | 40 | 10 | >3600 | >12 | 184 | 157 |
| 65 | 40 | 15 | 0-900 | 0-3 | 46 | 32 |
| 65 | 40 | 15 | 900-2100 | 3-7 | 52 | 40 |
| 65 | 40 | 15 | 2100-3600 | 7-12 | 78 | 59 |
| 65 | 40 | 15 | >3600 | >12 | 105 | 60 |
| 65 | 40 | 20 | 0-900 | 0-3 | 33 | 23 |
| 65 | 40 | 20 | 900-2100 | 3-7 | 37 | 28 |
| 65 | 40 | 20 | 2100-3600 | 7-12 | 55 | 42 |
| 65 | 40 | 20 | >3600 | >12 | 74 | 63 |
| 65 | 40 | 25 | 0-900 | 0-3 | 25 | 18 |
| 65 | 40 | 25 | 900-2100 | 3-7 | 28 | 22 |
| 65 | 40 | 25 | 2100-3600 | 7-12 | 42 | 32 |
| 65 | 40 | 25 | >3600 | >12 | 57 | 48 |

* For one way highways, use half the ADT shown for divided or undivided with 5 or more lanes.

## TABLE 12.11 (CONTINUED)
## RAILING SYSTEMS TEST LEVEL SELECTION CRITERIA

| Site Characteristics | | | | | Adjusted ADT Ranges for Railing Test Levels ($10^3$ vpd) — Highway Type | |
|---|---|---|---|---|---|---|
| Design Speed | | Truck percent | Rail Offset | | Divided or undivided with 5 or more lanes * | Undivided with 4 lanes or less |
| (km/h) | (mph) | | (mm) | (ft) | TL-4 permitted for Adjusted ADT up to the number below, otherwise, TL-5 is required | TL-4 permitted for Adjusted ADT up to the number below, otherwise, TL-5 is required |
| 80 | 50 | 0 | 0-900 | 0-3 | ∞ | ∞ |
| 80 | 50 | 0 | 900-2100 | 3-7 | ∞ | ∞ |
| 80 | 50 | 0 | 2100-3600 | 7-12 | ∞ | ∞ |
| 80 | 50 | 0 | >3600 | >12 | ∞ | ∞ |
| 80 | 50 | 5 | 0-900 | 0-3 | 162 | 107 |
| 80 | 50 | 5 | 900-2100 | 3-7 | 189 | 134 |
| 80 | 50 | 5 | 2100-3600 | 7-12 | 247 | 172 |
| 80 | 50 | 5 | >3600 | >12 | 315 | 245 |
| 80 | 50 | 10 | 0-900 | 0-3 | 50 | 32 |
| 80 | 50 | 10 | 900-2100 | 3-7 | 60 | 42 |
| 80 | 50 | 10 | 2100-3600 | 7-12 | 71 | 49 |
| 80 | 50 | 10 | >3600 | >12 | 89 | 68 |
| 80 | 50 | 15 | 0-900 | 0-3 | 30 | 19 |
| 80 | 50 | 15 | 900-2100 | 3-7 | 37 | 25 |
| 80 | 50 | 15 | 2100-3600 | 7-12 | 41 | 29 |
| 80 | 50 | 15 | >3600 | >12 | 52 | 39 |
| 80 | 50 | 20 | 0-900 | 0-3 | 21 | 13 |
| 80 | 50 | 20 | 900-2100 | 3-7 | 26 | 18 |
| 80 | 50 | 20 | 2100-3600 | 7-12 | 29 | 20 |
| 80 | 50 | 20 | >3600 | >12 | 36 | 28 |
| 80 | 50 | 25 | 0-900 | 0-3 | 16 | 10 |
| 80 | 50 | 25 | 900-2100 | 3-7 | 20 | 14 |
| 80 | 50 | 25 | 2100-3600 | 7-12 | 23 | 16 |
| 80 | 50 | 25 | >3600 | >12 | 28 | 21 |

* For one way highways, use half the ADT shown for divided or undivided with 5 or more lanes.

## TABLE 12.11 (CONTINUED)
## RAILING SYSTEMS TEST LEVEL SELECTION CRITERIA

| Site Characteristics | | | | | Adjusted ADT Ranges for Railing Test Levels ($10^3$ vpd) | |
|---|---|---|---|---|---|---|
| | | | | | Highway Type | |
| Design Speed | | Truck percent | Rail Offset | | Divided or undivided with 5 or more lanes * | Undivided with 4 lanes or less |
| | | | | | TL-4 permitted for Adjusted ADT up to the number below, otherwise, TL-5 is required | TL-4 permitted for Adjusted ADT up to the number below, otherwise, TL-5 is required |
| (km/h) | (mph) | | (mm) | (ft) | | |
| 100 | 60 | 0 | 0-900 | 0-3 | ∞ | ∞ |
| 100 | 60 | 0 | 900-2100 | 3-7 | ∞ | ∞ |
| 100 | 60 | 0 | 2100-3600 | 7-12 | ∞ | ∞ |
| 100 | 60 | 0 | >3600 | >12 | ∞ | ∞ |
| 100 | 60 | 5 | 0-900 | 0-3 | 107 | 70 |
| 100 | 60 | 5 | 900-2100 | 3-7 | 126 | 83 |
| 100 | 60 | 5 | 2100-3600 | 7-12 | 158 | 106 |
| 100 | 60 | 5 | >3600 | >12 | 204 | 138 |
| 100 | 60 | 10 | 0-900 | 0-3 | 40 | 25 |
| 100 | 60 | 10 | 900-2100 | 3-7 | 48 | 29 |
| 100 | 60 | 10 | 2100-3600 | 7-12 | 53 | 34 |
| 100 | 60 | 10 | >3600 | >12 | 68 | 44 |
| 100 | 60 | 15 | 0-900 | 0-3 | 24 | 15 |
| 100 | 60 | 15 | 900-2100 | 3-7 | 29 | 18 |
| 100 | 60 | 15 | 2100-3600 | 7-12 | 32 | 20 |
| 100 | 60 | 15 | >3600 | >12 | 41 | 26 |
| 100 | 60 | 20 | 0-900 | 0-3 | 18 | 11 |
| 100 | 60 | 20 | 900-2100 | 3-7 | 21 | 13 |
| 100 | 60 | 20 | 2100-3600 | 7-12 | 23 | 14 |
| 100 | 60 | 20 | >3600 | >12 | 29 | 19 |
| 100 | 60 | 25 | 0-900 | 0-3 | 14 | 9 |
| 100 | 60 | 25 | 900-2100 | 3-7 | 17 | 10 |
| 100 | 60 | 25 | 2100-3600 | 7-12 | 18 | 11 |
| 100 | 60 | 25 | >3600 | >12 | 23 | 15 |

* For one way highways, use half the ADT shown for divided or undivided with 5 or more lanes.

## TABLE 12.11 (CONTINUED)
## RAILING SYSTEMS TEST LEVEL SELECTION CRITERIA

| Site Characteristics | | | | | Adjusted ADT Ranges for Railing Test Levels ($10^3$ vpd) | |
|---|---|---|---|---|---|---|
| | | | | | Highway Type | |
| Design Speed | | Truck percent | Rail Offset | | Divided or undivided with 5 or more lanes * | Undivided with 4 lanes or less |
| | | | | | TL-4 permitted for Adjusted ADT up to the number below, otherwise, TL-5 is required | TL-4 permitted for Adjusted ADT up to the number below, otherwise, TL-5 is required |
| (km/h) | (mph) | | (mm) | (ft) | | |
| 110 | 70 | 0 | 0-900 | 0-3 | 191 | 165 |
| 110 | 70 | 0 | 900-2100 | 3-7 | 380 | 301 |
| 110 | 70 | 0 | 2100-3600 | 7-12 | ∞ | 402 |
| 110 | 70 | 0 | >3600 | >12 | ∞ | ∞ |
| 110 | 70 | 5 | 0-900 | 0-3 | 63 | 42 |
| 110 | 70 | 5 | 900-2100 | 3-7 | 80 | 52 |
| 110 | 70 | 5 | 2100-3600 | 7-12 | 96 | 64 |
| 110 | 70 | 5 | >3600 | >12 | 128 | 84 |
| 110 | 70 | 10 | 0-900 | 0-3 | 32 | 20 |
| 110 | 70 | 10 | 900-2100 | 3-7 | 39 | 23 |
| 110 | 70 | 10 | 2100-3600 | 7-12 | 42 | 27 |
| 110 | 70 | 10 | >3600 | >12 | 53 | 33 |
| 110 | 70 | 15 | 0-900 | 0-3 | 22 | 13 |
| 110 | 70 | 15 | 900-2100 | 3-7 | 25 | 15 |
| 110 | 70 | 15 | 2100-3600 | 7-12 | 27 | 17 |
| 110 | 70 | 15 | >3600 | >12 | 34 | 21 |
| 110 | 70 | 20 | 0-900 | 0-3 | 16 | 10 |
| 110 | 70 | 20 | 900-2100 | 3-7 | 19 | 11 |
| 110 | 70 | 20 | 2100-3600 | 7-12 | 20 | 12 |
| 110 | 70 | 20 | >3600 | >12 | 24 | 15 |
| 110 | 70 | 25 | 0-900 | 0-3 | 13 | 8 |
| 110 | 70 | 25 | 900-2100 | 3-7 | 15 | 9 |
| 110 | 70 | 25 | 2100-3600 | 7-12 | 16 | 10 |
| 110 | 70 | 25 | >3600 | >12 | 19 | 12 |

* For one way highways, use half the ADT shown for divided or undivided with 5 or more lanes.

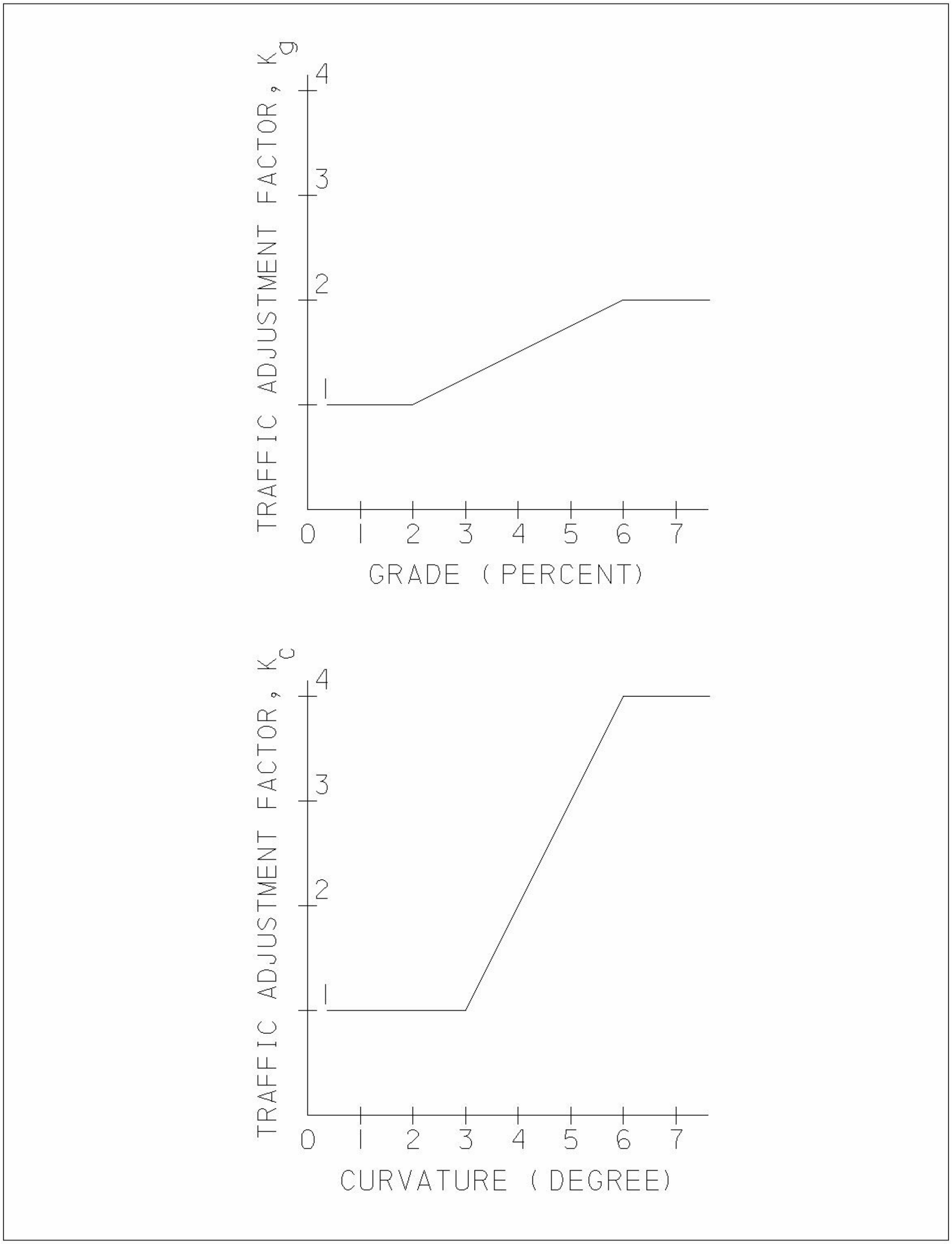


**FIGURE 12.13**
**GRADE TRAFFIC ADJUSTMENT FACTOR ($K_g$) AND CURVATURE TRAFFIC ADJUSTMENT FACTOR ($K_c$)**

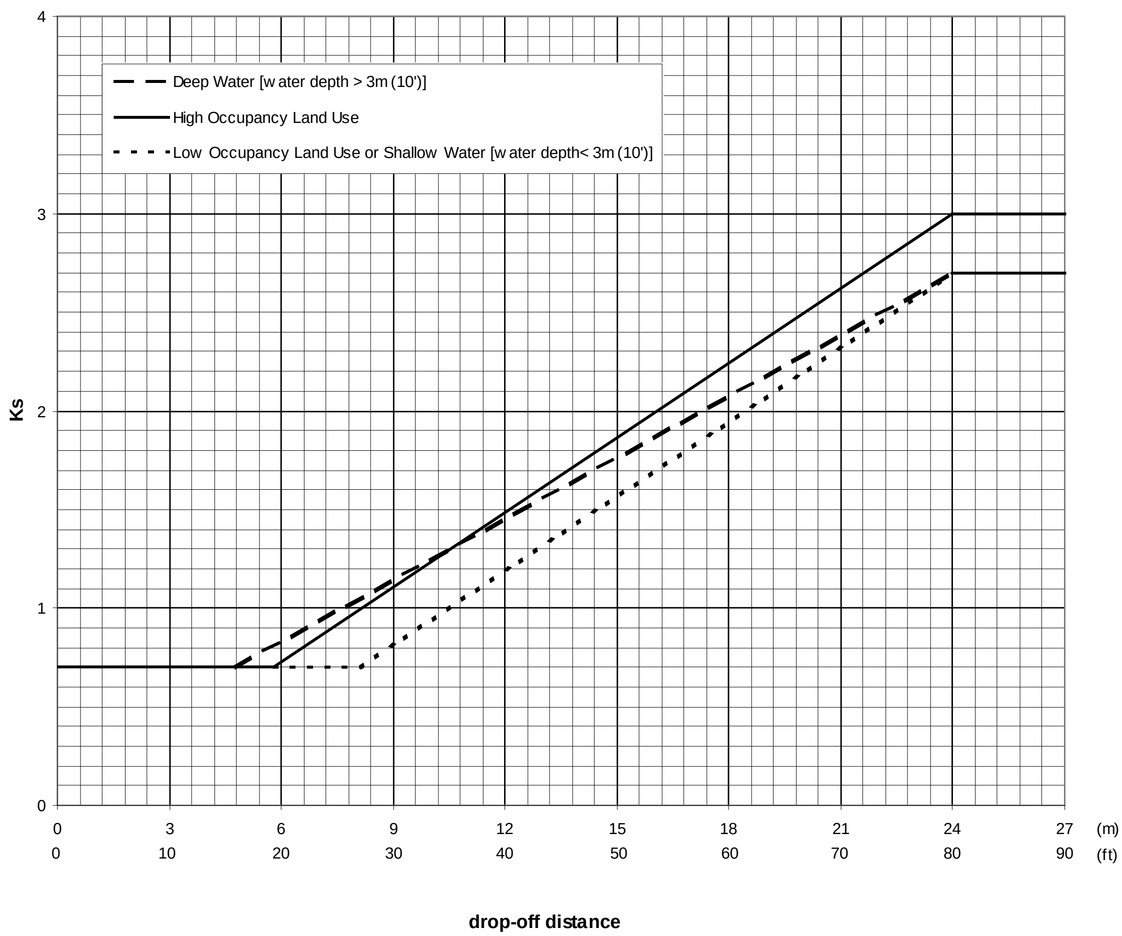


**FIGURE 12.14**
**DROP-OFF TRAFFIC ADJUSTMENT FACTOR ($K_S$)**

**FIGURE 12.15**
**SAMPLE AUTHORIZATION**

Date:

Subject: Alternate Bridge Railing Test Level Authorization
___________ County
SR____ Section____
Segment ____ Offset____

To: District Executive

From: Assistant District Executive - Design

Reference is made to your request dated (date) to specify Test Level ___ (TL-__) (Name of Standard Railing) detail (Railing Height) for the subject project in lieu of the Typical Bridge Railing.

The District Bridge Engineer and District Plans Engineer reviewed computations as per current Publication 13M (DM-2) Chapter 12, Section 12.11, Railing System Test Level Selection for Bridges and concurs with the use of Test Level 4 (TL-4) (Name of Standard Railing) detail (Railing Height) as per (Standard) on the proposed structure.

A copy of this Authorization will be kept in the permanent bridge inspection file.

Concurrence: ______________________ Date: _____
District Plans Engineer

Concurrence: ______________________ Date: _____
District Bridge Engineer

Concurrence: ______________________ Date: _____
District Executive

cc: Chief, Highway Design and Technology Section, Highway Delivery Division, Bureau of Project Delivery

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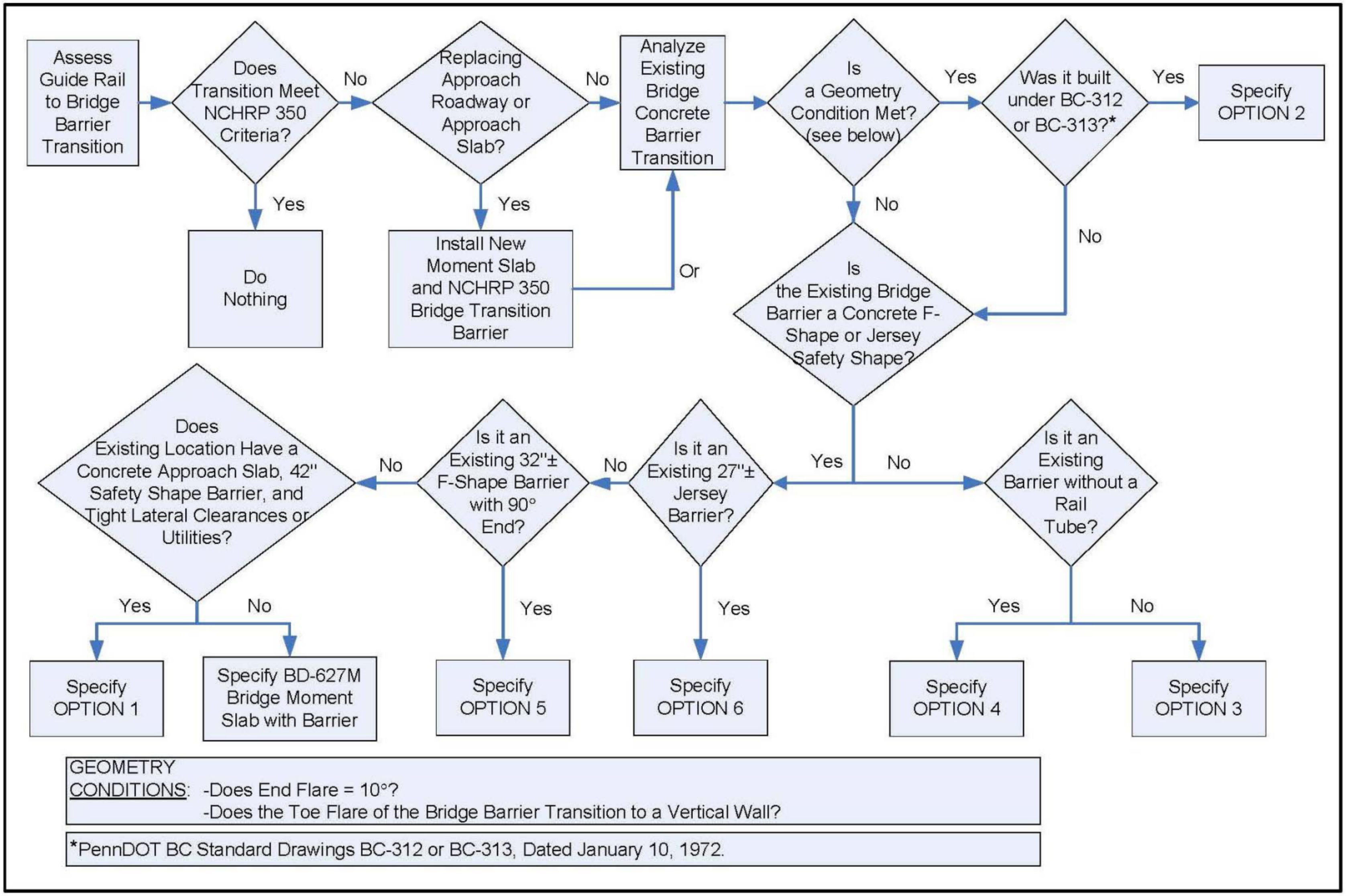
# CHAPTER 12, APPENDIX A

## BRIDGE BARRIER END TRANSITIONS

## Decision Tree for Upgrading Guide Rail to Bridge Barrier Transitions for Projects Scoped Under Pavement Preservation Guidelines



## GENERAL NOTES:

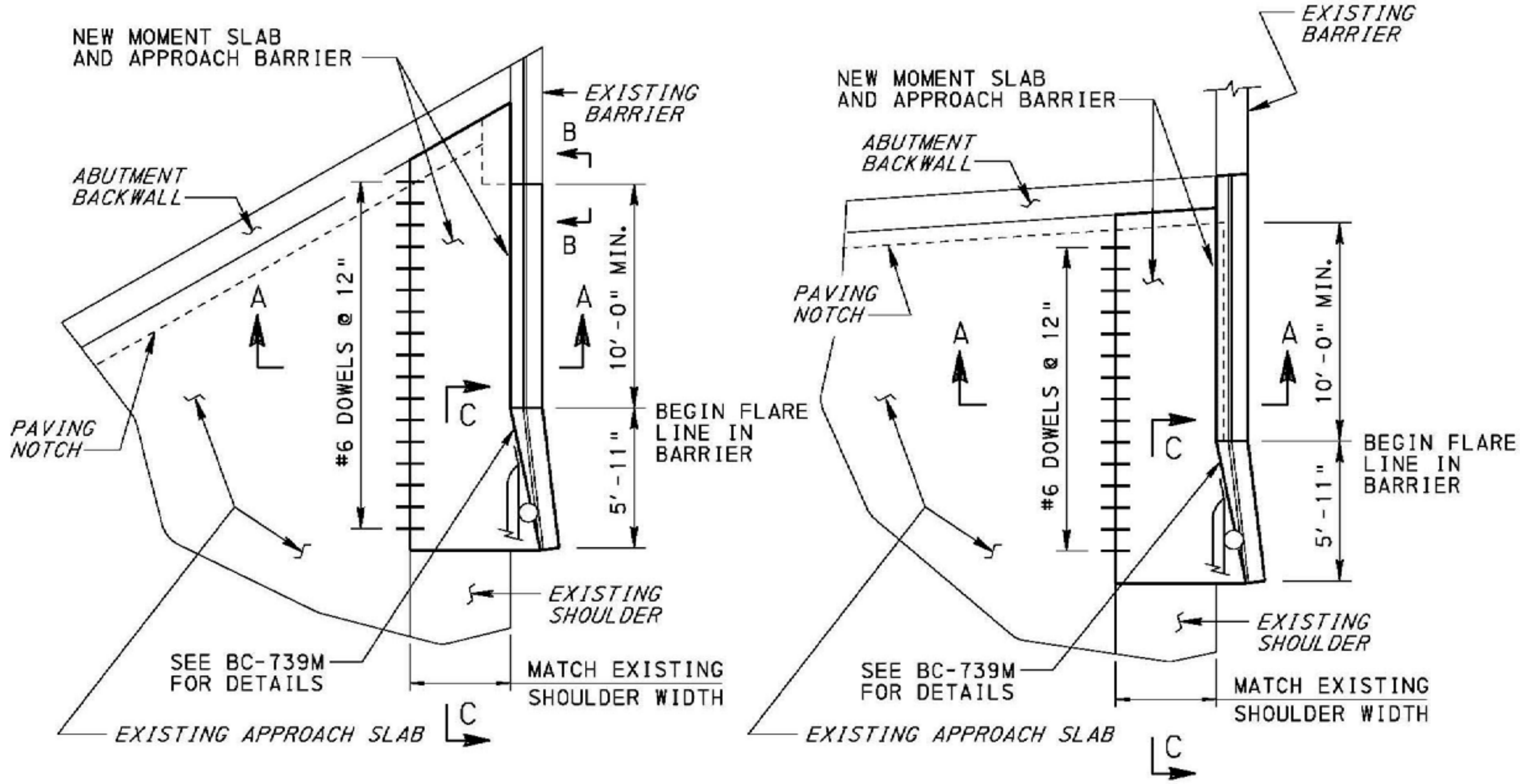
1. THE INFORMATION SHOWN IS PROVIDED FOR USE IN THE DEVELOPMENT OF THE CONTRACT DRAWINGS. THE DESIGNER IS RESPONSIBLE FOR THE PRESENTATION OF ALL REQUIRED DETAILS, QUANTITIES AND NOTES. WORK THESE DETAILS WITH RC-50M, BC-703M, AND BC-739M TO ENSURE CONTRACT DRAWINGS ARE COMPLETE AND PROPERLY REFERENCE THE CORRECT STANDARDS.
2. PROVIDE MATERIALS AND WORKMANSHIP IN ACCORDANCE WITH PUB. 408.
3. ALL STEEL REINFORCEMENT BARS MUST MEET THE REQUIREMENTS OF ASTM A615M, A996M, OR A706M.
4. SEE BRIDGE STANDARD BC-739M, RC-50M AND PUB. 408 SPECIFICATIONS FOR TYPICAL GUIDE RAIL TO BRIDGE BARRIER TRANSITION DETAILS.
5. CONTRACT DRAWINGS:
   PREPARE CONTRACT DRAWINGS IN ACCORDANCE WITH THE DESIGN MANUAL - PART 3, DESIGN MANUAL - PART 4, THESE DETAILS AND OTHER PENNDOT STANDARDS.
   PROVIDE COMPLETE DETAILS AND NOTES AS REQUIRED.
   PROVIDE COMPLETE REINFORCEMENT BAR DETAILS AND BAR SCHEDULE.
   PROVIDE TOP OF SLAB (OR ROADWAY) ELEVATIONS AT ALL TRANSVERSE JOINT LOCATIONS.
6. SEE BRIDGE STANDARD BD-627M FOR MOMENT SLAB MATERIALS AND REINFORCEMENT DETAILS. DESIGNER TO PROVIDE ALL MOMENT SLAB DETAILS ON CONTRACT DOCUMENTS.
7. SEE RC-50M AND RC-52M FOR ROADWAY BARRIER DETAILS AND HARDWARE NOT SHOWN.
8. DO NOT DAMAGE EXISTING REINFORCEMENT. USE PACOMETER TO LOCATE EXISTING REINFORCEMENT IN BARRIER PRIOR TO CORING. PLACE ANCHOR BOLT HOLES TO THE INSIDE OF EXISTING REINFORCEMENT.
9. PROVIDE CLASS AA CONCRETE AND EPOXY COATED REINFORCEMENT STEEL.
10. USE 2" COVER ON ALL REINFORCEMENT EXCEPT WHEN NOTED OTHERWISE. COVER MAY BE REDUCED TO 1½" WHEN USING CLASS AA CEMENT CONCRETE MODIFIED OR CLASS AAA CEMENT CONCRETE MODIFIED IN ACCORDANCE WITH PUB. 408, SECTION 1001, EXCEPT AS FOLLOWS:
    SECTION 1001.2 (d) - PROVIDE SYNTHETIC FIBERS COMPLYING WITH ASTM C 1116, TYPE III. FIBERS MUST BE 100% VIRGIN POLYPROPYLENE, FIBRILLATED FIBERS CONTAINING NO REPROCESSED OLEFIN MATERIALS AND SPECIFICALLY MANUFACTURED FOR USE AS CONCRETE SECONDARY REINFORCEMENT. VOLUME PER CUBIC YARD MUST EQUAL A MINIMUM OF 1.5 POUNDS PER CUBIC YARD OF CEMENT CONCRETE. USE FIBERS ¾" IN LENGTH. PROVIDE A MIX THAT IS WORKABLE AND ONE WHICH DOES NOT CONTAIN FIBER BALLS. DEVELOP AND SUBMIT THE CONCRETE MIX DESIGN WITH FIBERS FOR DEPARTMENT REVIEW AND APPROVAL AT LEAST TEN (10) DAYS PRIOR TO USE.
11. SCARIFY ¼" OF EXISTING CONCRETE AND COAT WITH EPOXY BONDING COMPOUND ALL SURFACES THAT ARE TO COME INTO CONTACT WITH NEW CONCRETE PRIOR TO PLACEMENT OF NEW CONCRETE.
12. ALL DIMENSIONS ARE IN FEET AND INCHES UNLESS NOTED OTHERWISE.
13. ALL MATERIAL IS NEW UNLESS DENOTED AS EXISTING.

GUIDE RAIL TO BRIDGE BARRIER
APPROACH TRANSITION RETRO-FITS

GENERAL NOTES

SHEET 1 OF 18

THRIEBEAM_RETRO.DGN




## APPROACH SLAB PLAN

EXISTING INLETS LOCATED WITHIN LIMITS OF MOMENT SLAB
ARE TO BE RELOCATED TO END OF MOMENT SLAB

GUIDE RAIL TO BRIDGE BARRIER
APPROACH TRANSITION RETRO-FITS

OPTION 1 - MOMENT SLAB
CONCRETE SAFETY SHAPE
90 DEGREE END

WORK WITH SHEETS 3 & 4.

SHEET 2 OF 18

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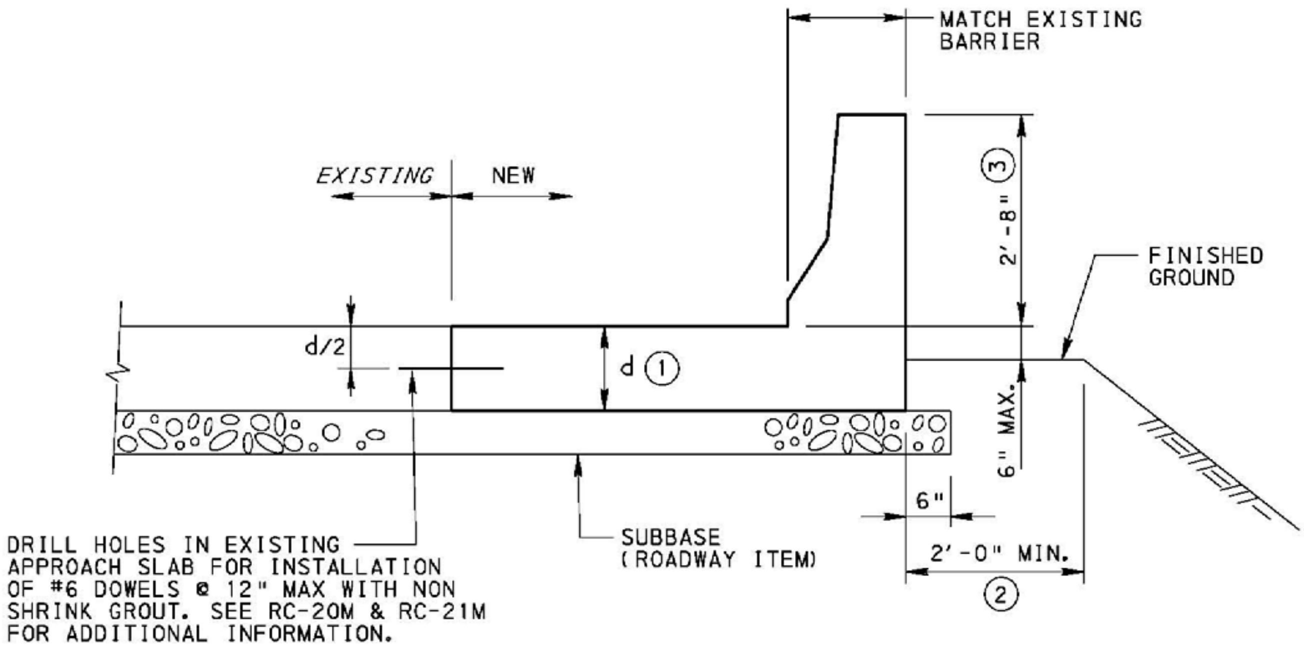



## SECTION A-A

(1) MOMENT SLAB TO MATCH DEPTH OF APPROACH SLAB 16" (MIN.)

(2) 2'-0" MIN. BENCH DUE TO EXTENDED SUBBASE, SEE BD-627M.

(3) 32" BARRIER SHOWN. SPECIFY 42" BARRIER IF EXISTING BARRIER HAS RAILING.

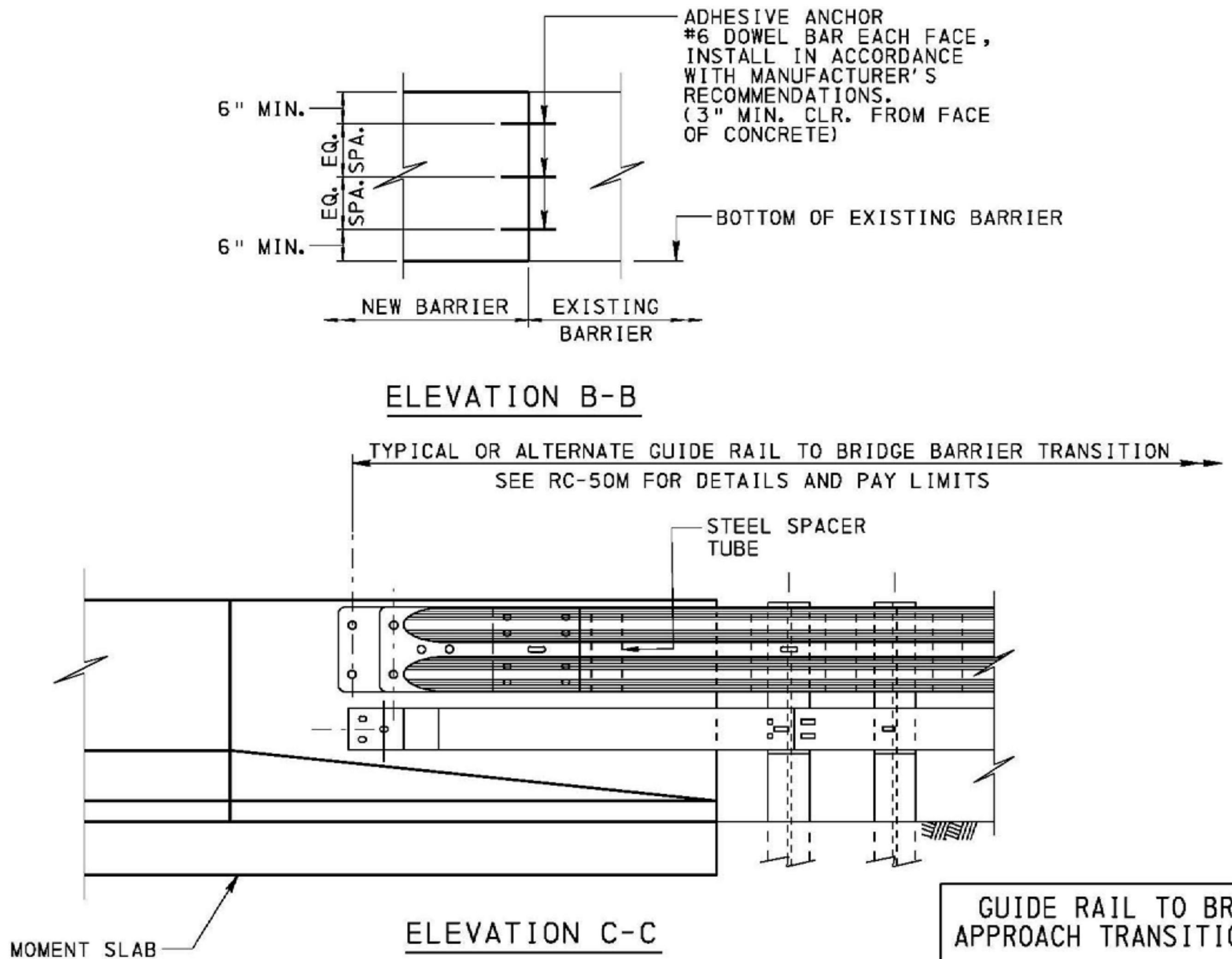
GUIDE RAIL TO BRIDGE BARRIER
APPROACH TRANSITION RETRO-FITS

OPTION 1 - MOMENT SLAB
CONCRETE SAFETY SHAPE
90 DEGREE END

WORK WITH SHEETS 2 & 4.

SHEET 3 OF 18

THRIEBEAM_RETRO.DGN

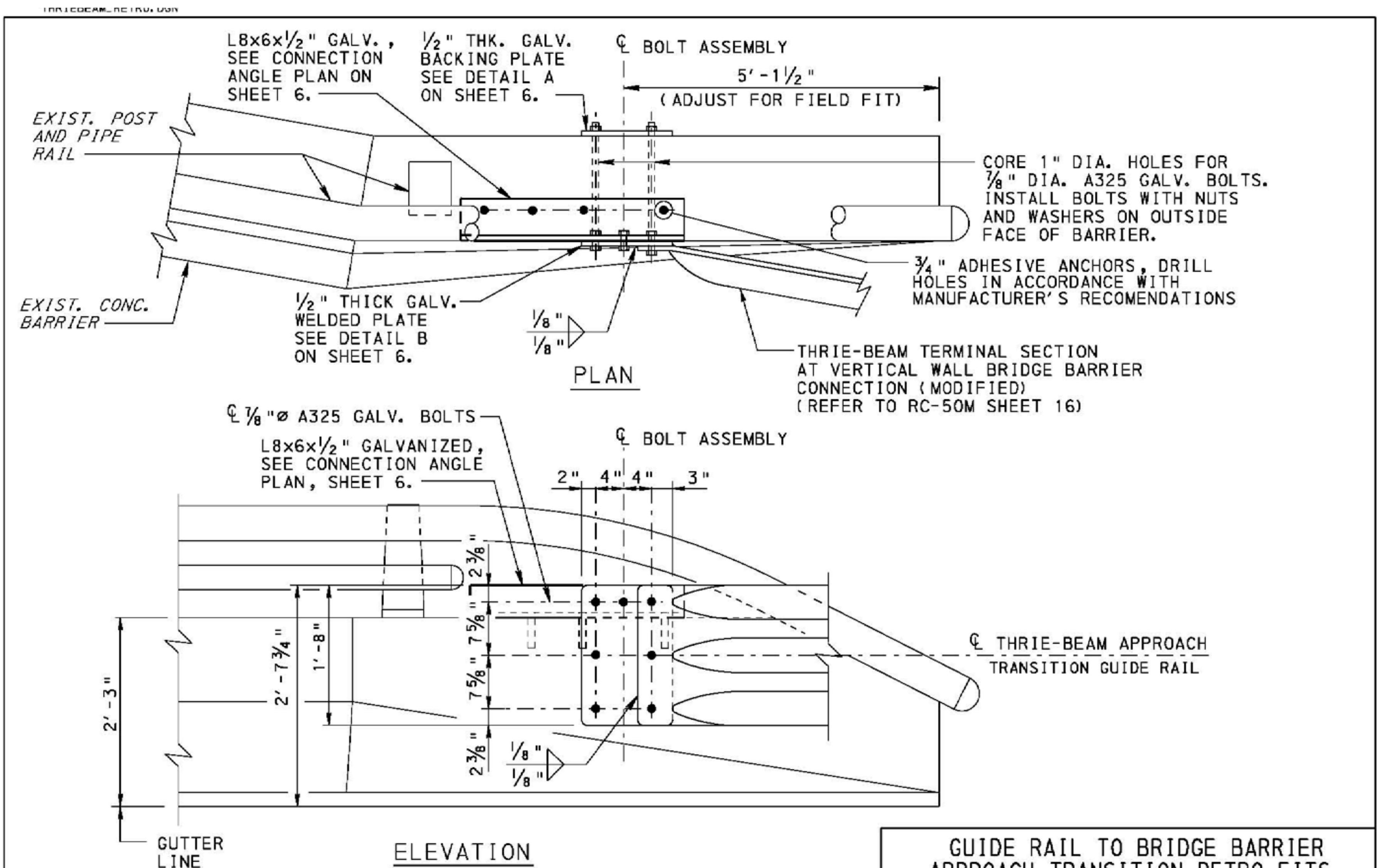



WORK WITH SHEETS 2 & 3.

GUIDE RAIL TO BRIDGE BARRIER APPROACH TRANSITION RETRO-FITS

OPTION 1 - MOMENT SLAB CONCRETE SAFETY SHAPE 90 DEGREE END

SHEET 4 OF 18



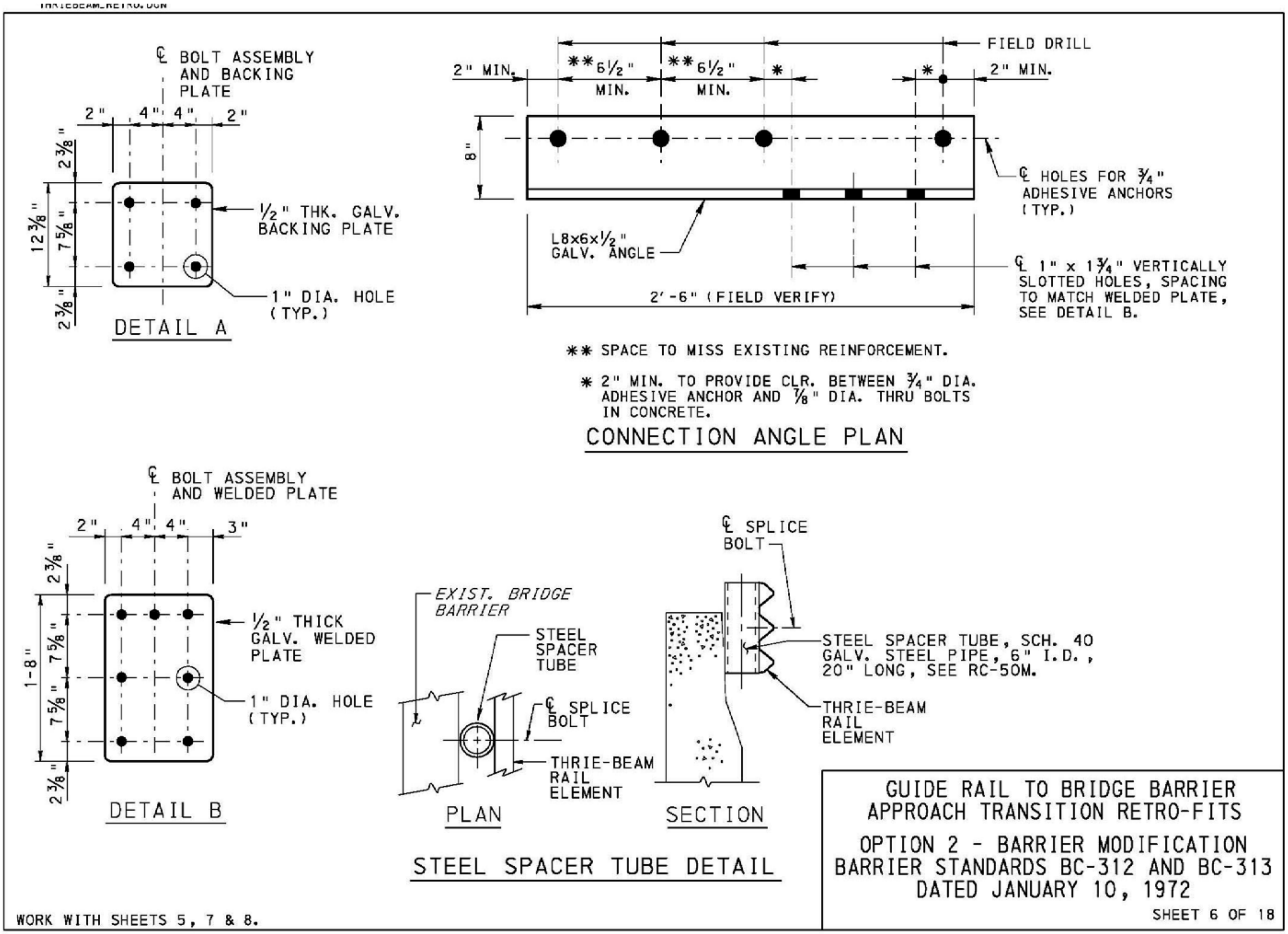

CONNECTION ANGLE DETAIL FOR THRIE-BEAM TO BRIDGE BARRIER TRANSITION

WORK WITH SHEETS 6, 7 & 8.

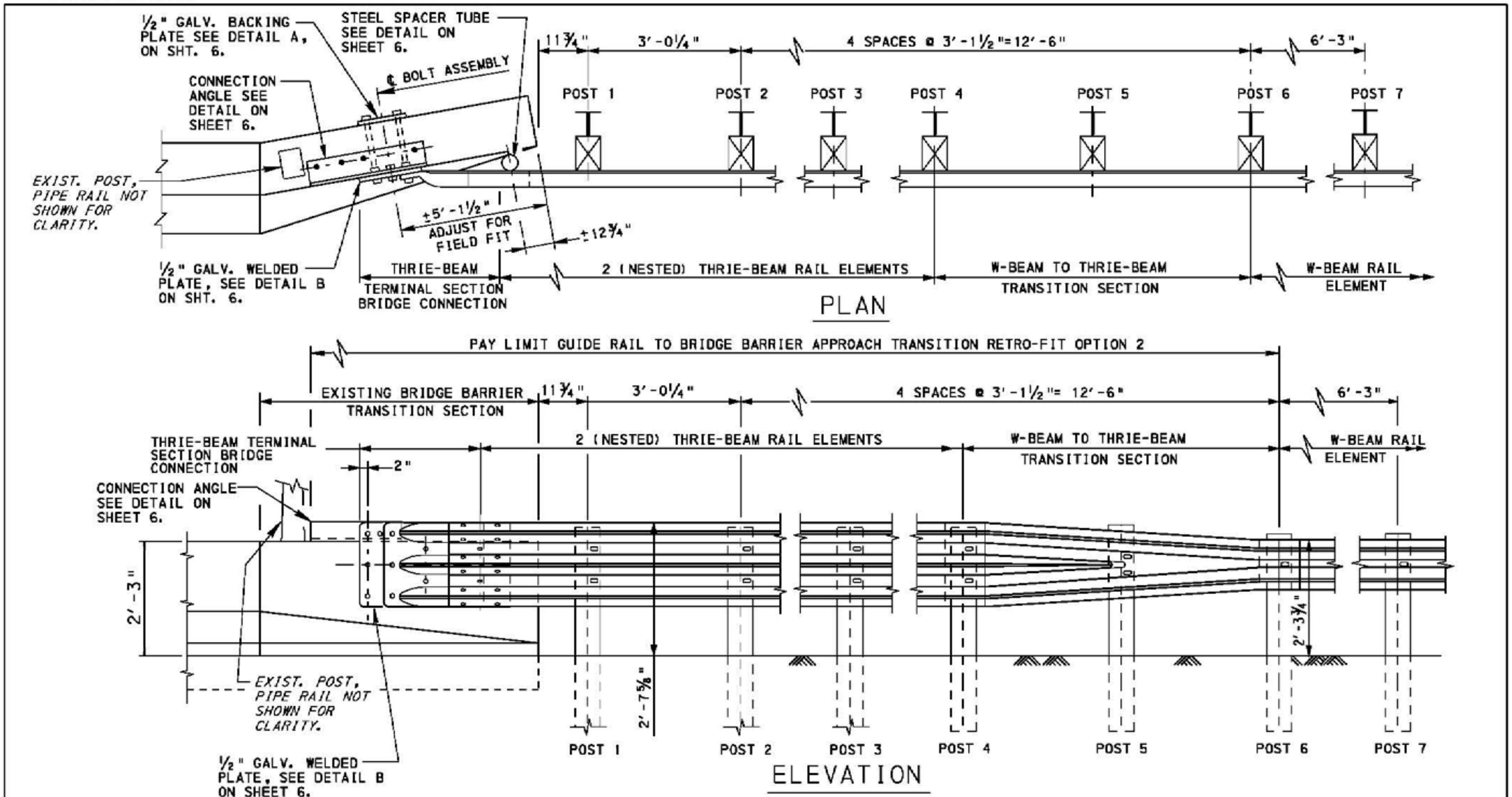
GUIDE RAIL TO BRIDGE BARRIER APPROACH TRANSITION RETRO-FITS

OPTION 2 - BARRIER MODIFICATION BARRIER STANDARDS BC-312 AND BC-313 DATED JANUARY 10, 1972

SHEET 5 OF 18


THRIEBEAM_RETRO.DGN
℄ BOLT ASSEMBLY AND BACKING PLATE
2" 4" 4" 2"
2⅜" 12⅜" 7⅝" 2⅜"
½" THK. GALV. BACKING PLATE
1" DIA. HOLE (TYP.)
DETAIL A
FIELD DRILL
2" MIN. **6½" MIN. **6½" MIN. * * 2" MIN.
8"
℄ HOLES FOR ¾" ADHESIVE ANCHORS (TYP.)
L8x6x½" GALV. ANGLE
℄ 1" x 1¾" VERTICALLY SLOTTED HOLES, SPACING TO MATCH WELDED PLATE, SEE DETAIL B.
2'-6" (FIELD VERIFY)
** SPACE TO MISS EXISTING REINFORCEMENT.
* 2" MIN. TO PROVIDE CLR. BETWEEN ¾" DIA. ADHESIVE ANCHOR AND ⅞" DIA. THRU BOLTS IN CONCRETE.
CONNECTION ANGLE PLAN
℄ BOLT ASSEMBLY AND WELDED PLATE
2" 4" 4" 3"
2⅜" 1'-8" 7⅝" 7⅝" 2⅜"
½" THICK GALV. WELDED PLATE
1" DIA. HOLE (TYP.)
DETAIL B
EXIST. BRIDGE BARRIER
STEEL SPACER TUBE
℄ SPLICE BOLT
THRIE-BEAM RAIL ELEMENT
PLAN
℄ SPLICE BOLT
STEEL SPACER TUBE, SCH. 40 GALV. STEEL PIPE, 6" I.D., 20" LONG, SEE RC-50M.
THRIE-BEAM RAIL ELEMENT
SECTION
STEEL SPACER TUBE DETAIL
GUIDE RAIL TO BRIDGE BARRIER APPROACH TRANSITION RETRO-FITS
OPTION 2 - BARRIER MODIFICATION BARRIER STANDARDS BC-312 AND BC-313 DATED JANUARY 10, 1972
SHEET 6 OF 18
WORK WITH SHEETS 5, 7 & 8.

THRIEBEAM_RETRO.DGN




## OPTION 2 - THRIE-BEAM TO BRIDGE BARRIER TRANSITION

(PIPE RAILING AND POSTS NOT SHOWN ON EXISTING BARRIER FOR CLARITY)

| TABLE A | | |
|---|---|---|
| POST | LENGTH | SIZE |
| 1 THRU 2 | 8'-0" | W8x21 |
| 3 THRU 6 | 7'-0" | W6x15 |
| BEYOND 6 | 6'-0" | W6x9 |

SEE NOTE 1

NOTE:

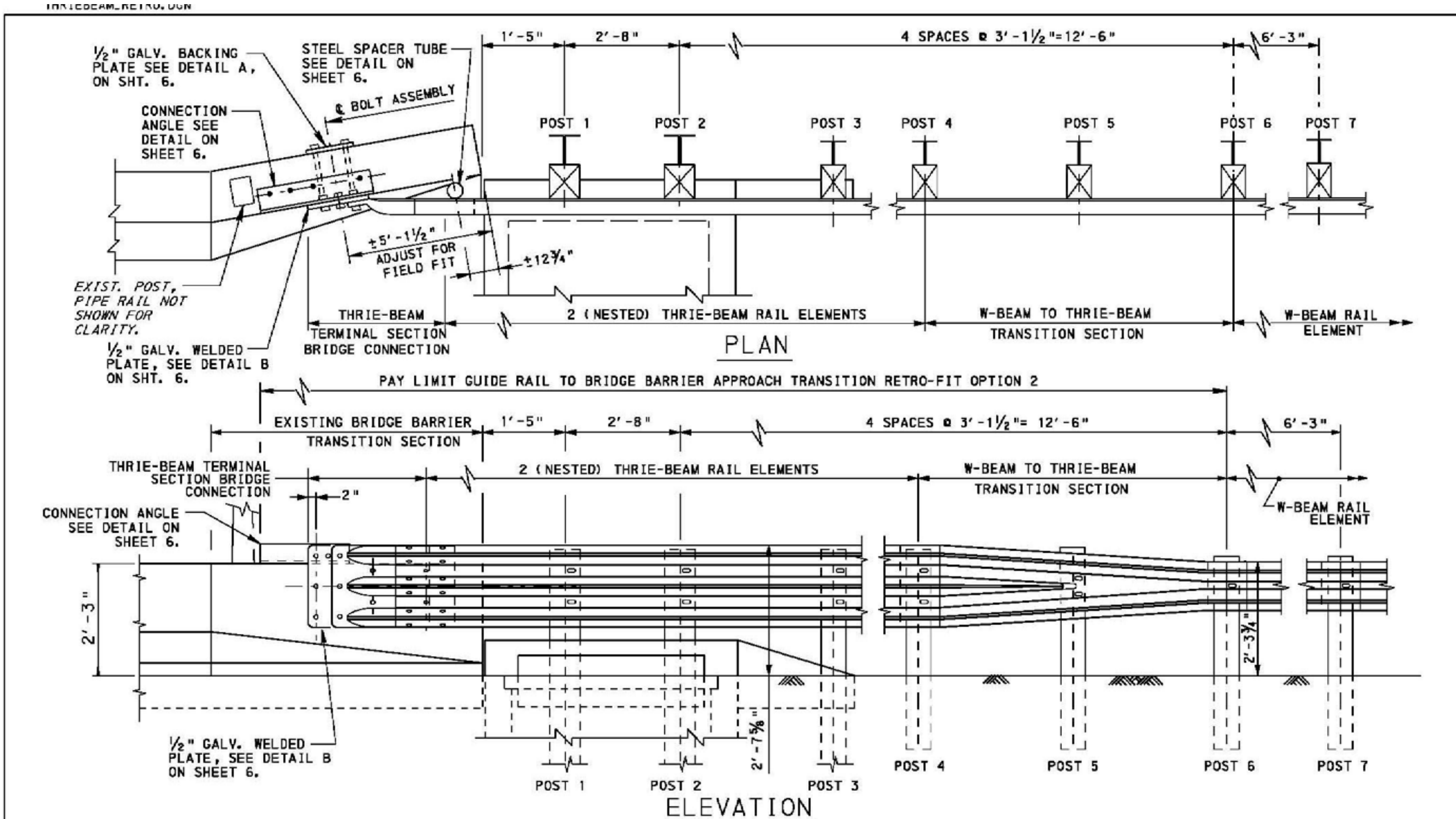
1. FOR POST LENGTH AND SIZE, SEE TABLE A.

WORK WITH SHEETS 5, 6 & 8.

GUIDE RAIL TO BRIDGE BARRIER APPROACH TRANSITION RETRO-FITS

OPTION 2 - BARRIER MODIFICATION BARRIER STANDARDS BC-312 AND BC-313 DATED JANUARY 10, 1972

SHEET 7 OF 18




## OPTION 2 - THRIE-BEAM TO BRIDGE BARRIER TRANSITION WITH INLET PLACEMENT OR UTILITY CONFLICT

(PIPE RAILING AND POSTS NOT SHOWN ON EXISTING BARRIER FOR CLARITY)

**NOTE:**

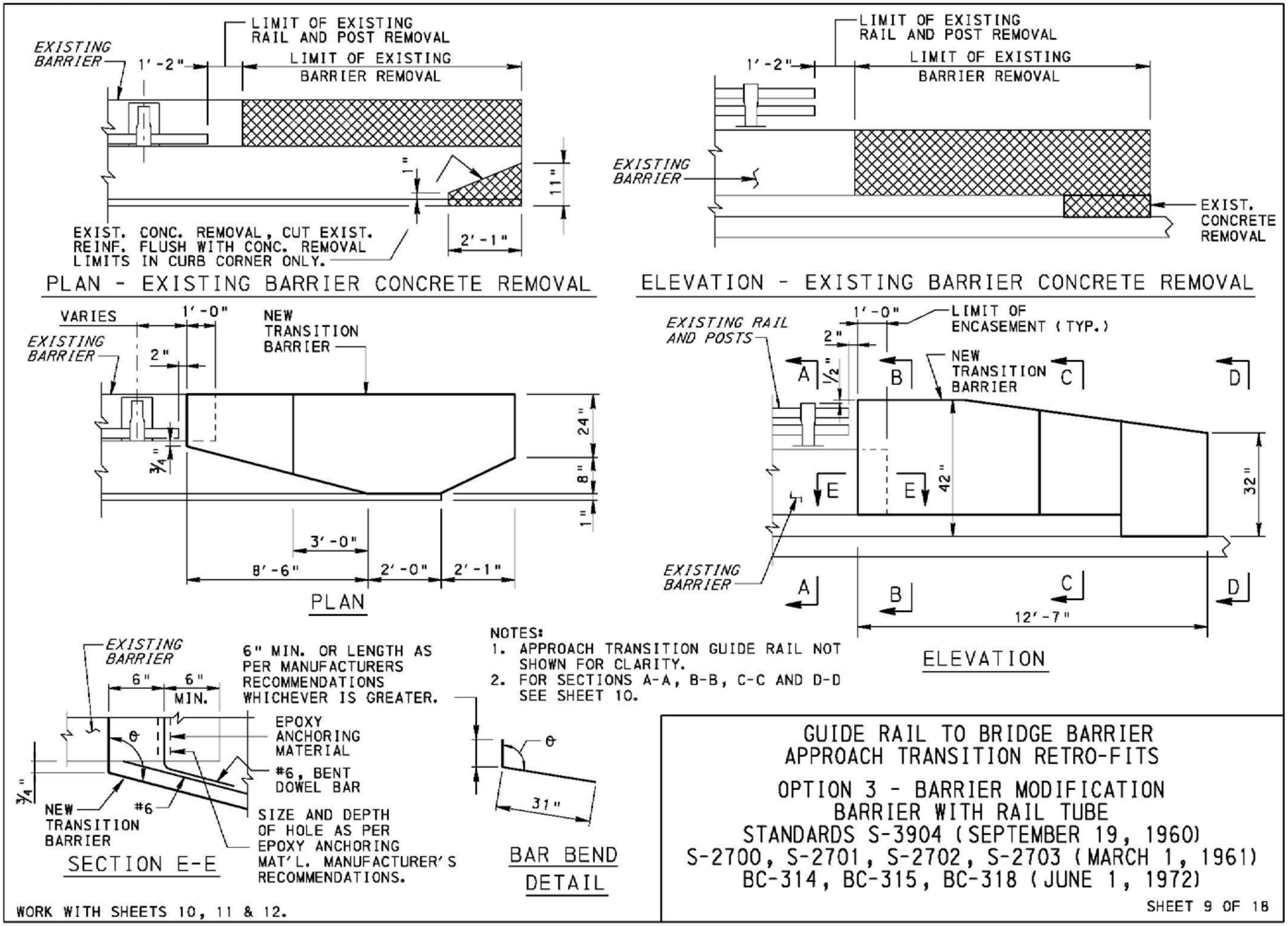
1. FOR POST SIZE AND SPACING, SEE TABLE A ON SHEET 7.

WORK WITH SHEETS 5, 6 & 7.

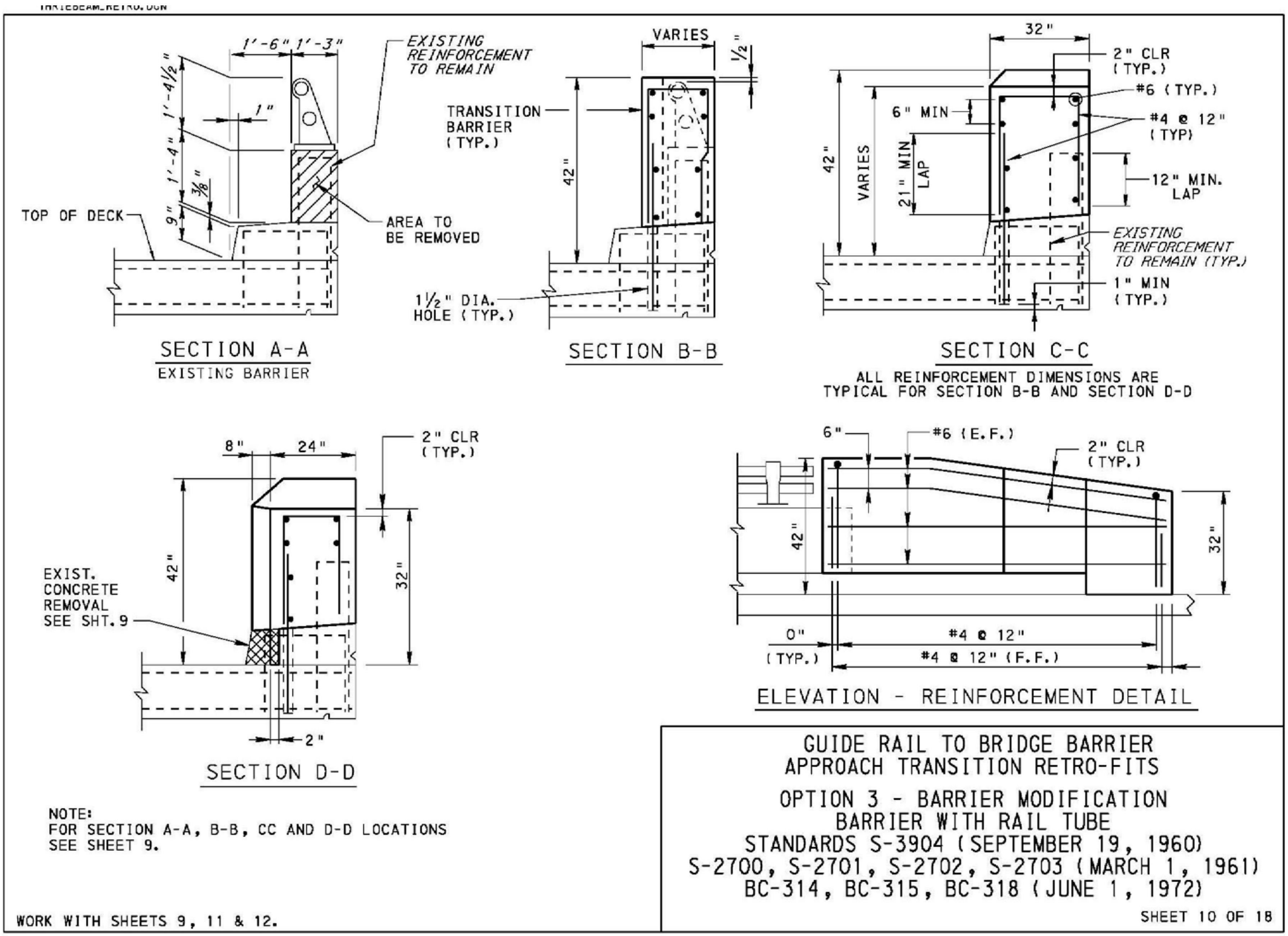
GUIDE RAIL TO BRIDGE BARRIER APPROACH TRANSITION RETRO-FITS

OPTION 2 - BARRIER MODIFICATION
BARRIER STANDARDS BC-312 AND BC-313
DATED JANUARY 10, 1972

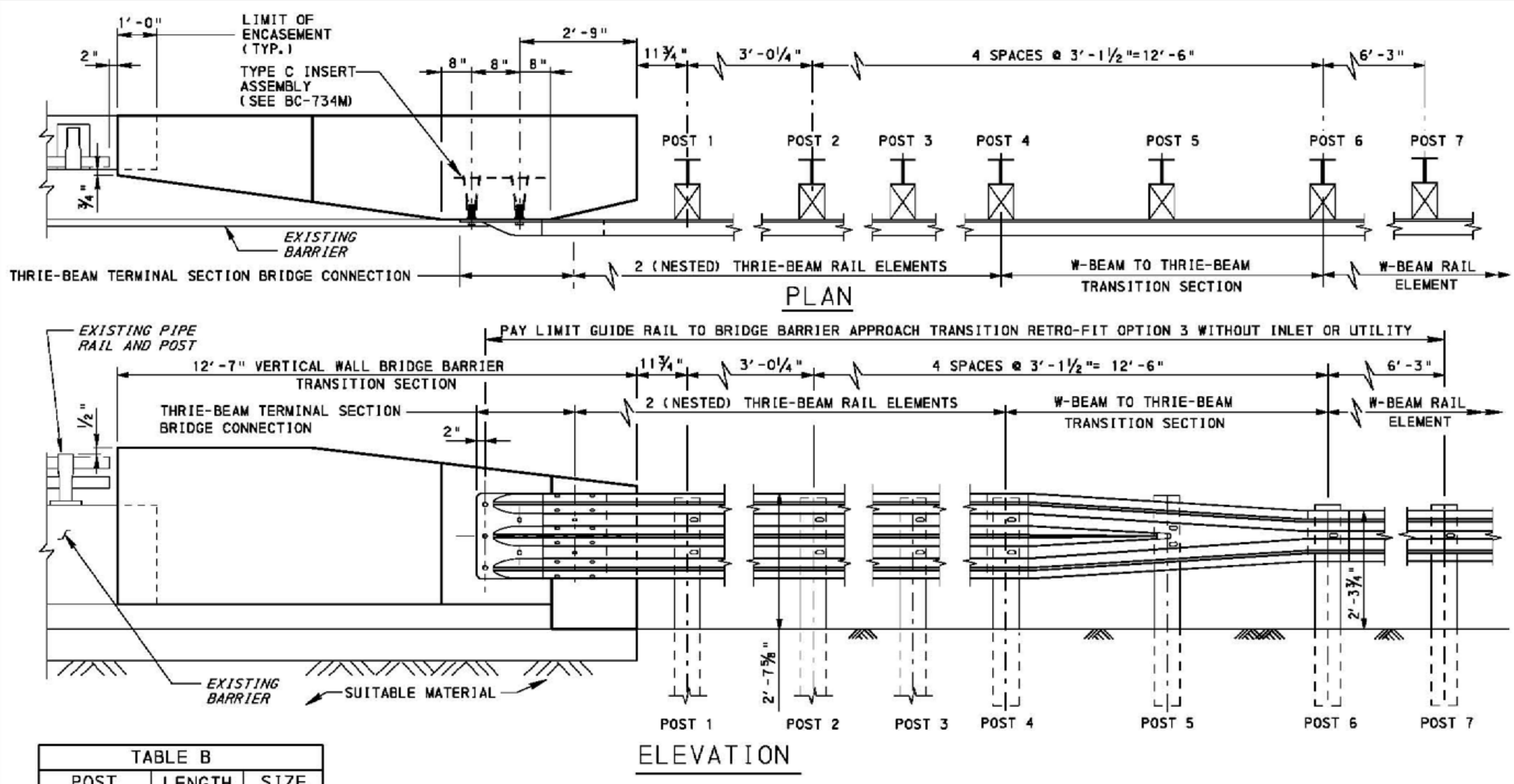
SHEET 8 OF 18



EXISTING BARRIER
1'-2"
LIMIT OF EXISTING RAIL AND POST REMOVAL
LIMIT OF EXISTING BARRIER REMOVAL
1"
11"
2'-1"
EXIST. CONC. REMOVAL, CUT EXIST. REINF. FLUSH WITH CONC. REMOVAL LIMITS IN CURB CORNER ONLY.
PLAN - EXISTING BARRIER CONCRETE REMOVAL
EXISTING BARRIER
EXIST. CONCRETE REMOVAL
ELEVATION - EXISTING BARRIER CONCRETE REMOVAL
VARIES
1'-0"
2"
EXISTING BARRIER
NEW TRANSITION BARRIER
3/4"
24"
8"
1"
3'-0"
8'-6"
2'-0"
2'-1"
PLAN
EXISTING RAIL AND POSTS
1'-0"
2"
1/2"
LIMIT OF ENCASEMENT (TYP.)
NEW TRANSITION BARRIER
A
B
C
D
E
42"
32"
EXISTING BARRIER
12'-7"
ELEVATION
EXISTING BARRIER
6"
6" MIN.
6" MIN. OR LENGTH AS PER MANUFACTURERS RECOMMENDATIONS WHICHEVER IS GREATER.
θ
EPOXY ANCHORING MATERIAL
#6, BENT DOWEL BAR
3/4"
NEW TRANSITION BARRIER
#6
SIZE AND DEPTH OF HOLE AS PER EPOXY ANCHORING MAT'L. MANUFACTURER'S RECOMMENDATIONS.
SECTION E-E
31"
BAR BEND DETAIL
NOTES:
1. APPROACH TRANSITION GUIDE RAIL NOT SHOWN FOR CLARITY.
2. FOR SECTIONS A-A, B-B, C-C AND D-D SEE SHEET 10.
GUIDE RAIL TO BRIDGE BARRIER APPROACH TRANSITION RETRO-FITS
OPTION 3 - BARRIER MODIFICATION
BARRIER WITH RAIL TUBE
STANDARDS S-3904 (SEPTEMBER 19, 1960)
S-2700, S-2701, S-2702, S-2703 (MARCH 1, 1961)
BC-314, BC-315, BC-318 (JUNE 1, 1972)
SHEET 9 OF 18
WORK WITH SHEETS 10, 11 & 12.


THRIEBEAM_RETRO.DGN
1'-6"
1'-3"
EXISTING REINFORCEMENT TO REMAIN
1'-4½"
1"
1'-4"
⅜"
9"
TOP OF DECK
AREA TO BE REMOVED
SECTION A-A
EXISTING BARRIER
VARIES
½"
TRANSITION BARRIER (TYP.)
42"
1½" DIA. HOLE (TYP.)
SECTION B-B
32"
2" CLR (TYP.)
#6 (TYP.)
6" MIN
#4 @ 12" (TYP)
42"
VARIES
21" MIN LAP
12" MIN. LAP
EXISTING REINFORCEMENT TO REMAIN (TYP.)
1" MIN (TYP.)
SECTION C-C
ALL REINFORCEMENT DIMENSIONS ARE TYPICAL FOR SECTION B-B AND SECTION D-D
8"
24"
2" CLR (TYP.)
42"
32"
EXIST. CONCRETE REMOVAL SEE SHT. 9
2"
SECTION D-D
6"
#6 (E.F.)
2" CLR (TYP.)
42"
32"
0" (TYP.)
#4 @ 12"
#4 @ 12" (F.F.)
ELEVATION - REINFORCEMENT DETAIL
NOTE:
FOR SECTION A-A, B-B, CC AND D-D LOCATIONS SEE SHEET 9.
WORK WITH SHEETS 9, 11 & 12.
GUIDE RAIL TO BRIDGE BARRIER APPROACH TRANSITION RETRO-FITS
OPTION 3 - BARRIER MODIFICATION
BARRIER WITH RAIL TUBE
STANDARDS S-3904 (SEPTEMBER 19, 1960)
S-2700, S-2701, S-2702, S-2703 (MARCH 1, 1961)
BC-314, BC-315, BC-318 (JUNE 1, 1972)
SHEET 10 OF 18

THRIEBEAM_RETRO.DGN




## OPTION 3 - THRIE-BEAM TO BRIDGE BARRIER TRANSITION

(WITHOUT INLET PLACEMENT OR UTILITY CONFLICT)

| TABLE B | | |
|---|---|---|
| POST | LENGTH | SIZE |
| 1 THRU 3 | 8'-6" | W6x25 |
| 4 THRU 7 | 7'-0" | W6x15 |
| BEYOND 7 | 6'-0" | W6x9 |

SEE NOTE 1

NOTES:

1. FOR LOCATIONS WITH NO UTILITY OR INLET CONFLICT, USE TABLE B, FOR POST LENGTH AND SIZE. FOR LOCATIONS WITH CONFLICT, SEE SHEET 12.
2. FOR REINFORCEMENT DETAILS NOT SHOWN SEE SHEET 10.

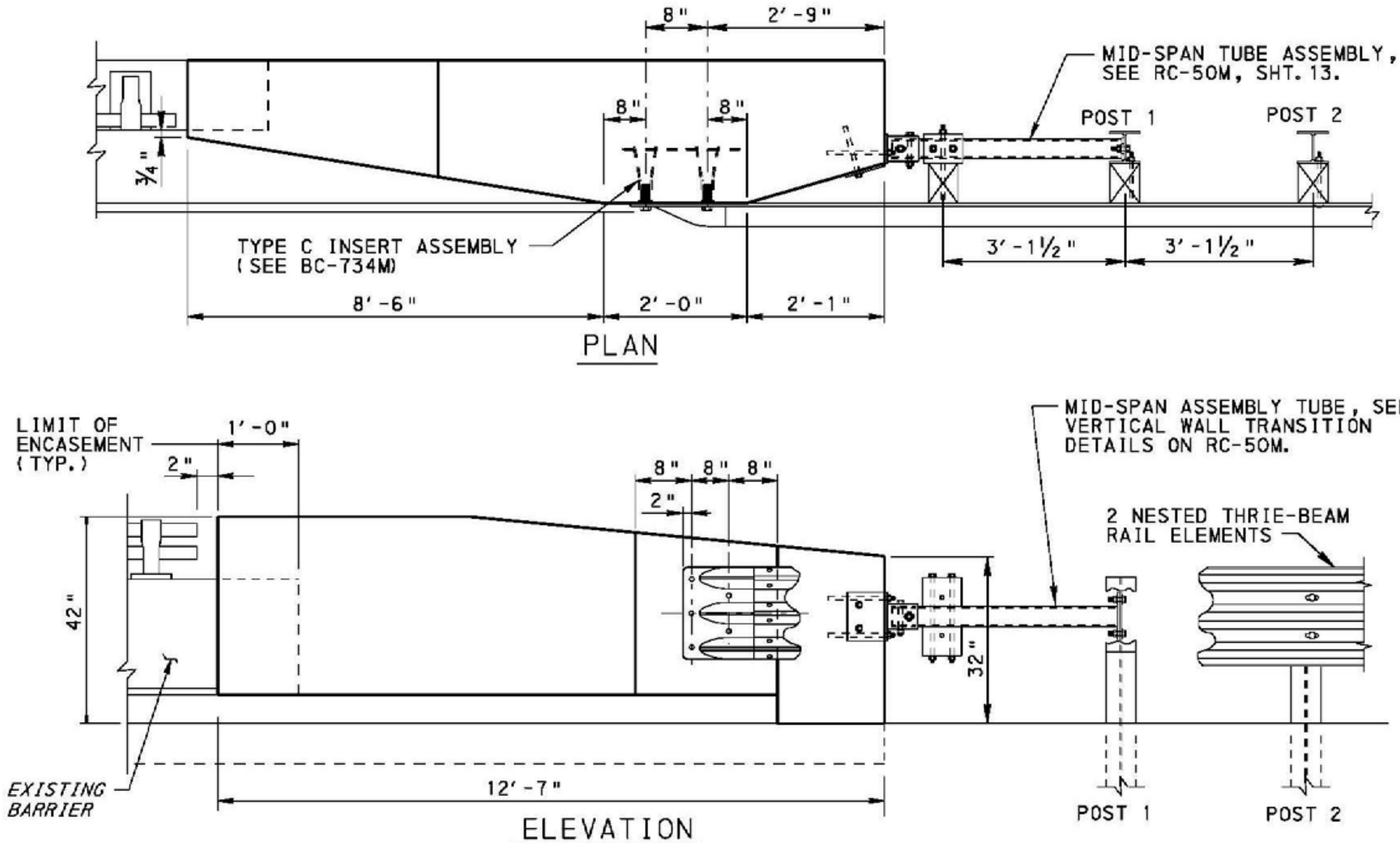
WORK WITH SHEETS 9, 10 & 12.

GUIDE RAIL TO BRIDGE BARRIER
APPROACH TRANSITION RETRO-FITS

OPTION 3 - BARRIER MODIFICATION
BARRIER WITH RAIL TUBE
STANDARDS S-3904 (SEPTEMBER 19, 1960)
S-2700, S-2701, S-2702, S-2703 (MARCH 1, 1961)
BC-314, BC-315, BC-318 (JUNE 1, 1972)

SHEET 11 OF 18

THRIEBEAM_RETRO.DGN




## OPTION 3 - THRIE-BEAM TO BRIDGE BARRIER TRANSITION WITH INLET OR UTILITY CONFLICT

**NOTES:**

1. FOR APPROACH TRANSITION POST NUMBERING, LENGTH, AND SIZE IN LOCATIONS WITH INLET OR UTILITY CONFLICT, USE TABLE FROM RC-50M FOR THRIE-BEAM TO VERTICAL WALL TRANSITIONS.
2. FOR POST AND MID-SPAN TUBE DETAILING NOT SHOWN SEE STANDARD DRAWING BC-703M, RC-50M AND PUB. 408 SPECIFICATIONS.
3. FOR REINFORCEMENT NOT SHOWN SEE SHEET 10.

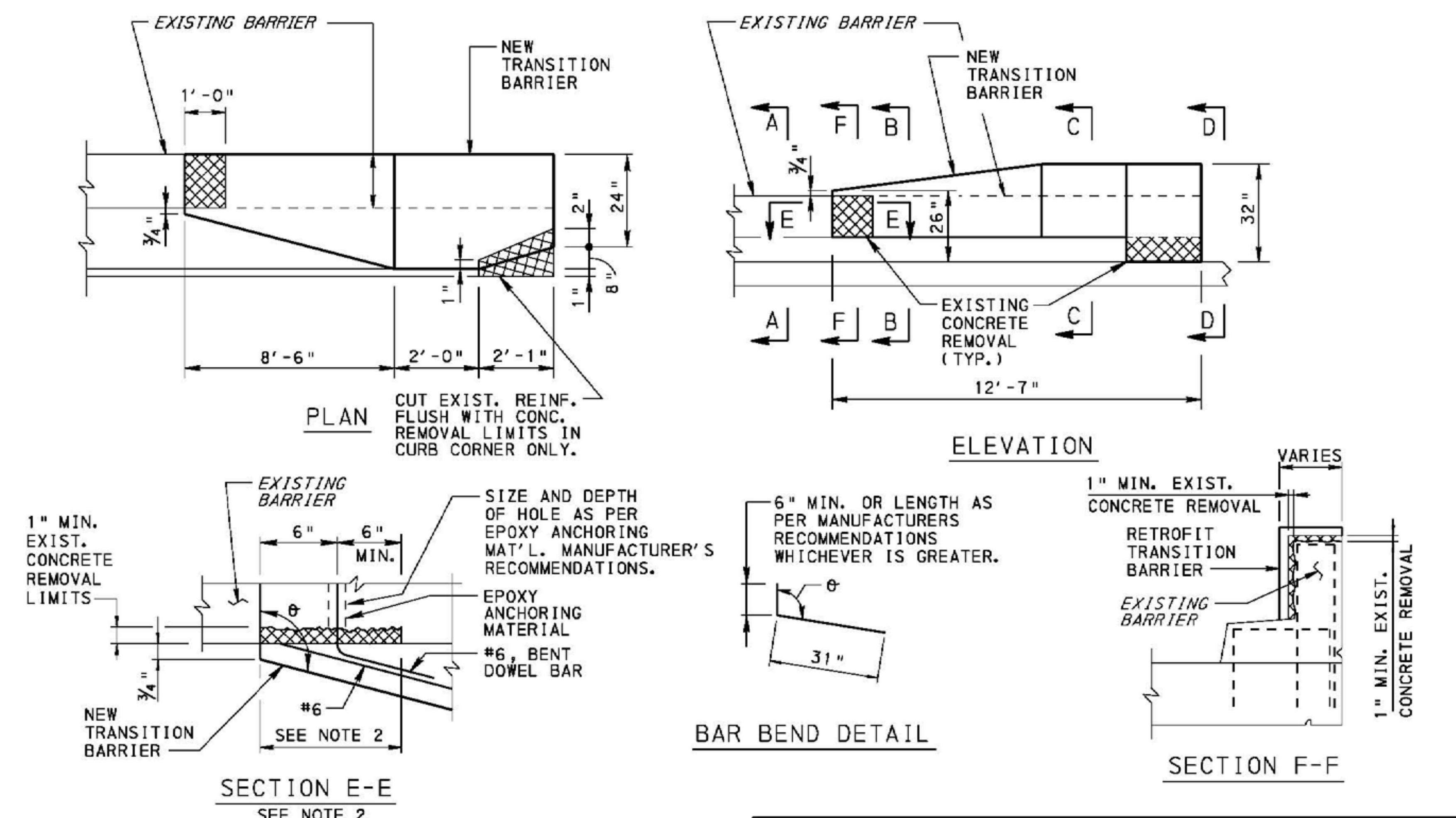
WORK WITH SHEETS 9, 10 & 11.

GUIDE RAIL TO BRIDGE BARRIER
APPROACH TRANSITION RETRO-FITS

OPTION 3 - BARRIER MODIFICATION
BARRIER WITH RAIL TUBE
STANDARDS S-3904 (SEPTEMBER 19, 1960)
S-2700, S-2701, S-2702, S-2703 (MARCH 1, 1961)
BC-314, BC-315, BC-318 (JUNE 1, 1972)

SHEET 12 OF 18

THRIEBEAM_RETRO.DGN




**NOTES:**

1. FOR REINFORCEMENT DETAILS NOT SHOWN SEE SHEET 14.
2. AS REQUIRED TO MAINTAIN COVER TO #6 BAR.

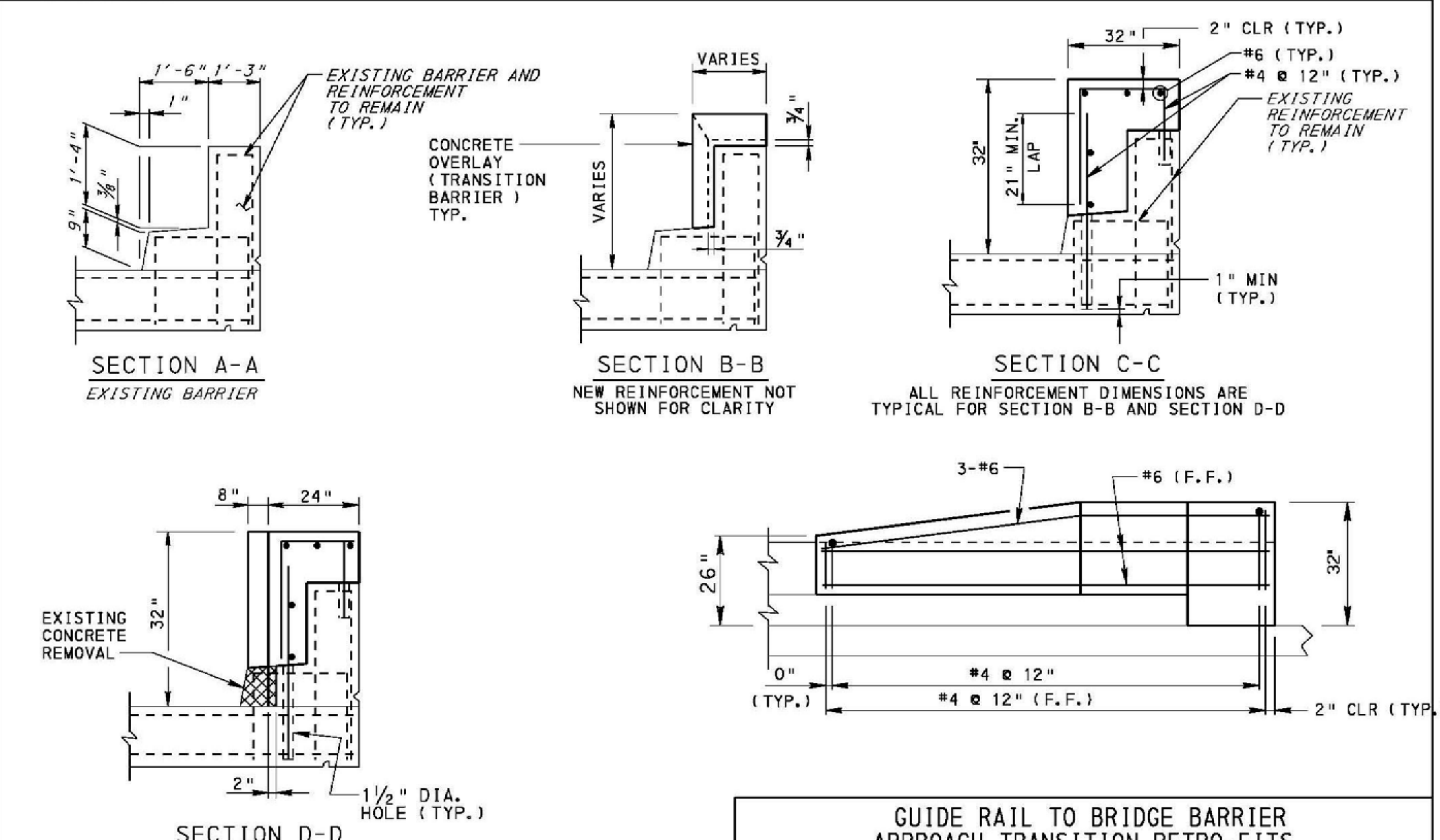
WORK WITH SHEETS 14, 15 & 16.

GUIDE RAIL TO BRIDGE BARRIER
APPROACH TRANSITION RETRO-FITS

OPTION 4 - BARRIER MODIFICATION
BARRIER WITHOUT RAIL TUBE
STANDARDS S-3904 (SEPTEMBER 19, 1960)
S-2700, S-2701, S-2702, S-2703 (MARCH 1, 1961)
BC-314, BC-315, BC-318 (JUNE 1, 1972)

SHEET 13 OF 18

THRIEBEAM_RETRO.DGN




NOTE:
FOR SECTION A-A, B-B, CC AND D-D LOCATIONS SEE SHEET 13.

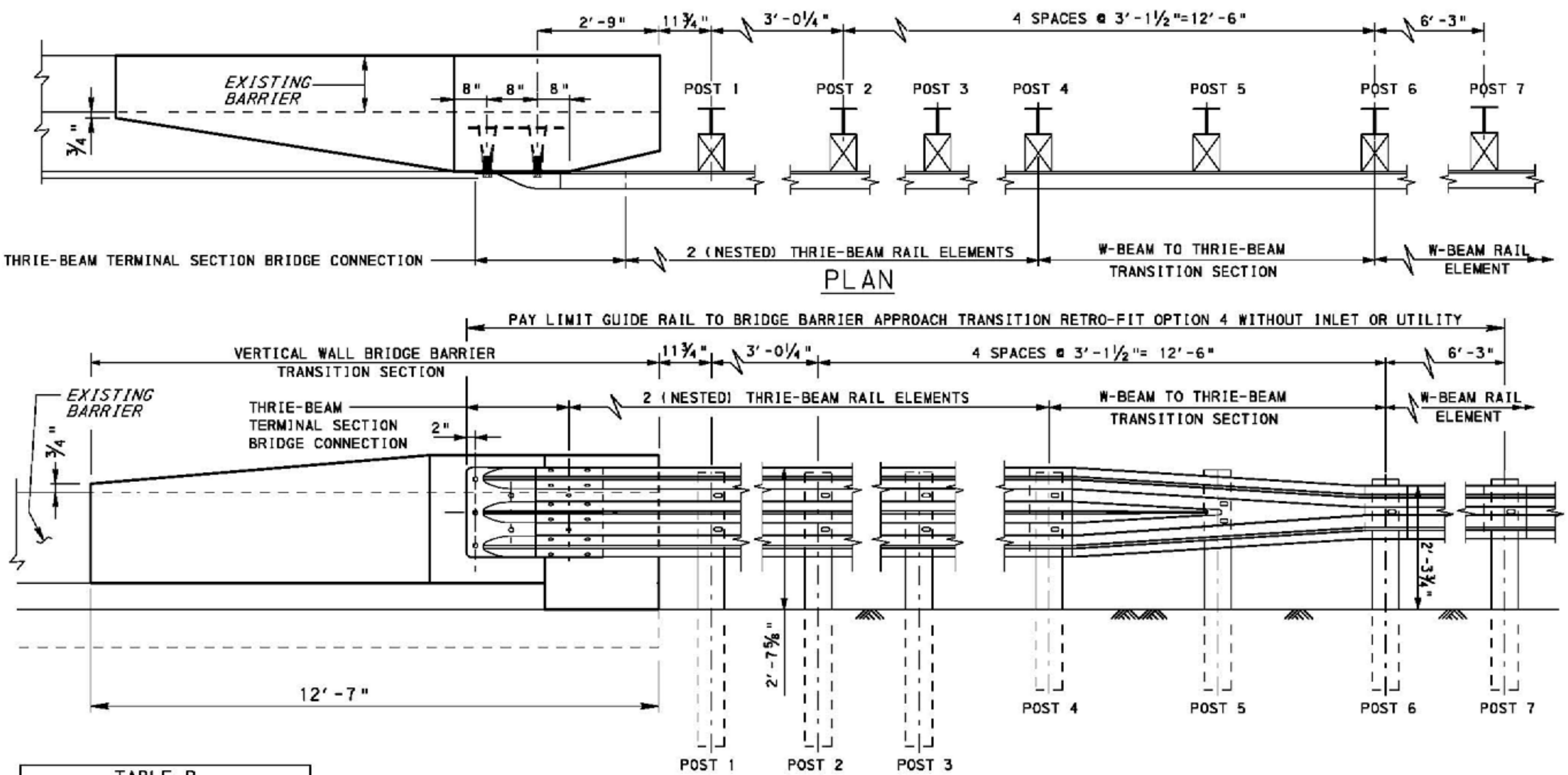
WORK WITH SHEETS 13, 15 & 16.

GUIDE RAIL TO BRIDGE BARRIER
APPROACH TRANSITION RETRO-FITS

OPTION 4 - BARRIER MODIFICATION
BARRIER WITHOUT RAIL TUBE
STANDARDS S-3904 (SEPTEMBER 19, 1960)
S-2700, S-2701, S-2702, S-2703 (MARCH 1, 1961)
BC-314, BC-315, BC-318 (JUNE 1, 1972)

SHEET 14 OF 18

THRIEBEAM_RETRO.DGN




ELEVATION

| TABLE B | | |
|---|---|---|
| POST | LENGTH | SIZE |
| 1 THRU 3 | 8'-6" | W6x25 |
| 4 THRU 7 | 7'-0" | W6x15 |
| BEYOND 7 | 6'-0" | W6x9 |

SEE NOTE 1

# OPTION 4 - THRIE-BEAM TO BRIDGE BARRIER TRANSITION

(WITHOUT INLET PLACEMENT OR UTILITY CONFLICT)

NOTES:

1. FOR LOCATIONS WITH NO UTILITY OR INLET CONFLICT, USE TABLE B, FOR POST LENGTH AND SIZE. FOR LOCATIONS WITH CONFLICT, SEE SHEET 16.

2. FOR REINFORCEMENT DETAILS NOT SHOWN SEE SHEET 14.

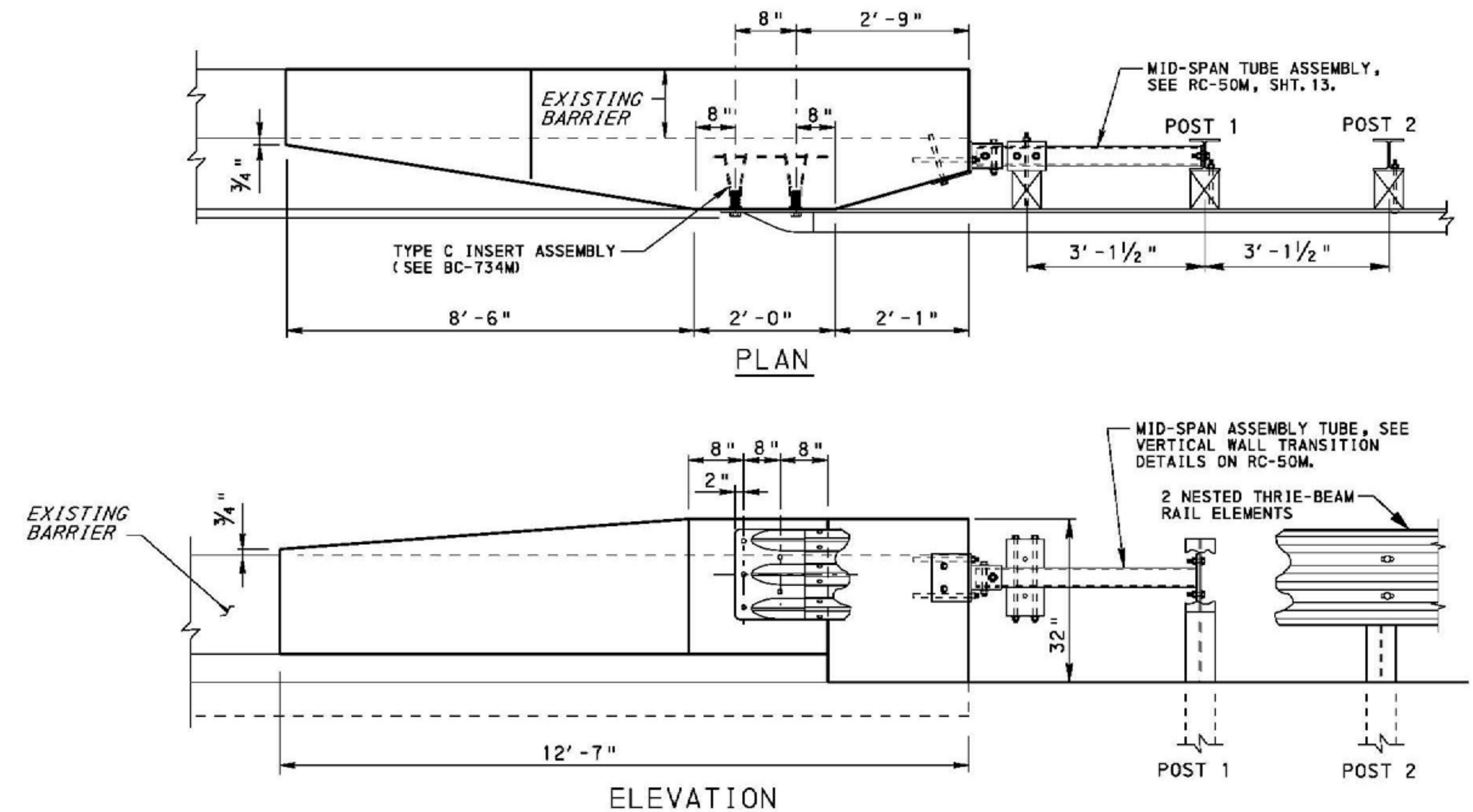
WORK WITH SHEETS 13, 14 & 16.

GUIDE RAIL TO BRIDGE BARRIER
APPROACH TRANSITION RETRO-FITS

OPTION 4 - BARRIER MODIFICATION
BARRIER WITHOUT RAIL TUBE
STANDARDS S-3904 (SEPTEMBER 19, 1960)
S-2700, S-2701, S-2702, S-2703 (MARCH 1, 1961)
BC-314, BC-315, BC-318 (JUNE 1, 1972)

SHEET 15 OF 18

THRIEBEAM_RETRO.DGN




## OPTION 4 - THRIE-BEAM TO BRIDGE BARRIER TRANSITION WITH INLET OR UTILITY CONFLICT

NOTES:

1. FOR APPROACH TRANSITION POST NUMBERING, LENGTH, AND SIZE IN LOCATIONS WITH INLET OR UTILITY CONFLICT, USE TABLE FROM RC-50M FOR THRIE-BEAM TO VERTICAL WALL TRANSITIONS.
2. FOR POST AND MID-SPAN TUBE DETAILING NOT SHOWN SEE STANDARD DRAWING BC-703M, RC-50M AND PUB. 408 SPECIFICATIONS.
3. FOR REINFORCEMENT NOT SHOWN SEE SHEET 14.

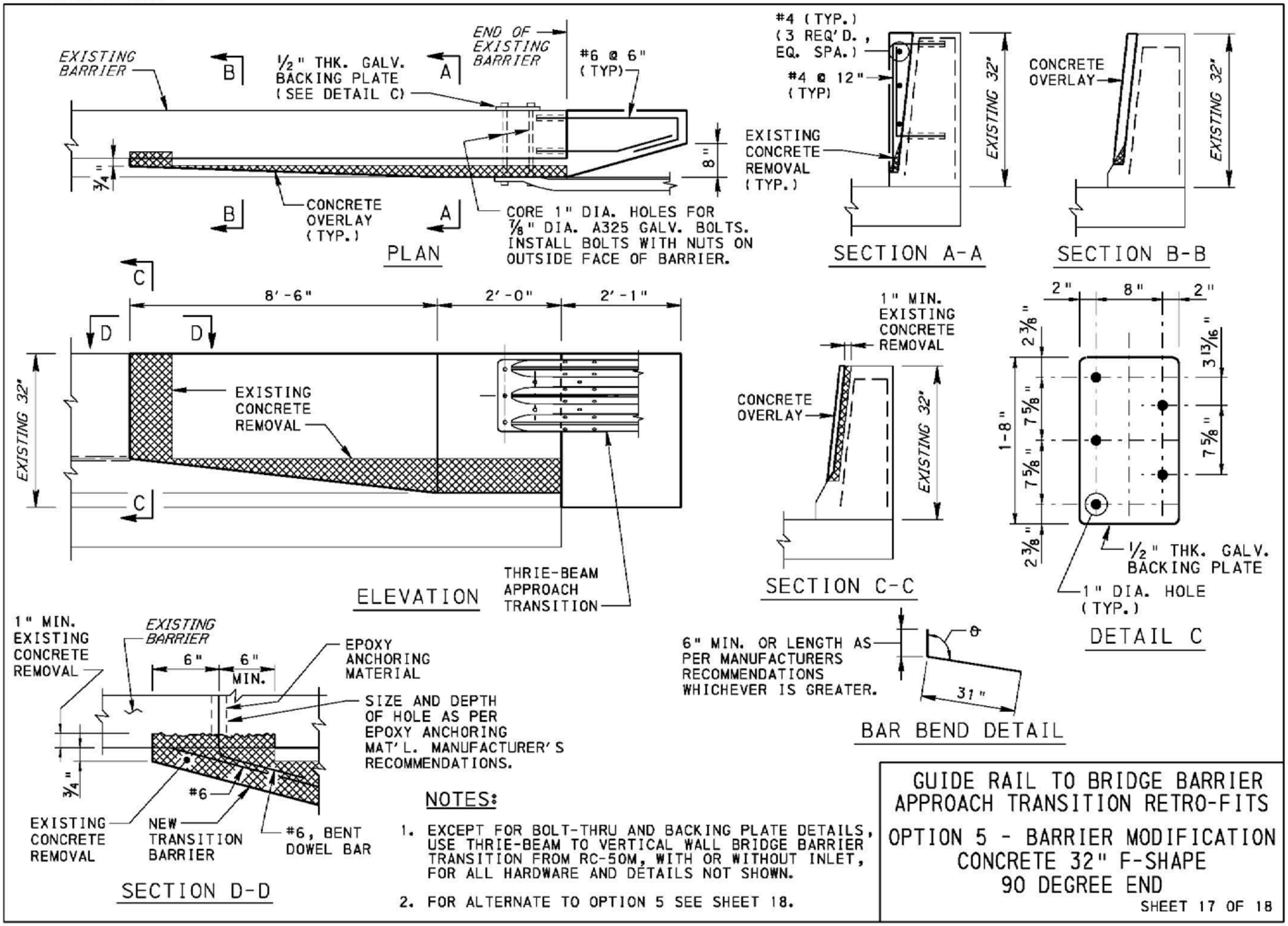
WORK WITH SHEETS 13, 14 & 15.

GUIDE RAIL TO BRIDGE BARRIER
APPROACH TRANSITION RETRO-FITS

OPTION 4 - BARRIER MODIFICATION
BARRIER WITHOUT RAIL TUBE
STANDARDS S-3904 (SEPTEMBER 19, 1960)
S-2700, S-2701, S-2702, S-2703 (MARCH 1, 1961)
BC-314, BC-315, BC-318 (JUNE 1, 1972)

SHEET 16 OF 18

THRIEBEAM_RETRO.DGN



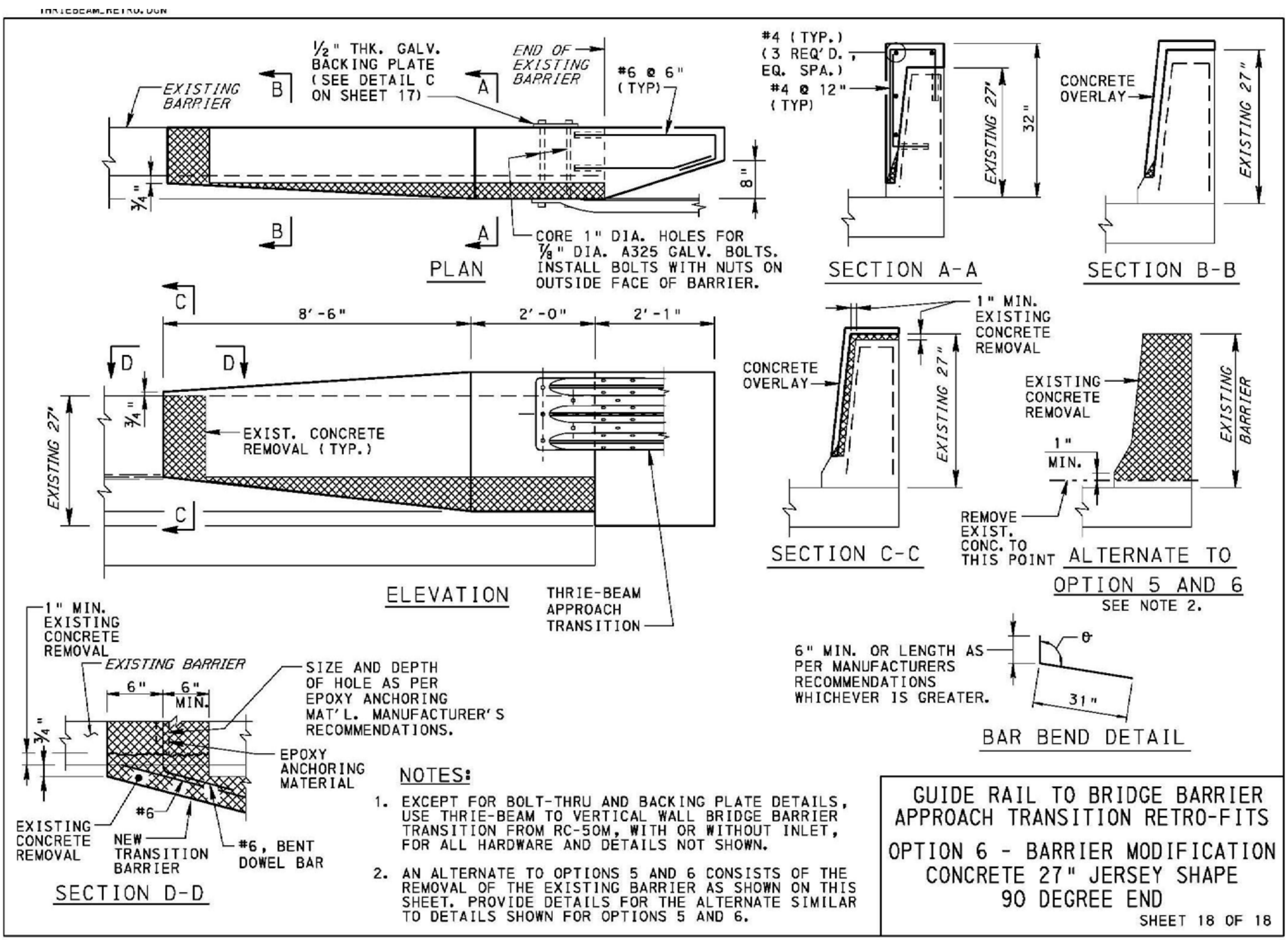

NOTES:

1. EXCEPT FOR BOLT-THRU AND BACKING PLATE DETAILS, USE THRIE-BEAM TO VERTICAL WALL BRIDGE BARRIER TRANSITION FROM RC-50M, WITH OR WITHOUT INLET, FOR ALL HARDWARE AND DETAILS NOT SHOWN.
2. FOR ALTERNATE TO OPTION 5 SEE SHEET 18.

GUIDE RAIL TO BRIDGE BARRIER APPROACH TRANSITION RETRO-FITS

OPTION 5 - BARRIER MODIFICATION CONCRETE 32" F-SHAPE 90 DEGREE END

SHEET 17 OF 18


THRIEBEAM_RETRO.DGN
½" THK. GALV. BACKING PLATE (SEE DETAIL C ON SHEET 17)
END OF EXISTING BARRIER
EXISTING BARRIER
#6 @ 6" (TYP)
8"
¾"
CORE 1" DIA. HOLES FOR ⅞" DIA. A325 GALV. BOLTS. INSTALL BOLTS WITH NUTS ON OUTSIDE FACE OF BARRIER.
PLAN
#4 (TYP.) (3 REQ'D., EQ. SPA.)
#4 @ 12" (TYP)
EXISTING 27"
32"
SECTION A-A
CONCRETE OVERLAY
EXISTING 27"
SECTION B-B
8'-6"
2'-0"
2'-1"
EXISTING 27"
EXIST. CONCRETE REMOVAL (TYP.)
ELEVATION
THRIE-BEAM APPROACH TRANSITION
1" MIN. EXISTING CONCRETE REMOVAL
CONCRETE OVERLAY
EXISTING 27"
SECTION C-C
EXISTING CONCRETE REMOVAL
EXISTING BARRIER
1" MIN.
REMOVE EXIST. CONC. TO THIS POINT
ALTERNATE TO OPTION 5 AND 6
SEE NOTE 2.
6" MIN. OR LENGTH AS PER MANUFACTURERS RECOMMENDATIONS WHICHEVER IS GREATER.
θ
31"
BAR BEND DETAIL
1" MIN. EXISTING CONCRETE REMOVAL
EXISTING BARRIER
6"
6" MIN.
SIZE AND DEPTH OF HOLE AS PER EPOXY ANCHORING MAT'L. MANUFACTURER'S RECOMMENDATIONS.
EPOXY ANCHORING MATERIAL
EXISTING CONCRETE REMOVAL
#6
NEW TRANSITION BARRIER
#6, BENT DOWEL BAR
SECTION D-D
NOTES:
1. EXCEPT FOR BOLT-THRU AND BACKING PLATE DETAILS, USE THRIE-BEAM TO VERTICAL WALL BRIDGE BARRIER TRANSITION FROM RC-50M, WITH OR WITHOUT INLET, FOR ALL HARDWARE AND DETAILS NOT SHOWN.
2. AN ALTERNATE TO OPTIONS 5 AND 6 CONSISTS OF THE REMOVAL OF THE EXISTING BARRIER AS SHOWN ON THIS SHEET. PROVIDE DETAILS FOR THE ALTERNATE SIMILAR TO DETAILS SHOWN FOR OPTIONS 5 AND 6.
GUIDE RAIL TO BRIDGE BARRIER APPROACH TRANSITION RETRO-FITS
OPTION 6 - BARRIER MODIFICATION CONCRETE 27" JERSEY SHAPE 90 DEGREE END
SHEET 18 OF 18

# CHAPTER 13

## EROSION AND SEDIMENT POLLUTION CONTROL

### 13.0 INTRODUCTION

Pennsylvania's Clean Streams Law of 1937 (Act 394), as amended, prohibits the discharge to the waters of the Commonwealth of any pollutive materials whether from industrial or domestic sources. It also allows the Pennsylvania Department of Environmental Protection (PA DEP) to regulate any activity which creates a danger of pollution or has a potential for pollution. Pennsylvania's program for the control of erosion and sediment pollution has been adopted under the authority of Chapter 102 of PA DEP's Rules and Regulations. To explain the requirements of this program pursuant to the Chapter 102, PA DEP's Bureau of Soil and Water Conservation published in April 1990 an implementation manual titled, "Erosion and Sediment Pollution Control Program Manual". (It was updated in March 2000.) Other related programs adopted by PA DEP are Chapter 105 (Dam Safety and Waterway Management) and Chapter 106 (Flood Plain Management) regulations. Pertinent regulations regarding the Storm Water Management Act of 1978 (Act 167) are addressed separately in Chapter 10, Drainage Design and Related Procedures.

Also, as stipulated in the Federal-Aid Policy Guide, 23 CFR 650, Subpart B, it is the policy of the Federal Highway Administration (FHWA) that Federal-aid highways and highways constructed under the direct supervision of FHWA shall be located, designed, constructed and operated according to standards that minimize erosion and sediment damage to the highway and adjacent properties and abate pollution of surface and ground water resources.

Water pollution degrades surface waters making them unsafe for drinking, fishing, swimming, and other activities. As authorized by the Federal Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. Point sources are discrete conveyances such as pipes or man-made ditches. In most cases, the NPDES permit program is administered by authorized states. Since its introduction in 1972, the NPDES permit program is responsible for significant improvements to our Nation's water quality. Section 13.5.B discusses the NPDES permit program for Pennsylvania in greater detail.

Soil erosion is the process by which the land surface is worn away by the action of wind, water, ice and gravity. Under natural conditions, erosion occurs at a very slow and uniform rate and is a vital requirement in maintaining environmental balance. Sedimentation is the process involving the gravitational deposit of transported material in flowing or standing water. Erosion and sedimentation are normal geologic processes and are a matter of concern when accelerated by highway related activities. Such activities include the removal of the natural protective vegetative cover, the disturbance of the soil or other significant changes in topography.

The disturbance of land during construction is frequently accompanied by sudden, drastic increases in soil erosion. This accelerated erosion can be minimized by prudent scheduling of construction activities. Control measures can reduce sediment production. PA DEP's Chapter 102 regulations require that all persons or municipalities engaged in earthmoving activities shall develop, implement and maintain erosion and sediment pollution control measures which effectively minimize accelerated erosion and prevent sediment pollution. Section 13.1 provides highlights of the Chapter 102 regulations.

### 13.1 CONSIDERATIONS RELEVANT TO CONSTRUCTION

Effective erosion control planning begins during the preliminary design phase of highway project development. Control of construction activities and knowledge of the soils encountered are basic to determine measures for preventing erosion and the movement of sediment. Control measures shall be designed to fit the environment, topography, soils, rainfall, land use and construction schedules. A highway location selected with consideration of the problems associated with these basic elements can greatly reduce erosion problems during and after construction.

Prevention of sediment pollution of waterways involves the following principles: (1) schedule construction activities to reduce soil area exposed; (2) control erosion at the source; (3) control water that flows across the right-of-way and (4) perform timely seeding and mulching operations to stabilize disturbed areas as soon as possible. The key to controlling sediment pollution is to control soil erosion at the source.

Special precautions should be taken in the use of construction equipment to prevent operations which promote erosion. Wheel tracks from heavy equipment are vulnerable to erosion from the concentration of water. Fording of streams with equipment shall be kept to a minimum and, where required, shall be performed in accordance with the requirements of Chapter 10, Drainage Design and Related Procedures, and regulatory permit requirements. Regulatory permit requirements take precedence over any design manuals.

Embankment slopes that encroach on or near stream channels should be adequately protected against erosion. Where possible, a protective buffer of vegetative cover should be preserved or established between the top of cuts or bottom of fills and the adjacent ditch or drainage way. The buffer area should be identified on the typical sections and plans and protected from construction activity.

Borrow pits and waste disposal areas should be selected with full consideration of erosion control requirements during borrow or disposal operations and during the final treatment or restoration of the area. Wherever located, special precautions shall be taken to control erosion and sediment problems and off-site effects. The disposal of waste in wetlands or in the flood channel area of any stream is prohibited. Regardless of the responsibility of the selection of borrow areas, plans of operation and of restoration, cleanup, shaping, seeding and mulching shall be approved by the Engineer.

Plans for the control of runoff must include measures to keep sediment from entering waterways before borrow or disposal operations begin. Diversion channels and sediment traps or sediment basins may be used for this purpose. Topsoil from the borrow pit area shall be salvaged for use in restoring the borrow area. Topsoil from a waste area should also be salvaged if it is needed for restoration. Stockpiled topsoil shall be protected from erosion. Final restoration of borrow and waste disposal areas shall include grading, establishment of vegetative cover and other treatments that blend the area into the surrounding landscape. The restored areas shall be well drained, unless approval is given to convert the pit area into wetlands or lakes for fish and wildlife, recreation, stock water or irrigation. Erosion and sediment pollution control shall be provided and maintained at wetland mitigation sites until they become established.

Where practical, erosion and sediment pollution control measures, also referred to as best management practices (BMPs), should be located within the normal right-of-way. However, when necessary, additional right-of-way acquisition may be required and shall be considered prior to completion of the right-of-way plans. If erosion and sediment pollution control measures will be removed during the construction contract, a temporary area for construction may be utilized. The control of the water across the right-of-way shall be completed prior to or concurrent with clearing and grubbing for the roadway. This may require offsetting the culverts from the natural drainage course to transport the water across the work area. All earth ditches or channels shall be stabilized before use to prevent erosion. Runoff from work areas shall be collected and controlled prior to entering a natural watercourse. All water originating outside of the project should be kept separate from that originating within the construction area.

Accelerated erosion can be minimized by the use of the following: (1) slopes which are rounded and blended into the natural terrain; (2) drainage channels properly designed with regard to location, width, depth, slope alignment and protective treatment; (3) proper facilities for ground water interception; (4) dikes; (5) berms and other protective devices; (6) protective ground covers and plantings and (7) properly designed sedimentation removal devices.

Erosion and sediment pollution control BMPs should be indicated on the construction drawings, as required, and so located that they do not interfere with the normal construction operations. The use of several smaller BMPs off the main stream has the advantage of not interfering with fish life and has less detrimental consequences in case of failure or overtopping of BMPs, since failure from overtopping is not likely to occur at all of the small BMPs simultaneously. BMPs located within a waterway may require a Chapter 105 permit from PA DEP.

Most erosion and sediment pollution control BMPs will be temporary, since most of the soil erosion occurs only during construction. Permanent detention basins provided for stormwater management purposes may be used as sediment basins during highway construction. Those basins located in a regulated watershed pursuant to the Storm

Water Management Act shall be designed and constructed in accordance with the standards of the individual watershed stormwater management plans. In some special cases, a multipurpose detention basin may be installed to provide water quality and wildlife habitat enhancements. Permanent erosion and sediment pollution control BMPs shall have a plan of maintenance. Temporary erosion and sediment pollution control BMPs shall be cleaned and maintained to assure proper functioning for the expected period of use. Some basins or ponds, because of size or location, may require protective fencing to limit unauthorized access.

Erosion and sediment pollution control BMPs shall be provided for all phases of construction activities including those items which are not normally specified in construction drawings. These BMPs also may be required for testing operations such as those for archeology and drilling.

## 13.2 SEEDING AND MULCHING STABILIZATION

Seeding with various grass or grass and leguminous plant mixtures is necessary to restore vegetative cover to soil surfaces exposed during excavation operations. Restoring the vegetative cover with deep-rooted, long lived and persistent adapted plant species is the most effective measure to prevent extensive soil erosion and any accompanying sedimentation loss and deposit in undesired areas. The use of permanent or temporary seeding or temporary mulching must be anticipated during earthwork operations.

**A. Standard Highway Seeding Mixtures.** Publication 408, *Specifications,* Section 804 lists several standard seeding mixture formulas which should be used on typical construction slopes for highway construction projects. A general description and guideline for their use is as follows:

**1.** Formula B. This is a refined lawn type, sod forming grass formula containing a large percentage of Kentucky bluegrasses with perennial ryegrass and red fescues. This mixture is generally used on non-steep surfaces where a more highly maintained and mowed surface, such as a lawn, is desired. Use only on areas which have topsoil.

**2.** Formula C. This is a mixture of predominantly crownvetch (leguminous plant) with a nurse crop of annual ryegrass. The ryegrass will hold the soil in place until the slower growing crownvetch establishes itself. This mixture is generally used on slopes steeper than 1V:3H where mowing is not anticipated or desired. Crownvetch is the state's official Soil Conservation Plant. Crownvetch will normally hinder the invasion of adjacent native vegetation for many years. Topsoil application is not necessary in areas to receive Formula C. Do not use within 6.0 m (20 ft) of areas where evergreen trees, shrubs, seedlings or vines are to be planted.

Although this plant species is good for erosion control, Formula C has the capability of moving beyond the right-of-way. It can "creep" over and shade out other low growing vegetation. It can also cling to low hanging branches and onto right-of-way fence. The Pennsylvania Department of Conservation and Natural Resources (DCNR) considers Formula C to be a problematic, invasive plant in certain areas when it establishes outside of the right-of-way into residential and agricultural properties or other native plant communities.

**3.** Formula D. This is a rougher grass type, sod forming mixture containing a large percentage of tall and fine fescues. This mixture is generally used on most highway slope areas not receiving Formula C where mowing may or may not be designated. In non-mowed areas, this formula will eventually allow invasion and succession by adjacent native woody plants or wildflowers. Normally used in drainage channels or swales requiring permanent seeding.

**4.** Formula E. This is a 100% crop of annual ryegrass which is generally used to quickly stabilize exposed soil surfaces since it generally germinates within 2 weeks when climate conditions are favorable. Since the life cycle of this grass averages 1 to 2 years, this formula is considered most often for temporary use on unfinished graded areas during construction.

**5.** Formula L. This is a fine textured, sod forming mixture of hard fescue, red fescue with a nurse crop of annual ryegrass. This mixture can be used on low maintenance slope areas which will not be normally mowed and on flatter areas which will not receive more than 2 mowing cycles per year. Mixture should not be used where mowing height will be less than 150 mm (6 in). Cutting less than 150 mm (6 in) is severely detrimental to establishment. Mixture has limited seedhead production and is not very adaptive to consistently wet soil conditions.

**6.** Formula W. This is a rough textured blend of tall fescue and birdsfoot trefoil (leguminous plant) with a nurse crop of redtop. This formula can be used on a wide assortment of conditions ranging from fairly dry to fairly wet soils where non-mow conditions are desired such as wetland replacement areas or wildlife habitat areas. This formula will eventually allow the desired invasion and succession of adjacent native plant material.

All areas of use for each seed formula will be shown on applicable typical sections and on the tabulation sheets.

Crownvetch crowns or potted plants can be used in lieu of Formula C seeding where a more positive and earlier establishment of crownvetch cover is essential or where successful seeding is questionable such as top of cut slopes or in areas of poor, erosive soil. Space plants 0.9 m × 0.9 m (3 ft × 3 ft) in a diamond pattern or under extreme conditions, 0.6 m × 0.6 m (2 ft × 2 ft). Show areas of use and spacing on applicable Typical Sections and on the Tabulation Sheets. Potted plants of flatpea may also be used in this way to establish a quicker vegetative cover.

Other seeding formulas for various specialty areas such as wetland replacements, wildlife habitat areas, wildflower establishment or other soil conservation areas can be developed on a project by project basis.

Permanent soil protection and drainage facilities should be completed as early as practical, particularly diversion channels and similar controls that will divert runoff from work areas and unprotected soil. Areas of bare soil and the length of their exposure to erosion processes should be minimized by the following:

**1.** Temporary Seeding. When project areas are constructed in a rough graded condition and erosion may be accelerated, or establishment of a temporary vegetative cover on exposed soil areas is desired, specify Formula E, according to Section 804 and mulch according to Publication 408, *Specifications,* Section 805. Mulch alone (such as wood chips, straw, hay or other approved material) can be used to protect constructed slopes and other bare areas brought to finished grade when seeding operations are unfavorable. In all cases, temporary seeding and/or mulching will be installed on all disturbed areas where additional grading, topsoiling, etc. will not occur for 20 or more days.

**2.** Permanent Seeding. When project areas are constructed to finished grade and seeding operations are required within the dates specified in Publication 408, *Specifications,* Section 804.3(a), specify Formulas B, C, D, W, L or other approved seed formulas to minimize erosion by timely scheduling and limiting the work areas. Immediately begin permanent seeding and mulching operations as ground surfaces are brought to final grade.

Limit the use of sod to situations where new construction adjoins established lawns or other fine turf or where the immediate establishment of vegetative cover is required (i.e., between sidewalks and curb).

All seeding, soil supplements and mulching items shall be placed in accordance with the requirements of Publication 408, *Specifications,* Sections 804 and 805 or other approved special provisions.

**B. Other Soil Conservation Seed Mixtures.** Seeding mixtures of soil conservation type plantings for areas within the right-of-way limits other than typical highway construction slopes can include other seed types than the specified seed formulas listed in Publication 408, *Specifications*. These areas could include habitat replacement areas, wetlands, ponds, dam or stream banks, dikes, spillways, spoil areas, borrow pits or other special areas affected by the highway construction.

Some persistent type species for consideration are:

| <u>Legumes</u> | <u>Grasses</u> | |
|---|---|---|
| Crownvetch | Tall Fescue | Redtop |
| Birdsfoot Trefoil | Deertongue | Switchgrass |
| Flatpea | Big Bluestem | Fine Fescues |
| Showy Tick Trefoil | Little Bluestem | Indiangrass |

Other useful species include: Weeping Lovegrass and Perennial Ryegrass.

Recommended Seed Varieties

* Indiangrass - 'Rumsey', 'Holt' or 'Lometa'
* Tall Fescue - 'Kentucky 31' for low maintenance sites, turf-type varieties for high maintenance sites. If endophyte - free tall fescue is desired, use 'Johnstone ', 'Barcel ' or 'Festorina'.
* Perennial Ryegrass - Any fine-leaf turf-type variety
* Fine Fescue - Any named variety
Redtop - Common seed, 'Streaker' or other named varieties
Switchgrass - 'Blackwell' for droughty site, 'Shelter' for habitat, 'Cave-in-Rock ' for forage, 'Alamo'
Deertongue - 'Tioga'
* Birdsfoot Trefoil - Any two of the following: 'Empire ', 'Norcen', 'Leo', 'Maitland' or 'Dawn'
Flatpea - 'Lathco'
Weeping Lovegrass - Common seed or 'Morpa'
* Crownvetch - 'Penngift'
Big Bluestem - 'Niagara' or 'Kaw'
Little Bluestem - 'Aldous', 'Camper' or 'Blaze'

* Use named varieties that originated in Pennsylvania or Northeastern United States whenever possible since they are generally more resistant to unfavorable soil conditions than are varieties of the same plant kind that originated in Midwest or western states.

**C. General Design Guidelines.**

**1.** Lespedeza species are often recommended in various literature as a good cover and food source for wildlife. However, Lespedeza species are not recommended for use in Pennsylvania due to survival limitations caused by varying climate conditions and its limited seed production.

**2.** Simple mixtures are easier to seed, establish and manage than complex mixtures containing 6 or more species.

**3.** Most species used for conservation plantings will only root where pH soil conditions are within a range of 5.5 to 7.0 and sufficient fertility is available to support plant growth.

**4.** For best results, seed in spring during March, April and May.

**5.** Grasses generally require 4-5 weeks of growth prior to hard frosts in order to survive winter conditions.

**6.** Legumes generally require 10-12 weeks to produce a seedling large enough to survive winter conditions. Seed legumes before July 15th in northern and western Pennsylvania and before August 15th in southeastern Pennsylvania. If seeding is necessary later than these dates, specify at least 30-35% or more of the legume seed to contain hard seed.

**7.** Inoculate legume seeds immediately prior to seed application with a selected culture of nitrogen fixing bacteria.

**D. Species Guidelines (Also see Table 13.1):**

**1.** Birdsfoot Trefoil (Lotus corniculatus):

**a.** Does not spread vegetatively from roots but spreads readily from seed. Perennial legume, deep rooted, long lived, prolific seed producer. Adaptable to wide range of soil types and moisture requirements. Will tolerate imperfectly drained soils.

**b.** Adapted over the entire state, except in the extreme southeast, where crown and root rot may injure stands.

**c.** Establishment can be suppressed by excessive competition from associated species.

**d.** Showy yellow flowers during summer.

**e.** Provides good food source and cover for many types of wildlife.

**2.** Perennial Ryegrass (Lolium perenne) and Annual Ryegrass (Lolium multiflorum):

**a.** Substitute approved perennial ryegrass varieties for annual ryegrass in most mixtures, since the vigorous annual ryegrass can prevent or retard the longer-lived but slower establishing grasses or legumes from becoming established.

**b.** Rye grasses germinate and establish relatively quickly if soil and climate conditions are optimum.

**c.** Use "turf" type varieties of perennial ryegrass.

**3.** Redtop (Agrostis alba):

**a.** Do not exceed recommended application rates. Seeds are very small and numerous. Excessive seeding rate can retard or suppress establishment of more persistent species in a mixture. Rapid germination under good conditions.

**b.** Creeping growth habit forming a coarse, loose turf, short lived.

**c.** Very adaptable to poor soil and wet or dry soils.

**4.** Weeping Lovegrass (Eragrostis curvula):

**a.** Short lived, perennial, "warm season" grass, often winter kills under Pennsylvania conditions. Drought resistant. Tolerant to low pH and aluminum soils such as reclaimed strip mined soils where high-sulfur material has been unearthed.

**b.** Useful in mixtures since it furnishes a quick cover until slower growing species such as deertongue can become established. Will not establish as quickly as ryegrass or some cereal grains.

**c.** Do not exceed recommended application rate since seeds are very small and numerous. Excessive seeding rate can suppress other specie development.

**5.** Switchgrass (Panicum virgatum):

**a.** Range type, bunch perennial "warm season" grass. Long-lived and deep rooted with good tolerance to relatively low soil pH and low fertility.

**b.** May often require 2-3 years or more to develop an acceptable dense vegetative cover.

**c.** Good for mine spoil areas and wildlife habitat replacement areas.

**d.** Compatible with Birdsfoot Trefoil.

**6.** Deertongue (Panicum clandestinum):

**a.** Do not plant in mixtures with Tall Fescue, Fine Fescues, Kentucky Bluegrass, Redtop, Reed Canarygrass, Annual or Perennial Ryegrasses, Crownvetch or Flatpea since it will not tolerate competition from these species.

**b.** May often require 2-3 years or more to develop an acceptable dense vegetative cover.

**c.** Seed 2-3 years old if of high vigor often germinates more readily than seed from previous years harvest.

**d.** Stratification of seed for 3-4 weeks at a temperature of 2-8 °C (35-45 °F) is often helpful in breaking seed dormancy.

**e.** Perennial "warm season" grass, useful in acid or infertile soils and droughty and moist soils.

**f.** Compatible with Birdsfoot Trefoil.

**7.** Crownvetch (Coronilla varia):

**a.** Perennial legume, somewhat slow to establish. Once established, it is a long lived, very vigorous grower and tends to dominate stands because of its ability to produce new plants from its roots.

**b.** Suppresses invasion of other plant species. Will "climb" onto fences and other low vegetation within reach.

**c.** Can also be planted using potted plants and crowns.

**d.** Herbaceous top growth dies back to ground each year.

**e.** Does best in a well-drained soil with pH of 6.0 or above, but has also been successfully established in soils with a pH as low as 5.4.

**8.** Flatpea (Lathyrus sylvestris):

**a.** Perennial, persistent, long lived, legume. Provides a dense mat of foliage.

**b.** Once established, it is very vigorous and spreads by underground rhizomes. Normal two year establishment.

**c.** Suppresses other invasive vegetation.

**d.** May also be planted using potted plants.

**e.** Food source and cover plant for many types of wildlife.

**f.** Herbaceous top growth dies back to ground each year.

**g.** Requires a well-drained soil with pH of 6.0 or above.

**9.** Tall Fescue (Festuca arundinacea):

**a.** Aggressive, deep rooted, tufted, long lived perennial.

**b.** Grows well on wet, poorly drained soil but also on drier soils and soils of low fertility. Withstands hot, dry weather.

**c.** Spreads by short underground stems.

**10.** Fine Fescues (Festuca spp):

**a.** Fine fescues include Creeping Red, Chewings, Hard and Sheep fescue.

**b.** Finest leaf of any lawngrass. Blends well with most other "cool-season" grasses.

**c.** Usually used in combination with another grass and a legume for soil conservation purposes.

**d.** Tolerates a wide range of light conditions from full sun to fairly dense shade.

**e.** Tolerates dry soils but does poorly on saturated soils. Performs well on roadsides with infrequent high mowing.

**f.** Not overly competitive in seedling stage. Fairly rapid germination and seedling establishment.

**11.** Big Bluestem (Andropogan gerardi)

**a.** Tall growing, perennial, deep rooted, vigorous bunch grass, sod forming. More drought tolerant than other "warm season" grasses. Grows 1 to 2 m (3 to 6 ft) tall.

**b.** Grows well on most soil types but can be used on excessively drained soil with low water holding capacity. Good tolerance to low pH and low fertility. Can be used on coal waste areas or strip-mined soils.

**c.** Generally takes 2 years to reach its maximum growth potential because of slow germination and seedling growth.

**d.** Seed is chaffy and will not flow well unless debearded. Specify 'Debearded' seed only. (Note: There are several specially designed seedbox seeders that will accommodate 'fluffy' seed.)

**e.** Important forage grass in the Midwest prairie states.

**f.** Wildlife use by songbirds and white-tailed deer for food and for nesting and escape cover.

Refer to Table 13.2 for various seed mixtures recommended for permanent cover for soil conservation planting areas.

Other seed mixtures than those listed in Table 13.2 may also be developed for selected areas but shall be approved by the Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section.

Refer to Table 13.3 for various specialty soil conservation areas where the recommended seed mixtures listed in Table 13.2 can be used.

Refer to Table 13.4 to convert the seeding rates listed in Table 13.2 to kg/1000 $m^2$ (lb/1000 SY) which is the standard area measurement for Department seeding applications.

# TABLE 13.1
# SPECIES FOR EROSION CONTROL AND SOIL CONSERVATION PLANTINGS

| SPECIES | GROWTH HABIT[1] | TOLERATES | | | | | PERSISTENCE[4] | MINIMUM SEED SPECIFICATIONS[5] | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | WET SOIL | DRY SITE | LOW FERTILITY | ACID SOIL (pH 5-5.5)[2] | ALUMINUM[3] | | PURITY (%) | READY GERM (%) | HARD SEED (%) | TOTAL GERM (%) | SEEDS/kg (1000's) | SEEDS/lb (1000's) |
| **Warm-Season Grasses** | | | | | | | | | | | | | |
| Deertongue grass | bunch | yes | yes | yes | yes | H | L | 95 | 75 | — | 75 | 551 | 250 |
| Weeping lovegrass | bunch | no | yes | yes | yes | M | S to M | 97 | 75 | — | 75 | 3307 | 1500 |
| Switchgrass | bunch | yes | yes | yes | yes | M | L | 95 | 75 | — | 75 | 860 | 390 |
| Big Bluestem | bunch | yes | yes | yes | yes | M | L | 60 PLS | | | | 331 | 150 |
| **Cool-Season Grasses** | | | | | | | | | | | | | |
| Tall fescue | bunch | yes | no | yes | no | L | M to L | 95 | 80 | — | 80 | 500 | 227 |
| Redtop | sod | yes | yes | yes | yes | L | M | 92 | 80 | — | 80 | 11 023 | 5000 |
| Fine fescues | sod | no | no | yes | no | L | L | 95 | 80 | — | 80 | 882 | 400 |
| Perennial ryegrass | bunch | yes | no | no | no | L | S to M | 95 | 85 | — | 85 | 500 | 227 |
| Annual ryegrass | bunch | yes | no | yes | no | L | S | 95 | 85 | — | 85 | 500 | 227 |
| **Legumes** | | | | | | | | | | | | | |
| Crownvetch | sod | no | yes | yes | no | L | L | 98 | 40 | 30 | 70 | 265 | 120 |
| Birdsfoot trefoil | bunch | yes | no | yes | yes | L | L | 98 | 60 | 20 | 80 | 882 | 400 |
| Flatpea | sod | no | no | yes | yes | L | L | 98 | 55 | 20 | 75 | 22 | 10 |

NOTES

[1] Growth habit refers to the ability of the species either to form a dense sod by vegetative means (stolons, rhizomes, or roots) or to remain in a bunch or single plant form. If seeded heavily enough, even bunch formers can produce a very dense stand. This is sometimes called a sod but not in the sense of a sod formed by vegetative means.

[2] Once established, plants may grow at somewhat lower pH, but cover generally is only adequate at pH 6.0 or above.

[3] Tolerance to aluminum is relative. Soil and spoils must be limed to a pH of 5.5 to 5.7 to eliminate possible aluminum and manganese toxicity. Tolerance ratings: H = high; M = medium; L = low.

[4] Persistence under favorable conditions: L = long duration; M = moderate duration; S = short duration (1 year or less).

[5] MINIMUM SEED SPECIFICATIONS ARE TRULY MINIMUM, AND SEEDLOTS TO BE USED FOR REVEGETATION PURPOSES SHOULD EQUAL OR EXCEED THESE STANDARDS. Thus, deertongue grass should germinate 75% or better. Crownvetch should have at least 40% readily germinable seed and 30% hard seed. Commonly, seedlots are available that equal or exceed the minimum specifications. Remember that disturbed sites are adverse for plant establishment. Ready germination refers to seed that germinates during the period of the germination test and that would be expected, if conditions are favorable, to germinate rapidly when planted. The opposite of ready germination is dormant seed, of which hard seed is one type.

## TABLE 13.2 (METRIC)
## RECOMMENDED SEED MIXTURES FOR PERMANENT COVER FOR SOIL CONSERVATION PLANTINGS

| MIXTURE NUMBER | SPECIES | SEEDING RATE (kg/ha) PLS** | |
|---|---|---|---|
| | | MOST SITES | ADVERSE SITES **** |
| 1*** | tall fescue, or | 67 | 84 |
| | fine fescue | 39 | 45 |
| | plus redtop*, or | 3.4 | 3.4 |
| | perennial ryegrass | 17 | 22 |
| 2 | birdsfoot trefoil, plus | 6.7 | 11 |
| | tall fescue, plus | 34 | 39 |
| | redtop* | 3.4 | 5.6 |
| 3 | birdsfoot trefoil, plus | 6.7 | 11 |
| | crownvetch, plus | 11 | 22 |
| | tall fescue | 22 | 34 |
| 4 | flatpea, plus | 22 | 34 |
| | tall fescue, or | 22 | 34 |
| | perennial ryegrass | 22 | 28 |
| 5 | tall fescue, plus | 45 | 67 |
| | fine fescue | 11 | 17 |
| 6 | deertongue grass, plus | 17 | 22 |
| | weeping lovegrass*, plus | 1.1 | 1.1 |
| | birdsfoot trefoil | 6.7 | 11 |
| 7 | switchgrass, or Big Bluestem plus | 17 | 22 |
| | weeping lovegrass*, plus | 1.1 | 1.1 |
| | birdsfoot trefoil | 6.7 | 11 |

**** Soil conditions that are very acidic, infertile, severely eroded or possibly toxic and where liming, fertilization or other seedbed preparations are difficult to accomplish.

*** This mixture suitable for frequent mowing. Do not cut shorter than 100 mm.

** PLS means Pure Live Seed. PLS is the product of the percentage of pure seed times percentage germination divided by 100. For example, to secure the actual planting rate for switchgrass, divide 13 kg PLS by the PLS percentage shown on the seed tag. Thus, if the PLS content of a given seed lot is 35%, divide 13 PLS by 0.35 to obtain 37 kg of seed (35 percent PLS), the amount of seed required to plant 1 ha. All mixtures in Table 13.2 are shown in terms of PLS.

* Keep seeding rate of that recommended in table. These species have many seeds per kilogram and are very competitive. To seed small quantities of small seeds such as weeping lovegrass and redtop, dilute with dry sawdust, sand, rice hulls, buckwheat hulls, etc.

## TABLE 13.2 (ENGLISH)
## RECOMMENDED SEED MIXTURES FOR PERMANENT COVER FOR SOIL CONSERVATION PLANTINGS

| MIXTURE NUMBER | SPECIES | SEEDING RATE (lb/acre) PLS** | |
|---|---|---|---|
| | | MOST SITES | ADVERSE SITES **** |
| 1*** | tall fescue, or<br>fine fescue<br>plus redtop*, or<br>perennial ryegrass | 60<br>35<br>3<br>15 | 75<br>40<br>3<br>20 |
| 2 | birdsfoot trefoil, plus<br>tall fescue, plus<br>redtop* | 6<br>30<br>3 | 10<br>35<br>5 |
| 3 | birdsfoot trefoil, plus<br>crownvetch, plus<br>tall fescue | 6<br>10<br>20 | 10<br>20<br>30 |
| 4 | flatpea, plus<br>tall fescue, or<br>perennial ryegrass | 20<br>20<br>20 | 30<br>30<br>25 |
| 5 | tall fescue, plus<br>fine fescue | 40<br>10 | 60<br>15 |
| 6 | deertongue grass, plus<br>weeping lovegrass*, plus<br>birdsfoot trefoil | 15<br>1<br>6 | 20<br>1<br>10 |
| 7 | switchgrass, or Big Bluestem plus<br>weeping lovegrass*, plus<br>birdsfoot trefoil | 15<br>1<br>6 | 20<br>1<br>10 |

**** Soil conditions that are very acidic, infertile, severely eroded or possibly toxic and where liming, fertilization or other seedbed preparations are difficult to accomplish.

*** This mixture suitable for frequent mowing. Do not cut shorter than 4 in.

** PLS means Pure Live Seed. PLS is the product of the percentage of pure seed times percentage germination divided by 100. For example, to secure the actual planting rate for switchgrass, divide 12 lb PLS by the PLS percentage shown on the seed tag. Thus, if the PLS content of a given seed lot is 35%, divide 12 PLS by 0.35 to obtain 34.3 lb of seed (35 percent PLS), the amount of seed required to plant 1 acre. All mixtures in Table 13.2 are shown in terms of PLS.

* Keep seeding rate of that recommended in table. These species have many seeds per pound and are very competitive. To seed small quantities of small seeds such as weeping lovegrass and redtop, dilute with dry sawdust, sand, rice hulls, buckwheat hulls, etc.

## TABLE 13.3
## SOIL CONSERVATION PLANTING AREAS

| SEED MIXTURE APPLICATION, TYPE OF AREA | TABLE 13.2 SEED MIXTURE NUMBERS |
|---|---|
| Slopes and banks (non-mowed)<br>(a) Well-drained<br>(b) Variable drainage | <br>4 or 7<br>2 or 3 |
| Slopes and banks (mowed)<br>(a) Well-drained | <br>1 or 5 |
| Gullies and eroded areas | 2, 3 or 7 |
| Conservation structures<br>(a) Sod waterways, spillways and other frequent water flow areas<br>(b) Drainage ditches<br>(1) shallow, less than 1.0 m (3 ft)<br>(2) deep, non-mowed<br>(c) Pond banks, dikes, levees, dams, diversion channels and occasional water flow areas | <br>1 or 2<br><br>1 or 2<br>3<br>2 or 3 |
| Sanitary landfill areas | 2, 3, 6 or 7 |
| Strip-mine spoils, mine wastes, fly ash, slag, settling-basin residues and other severely disturbed areas | 2, 3, 4,<br>6 or 7 |

## TABLE 13.4 (METRIC)
## SEEDING APPLICATION RATE CONVERSION CHART
## 1 ha = 10 000 $m^2$

| kg/ha | kg/1000 $m^2$ | kg/ha | kg/1000 $m^2$ |
|---|---|---|---|
| 1.1 | 0.11 | 17 | 1.7 |
| 2.2 | 0.22 | 22 | 2.2 |
| 3.4 | 0.34 | 28 | 2.8 |
| 4.5 | 0.45 | 34 | 3.4 |
| 5.6 | 0.56 | 39 | 3.9 |
| 6.7 | 0.67 | 45 | 4.5 |
| 9.0 | 0.90 | 56 | 5.6 |
| 11 | 1.1 | 67 | 6.7 |
| 13 | 1.3 | 84 | 8.4 |

## TABLE 13.4 (ENGLISH)
## SEEDING APPLICATION RATE CONVERSION CHART
## 1 acre = 43,560 SF = 4,840 SY

| lb/acre | lb/1,000 SY | lb/acre | lb/1,000 SY |
|---|---|---|---|
| 1 | 0.25 (4 oz) | 15 | 3 |
| 2 | 0.5 (8 oz) | 20 | 4 |
| 3 | 0.6 (10 oz) | 25 | 5 |
| 4 | 0.8 (13 oz) | 30 | 6.25 |
| 5 | 1 | 35 | 7.25 |
| 6 | 1.25 | 40 | 8.25 |
| 8 | 1.75 | 50 | 10.5 |
| 10 | 2 | 60 | 12.5 |
| 12 | 2.5 | | |

Seeding design selections are also controlled by several physical and chemical factors which must be considered prior to selecting a seed mixture. Some design considerations are as follows:

**1.** Soil analysis including composition, acidity, fertility, moisture content or any toxic properties.

**2.** Site conditions such as full sun, partial or heavy shade as well as directional slope exposures.

**3.** Slope criteria including steepness, embankment (fill) or cut surfaces.

**4.** Desired long term or short term longevity of selected plants including plant specie competition from species in the mixture and from adjacent vegetation.

**5.** Anticipated maintenance requirements.

A logical guideline procedure for seeding design would include:

**1.** Carefully analyze any limiting site factors, both physical and chemical.

**2.** Select an appropriate combination of adaptable plant species.

**3.** Select an appropriate set of establishment procedures consistent with the needs of the plant species to be seeded and the need to overcome any limiting site factors.

**4.** Only use seed of proper plant species or varieties of high germination capacity and vigor.

The proper use of lime and fertilizers and the addition of various soil amendments can rectify many unfavorable soil conditions and result in establishing an adequate vegetative cover with desired species.

**E. Specification Preparation and Approvals.** Seeding specifications for soil conservation plantings shall be prepared to include the following format: (1) soil supplements, (2) specie selections, (3) purity and germination percentages, (4) application rates and (5) construction requirements.

Refer to Figure 13.1 for seeding special provision format.

All seeding specifications and proposed seeding locations for soil conservation plantings shall be approved by the Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section.

**F. Seed Quality.** All seed sold in Pennsylvania must, by law, have a tag or label listing the tested percentages of pure seed, inert matter, crop seed and weed seed as well as germination percentage and test date. Seed with a test date older than nine months should not be used.

Certified seed is the best assurance of obtaining seed of high physical quality and known genetic identity especially for named varieties. For erosion control and conservation plantings, seed should be high in germination and purity rates.

PLS (Pure Live Seed) is a method of defining the planting quality of chaffy seeds such as various wildflowers and switchgrass. The PLS number is calculated by multiplying the % of pure seed by the % of germination and then dividing by 100. Example: 72% pure seed × 85% germination ÷ 100 = 61% PLS. This allows the amount of seed required to be adjusted to compensate for low purity and germination (see Table 13.2 note for an example of how the seed application rate is adjusted for the desired PLS number).

Generally "common seed" or seed of unknown genetic origin can be used for soil conservation plantings if certified seed is not available.

# FIGURE 13.1
# SPECIAL PROVISION FORMAT FOR SPECIAL SEEDING MIXTURES

SAMPLE SPECIAL PROVISION

Item 9804 - ×××× - Seeding and Soil Supplements - (Insert appropriate name)

DESCRIPTION - This work is furnishing and placing seed and soil supplements of the type specified.

MATERIALS -

| | | |
|---|---|---|
| (a) | Pulverized Agricultural Limestone | Section 804.2(a)1 |
| (b) | Commercial Fertilizer | Section 804.2(a)2 |
| (c) | Slow-Release Nitrogen Fertilizer | Section 804.2(a)3 |
| (d) | Inoculant (When Applicable) | Section 804.2(c) |
| (e) | Seed Formula | |

| SEEDING RATE<br>kg/1000 $m^2$ (lb/1000 SY) | MIN%<br>PURITY/GERMINATION | MAX%<br>WEED SEED |
|---|---|---|

(Insert Desired Seed Formula)

Seed to meet applicable requirements of Section 804.2(b) for seed tests, PA Dept of Agriculture regulations, PA Seed Act of 1965, Act No. 187 and delivery of seed to work area.

CONSTRUCTION -

Loosen or roughen soil surface on all areas to receive seed to a depth of at least 50 mm (2 in).

Apply soil supplements in accordance with Section 804.3(c). Prior to project completion apply slow-release nitrogen fertilizer to soil surface.

When applicable, inoculate leguminous seed in accordance with Section 804.3(d).

Apply seed in accordance with Section 804.3(e). Spread seed where indicated and at the specified rate within the following dates, or as directed.

(Insert Desired Seeding Dates)

Follow Sections 804.3(i) and (j) for liability and maintenance requirements.

Mulch seeded area with straw in accordance with Section 805.

MEASUREMENT AND PAYMENT -

(a) Seeding and Soil Supplements. Kilograms (Pounds).
(b) Mulching. Section 805.4(a).

Some seeds, generally unscarified seeds of legumes such as crownvetch, birdsfoot trefoil and flatpea may have a watertight seedcoat. The seedcoat is eventually broken by either frost action or microbial action and germination will then produce a seedling. Seeds impervious to water are termed hard seed. The percentage of hard seeds in a given lot is added to the percentage of readily germinating seed to yield the total germination percentage. Legume seed lots should contain a certain minimum amount of hard seed as an insurance factor.

**G. Seed Bed Preparation.** Prior to seed application, soil supplements such as pulverized agricultural limestone and various fertilizer applications are required to prepare the area to be seeded.

Formula E does not normally require any applications of soil supplements. However, separate applications of lime, fertilizer or both may be necessary to establish the temporary grass cover in certain situations where anticipated soil conditions would not be conducive to good grass germination and growth.

Formulas B, C, D, L and W require soil supplement applications as specified in Publication 408, *Specifications*, Section 804.

Special soil conditions may require altering the standardized soil supplement application rates. All revisions shall be approved by the Bureau of Project Delivery.

Finished slopes should be seeded and mulched in increments of approximately 4.5 m (15 ft) with permanent in-season seeding at the full application rates specified for soil supplements, seed and mulch. If out-of-season seeding is approved, apply either the full specified quantities for supplements, seed and mulch or apply full supplements and 50% of the seed application rate to be followed by the remaining 50% within the next seeding dates. Full mulch rate applications will be required for each seeding application to prevent soil erosion until seed germinates.

**H. Mulching.** All seeded areas should be mulched with an appropriate approved mulch to reduce the potential for erosion while the seeds germinate. Mulch also aids seed germination by conserving moisture in the soil, encouraging water infiltration and helping to regulate soil temperature from excessive exposure to the sun's heat.

Several mulch materials such as straw, hay, wood fiber, pellet mulch and bonded fiber matrixes are approved for use with seeding operations. Wood chips have also been successfully used in some conservation type seeding areas if application depths are strictly followed.

**1.** Straw. This material is one of the most preferred and one of the least expensive mulches for most seeding operations. Use on all topsoiled areas. Straw needs to be secured in place with either approved mulch control binders or mulch control netting to prevent loss of material by natural winds or breezes caused by vehicular movement.

**2.** Hay. This material is more adaptable to steeper slope conditions than straw but is more apt to introduce undesirable weed seeds. This application may have wide use for development of wildlife habitat areas where it helps to introduce more diverse plant types. Use on untopsoiled areas. Hay needs to be secured in place with either approved mulch control binders or mulch control netting to prevent loss of material by wind.

**3.** Wood Fiber. This material is applied with hydraulic mulching/seeding equipment and after drying, provides a thin protective cover. Wood fiber does not provide as much erosion protection or moisture retention for seed germination as straw or hay. The wood fiber must adhere to the soil surface and its protective longevity is less than other mulches. Use on areas where fire hazard potential for straw or hay is high or where a less conspicuous mulch appearance is desired. No weed seeds are introduced with this material.

**4.** Wood Chips. Placing wood chips in thin mulch layers not deeper than 50 mm (2 in) has been successfully used in conservation type seeding areas. Thicker mulch layers of 75 mm (3 in), 100 mm (4 in) or deeper can be used without seed in temporary areas to provide erosion control until the permanent soil surface is prepared.

**5.** Pellet Mulch. This mulch is compressed pellets of shredded recycled paper which lose their pellet shape and adhere to other pellets, after water application, to form a thin protective cover. Pellet mulch is best used on flatter areas where a more refined turf grass, such as a lawn, is desired. Pellet mulch will not blow away.

Pellets are applied using rotary or drop-spreader equipment; therefore, slope steepness must be considered. No weed seeds are introduced with this material.

**6.** Bonded Fiber Matrix (BFM). This mulch is composed of fibrous material bonded together with adhesive agents to form a continuous, porous, erosion resistant protective cover which also adheres to the soil surface. BFM must be applied using hydro-mulching/seeding equipment and is applied at higher rates than standard wood fiber mulch. Generally use BFM on steep slopes where access and soil preparation is difficult. Use also on flatter areas where tacked straw or hay are prone to blow away or as an alternate to erosion control mats or blankets on slopes. Avoid using in direct water flow areas such as ditches, channels and swale centerlines, etc.

All areas of mulch use for seeding will be shown on the applicable typical sections and on the tabulation sheets.

Apply mulches at the rates specified in Publication 408, *Specifications*, Section 805.

## 13.3 OTHER STABILIZATION METHODS

**A. Discussion.** In most flat slope areas and areas where water generally does not have a concentrated flow, applying only mulch to the seeded area will be sufficient to provide the initial protection until the grass cover is established. On steeper slope areas, highly erodible soils, and drainage channels, other erosion control material will be necessary to provide the required protection to the seed and soil. Erosion control mats and blankets are commonly used for these applications. Turf reinforcement mats can artificially reinforce or augment the grass surface to permanently increase or enhance its resistance to erosion, and reduce the risk of grass failure due to localized poor cover establishment.

On the other hand, there are situations where grass establishment is not the most appropriate or, perhaps, cost-effective means of stabilization. Acceptable non-vegetated stabilization options are listed below.

Design guidance for all of the stabilization measures listed below can be found in Publication 584, *PennDOT Drainage Manual*, Chapter 8, Open Channels and Chapter 12, Erosion and Sediment Pollution Control.

**B. Approved Measures.**

**1.** Rolled Erosion Control Products (RECPs). Most provide temporary stabilization. Turf reinforcement mats are considered long-term, permanent stabilization measures.

**a.** Organic Erosion Control Blankets/Mats (ECBs).

- Erosion Control Mats.
- Erosion Control Mulch Blankets.
- High Velocity Erosion Control Mulch Blankets.

**b.** Synthetic Erosion Control and Revegetation Mats (ECRMs).

**c.** Turf Reinforcement Mats (TRMs).

**2.** Spray on Mulches. Method of applying mulch (usually also seed and fertilizer) as a spray from a hydraulic tanker truck.

**3.** Geocell Slope Confinement. Cellular HDPE material that is typically used to stabilize steep side slopes.

**4.** Articulated Concrete Block Revetment System (ACBR). Interlocking or tied blocks of concrete used to permanently stabilize slopes.

**5.** Gabions. Wire baskets filled with stone or riprap that can be stacked and somewhat deformed, if necessary.

## 13.4 EROSION CONTROL MEASURES

**A. Discussion.** Erosion control measures, or Best Management Practices (BMPs) are used to prevent the erosion of earth by the forces in stormwater runoff. Erosion of unstabilized and unprotected earth can occur very easily. The previous section dealt primarily with protecting disturbed slopes while vegetation is being established or where vegetation alone is not sufficient. Most of the erosion control BMPs in this section are associated with the protection of slopes or channels receiving concentrated flow, such as from an upstream channel, pipe, or culvert.

**B. Approved Measures.** A number of erosion control BMPs that are appropriate for use on highway projects have been approved by the Department. The list below contains the names and brief descriptions of some of these approved BMPs. Additional information on these devices can be found in Publication 584, *PennDOT Drainage Manual*, Chapter 8, Open Channels and Chapter 12, Erosion and Sediment Pollution Control. Plan drawing details for most of the BMPs are located in the Publication 72M, *Roadway Construction Standards*; these should be included in the Erosion & Sediment Pollution Control (E&SPC) Plan.

**1.** Channel Lining. Flexible (grass, RECPs, rock, etc.) or rigid (concrete) materials used to protect the underlying soil from erosion. Publication 584, *PennDOT Drainage Manual*, Chapter 8, Open Channels contains relevant design procedures and information.

**2.** Paved Energy Dissipator. Section of concrete channel lining containing partially embedded stones designed to dissipate energy in channels with velocities greater than 4.2 m/s (14 ft/s).

**3.** Rock Apron. Used to prevent scour and dissipate energy at pipe or channel outfalls where anticipated discharge velocities do not exceed 4.3 m/s (14.5 ft/s) and where the apron can be installed on a level grade.

**4.** Rock Basin or Rock Energy Dissipator. Pre-formed scour holes that are used to dissipate energy and control erosion at pipe outlets where outlet velocities exceed the allowable limits of the soil or channel lining, but are 5.7 m/s (19 ft/s) or less.

**5.** Stilling Well. Concrete energy dissipator constructed below grade at the outlet end of pipes and culverts.

**6.** Temporary Slope Pipe Drain. Installed to transport stormwater runoff safely down the face of a cut or fill slope to a stabilized area. Should be used prior to the installation of permanent facilities and/or growth of adequate ground cover on the slopes.

**7.** Diversion Ditch. Any type of channel that is constructed above a disturbed area to intercept and convey offsite runoff or runoff from undisturbed areas away from unstabilized areas.

**C. Design Flows.** In general, the temporary erosion control BMPs listed above must be designed to resist erosion for the 2-year storm event. Exceptions to this must be made for disturbances within Special Protection Watersheds (SPW) and for measures that will become permanent stormwater management or drainage facilities. Channels within a SPW must be provided with temporary lining able to resist erosion for the 5-year storm event. Permanent channel lining in any watershed must be resistant to erosion for the 10-year storm event, at a minimum. Temporary pipes, and outlet protection for temporary pipes, must be designed for the 2-year storm event (5-year storm event for SPW). Permanent outlet protection shall be designed for the maximum anticipated velocity from the discharging pipe.

## 13.5 SEDIMENT POLLUTION CONTROL DEVICES

**A. Discussion.** Sediment pollution control devices, which are also referred to as BMPs, are installed in and around construction sites to prevent sediments from being transported away from the site. Sediments can be carried off site by stormwater runoff and wind, or they can be attached to construction vehicles and deposited on roads adjacent to or near the site. Some sediment control BMPs temporarily hold runoff to allow sediments to settle out by gravity. Other BMPs filter runoff by straining sediment-laden water through a fine medium, such as filter fabric or gravel. The type of BMP used depends on the specific area of application.

**B. Approved Devices.** A number of sediment pollution control BMPs that are appropriate for use on highway projects have been approved by the Department. The list below contains the names and brief descriptions of the approved BMPs. Additional design and plan information on the devices listed in this section can be found in Publication 584, *PennDOT Drainage Manual*, Chapter 12, Erosion and Sediment Pollution Control. Plan drawing details for most of the BMPs are located in the Publication 72M, *Roadway Construction Standards*; these should be included in the E&SPC Plan.

**1.** Rock Construction Entrance. Used to remove mud from the tires of construction vehicles leaving the site. Required whenever vehicular access onto unpaved areas is necessary.

**2.** Rock Filter Outlet. Used to replace damaged sections of silt barrier fence or to fill in space between the end of a section of silt barrier fence and a slope.

**3.** Compost Filter Sock. A perimeter control device that filters runoff in the form of sheet flow. Use at the bottom of disturbed slopes that would normally drain across the right-of-way line or into a channel. Consists of compost material wrapped in a geotextile container.

**4.** Compost Filter Berm. Same as compost filter sock, except that the compost is mounded instead of being wrapped in a geotextile container.

**5.** Silt Barrier Fence. Same application as a compost filter sock. Geotextile fabric is fastened to stakes that are driven vertically into the ground.

**6.** Heavy Duty Silt Barrier Fence. Should be used when slope lengths exceed the capacity of standard silt barrier fence. Fabric is reinforced with wire mesh backing and metal posts are used instead of wood stakes.

**7.** Vegetated Filter Strip. Well-established perennial grassy area located below a disturbed area used to remove sediment from runoff prior to it reaching receiving waters.

**8.** Pumped Water Filter Bag. Used to filter out sediments from water pumped from excavation holes associated with bridge piers and abutments. Also used to dewater trenches and filter water pumped from sediment traps and basins.

**9.** Storm Inlet Protection. Used to filter or settle out sediment in runoff from disturbed areas before it enters the storm sewer. Includes inlet filters, traps, and berms.

**10.** Rock Barrier. Temporary stone dam installed across a channel to remove sediment originating from flow in the channel before vegetation is fully established.

**11.** Sediment Trap. Temporary storage area used to detain sediment-laden runoff from small, disturbed areas. Types include embankment, Type M inlet, and riser sediment traps.

**12.** Sediment Basin. Large ponding area used to detain sediment-laden runoff from large, disturbed areas.

## 13.6 PREPARATION AND PROCESSING OF EROSION AND SEDIMENT POLLUTION CONTROL PLANS

**A. Plan Preparation.** In order to minimize accelerated erosion and to control sediment pollution during highway construction, proper preparation and adherence to implementation of the scheduled sequence of operation of E&SPC Plans is of primary importance.

Erosion and sediment pollution control should be initially considered in the preliminary design stage and plans fully developed during the final design stage of a highway project.

The purpose of the E&SPC Plan is to identify potential erosion problems and to define effective and economical measures to be used in conjunction with construction activities to minimize erosion and sediment pollution. The E&SPC Plans for a project shall be prepared and processed in accordance with Publication 14M, Design Manual, Part 3, *Plans Presentation,* Chapter 6. All erosion and sediment pollution control BMPs shall be indicated by the applicable symbols presented in Publication 14M, Design Manual, Part 3, *Plans Presentation*, Chapter 13.

An E&SPC Plan, as applied to Department projects, shall consist of three parts: (1) maps and drawings showing the topography of the area, the proposed alteration to the area and the erosion and sediment pollution control BMPs; (2) a narrative report describing the project and indicating the purpose and the engineering assumptions and calculations for control BMPs; and (3) detailed instruction in the contract proposal and/or the plan, as extracted from the narrative report data, to define staging, sequencing and scheduling of earthmoving activities and the installation of the erosion and sediment pollution control BMPs. The staging should be determined on the basis of such factors as: (1) drainage divide, (2) grade line direction, (3) efficient and economical construction operation, (4) earthwork balancing, (5) protection of traffic, and (6) maintenance consideration.

The following references located in Publication 584, *PennDOT Drainage Manual*, is useful information for developing PennDOT E&SPC Plans:

- Chapter 8 – Design procedure and guidance for channel lining
- Chapter 12 – Design guidance for approved BMPs
- Chapter 12, Appendix B – Recommended notes for E&SPC Plans
- Chapter 12, Appendix C – Recommended standards for E&SPC Plans

**B. Implementation and Maintenance.** Implementation of the E&SPC Plan on the project site and maintenance of BMPs thereafter are the responsibilities of the party performing the work, which is either the Department or the contractor. Every E&SPC Plan shall contain a sequence of earthwork activities that includes installation and removal of all proposed temporary and permanent BMPs. The contractor will be responsible for implementing the plan per this sequence. The contractor shall also be notified of his responsibilities, which include but are not limited to the following:

- Ensure that the E&SPC Plan is properly and completely implemented in accordance with the drawings and the technical specifications.
- Perform maintenance inspections on all BMPs after each rainfall event and, at a minimum, on a weekly basis, and document the inspections using inspection log sheets. All preventative and remedial work must be performed immediately.
- Obtain approval from the appropriate county conservation district or PA DEP regional office if deviation from the E&SPC Plan is necessary or desired.
- Maintenance of all permanent BMPs becomes the responsibility of the owner in perpetuity upon completion of construction and acceptance by owner, subject to the terms of the warranty period specified in the contract documents.
- Fines and related costs resulting from the contractor's failure to provide adequate protection against soil erosion and for any violations of the Clean Streams Law and the rules and regulations promulgated thereunder shall be borne by the contractor.

These responsibilities and others specific to the project shall be described in the E&SPC Plan. Maintenance instructions for each BMP to be used on a project must be provided on the plan.

**C. Other Necessary Actions for Project Compliance.** To assure compliance with regulatory requirements and to provide additional emphasis on erosion and sediment pollution control, necessary actions should be taken to comply with the following:

**1.** The E&SPC Plans should be judiciously developed and implemented in accordance with the procedures and criteria specified in Publication 584, *PennDOT Drainage Manual*, Design Manuals, and Publication 72M, *Roadway Construction Standards*. If the proposed measures and facilities deviate from the specified procedures or criteria, it should be demonstrated that the alteration shall also result in prevention of accelerated erosion and sedimentation.

In general, only one E&SPC Plan needs to be developed throughout the life of a project. This plan would normally cover all staged earthmoving activities. However, on major highway projects, it may be necessary to develop two or more control plans to address earthmoving activities which will occur before or after the prime construction project, or to be performed by a separate contractor or consultant.

**2.** A National Pollutant Discharge Elimination System (NPDES) permit is required for those highway projects in which the total project earth disturbance area is equal to or greater than 0.4 ha (1 acre). In Pennsylvania, the NPDES permit program is delegated to and administered by PA DEP. PA DEP has delegated the management of the NPDES program to most of the County Conservation Districts. PA DEP and County Conservation Districts jointly regulate construction activities utilizing existing state regulations concerning erosion control and NPDES permits to implement the Federal requirements.

The 1972 amendments to the Federal Water Pollution Control Act (Clean Water Act or CWA) prohibit the discharge of any pollutant to Navigable Waters of the United States from a point source unless the discharge is authorized by a NPDES permit. The U.S. Environmental Protection Agency (EPA) has promulgated rules for the NPDES permit process:

- Phase I: Established in 1990, Phase I addresses discharges from large construction activities disturbing 5 acres or more of land.

- Phase II: Established on December 8, 1999, Phase II covers small construction activities that result in a land disturbance of equal to or greater than 1 acre and less than 5 acres. Site activities disturbing less than 1 acre are also to be regulated as a small construction activity if they are part of a larger common plan of development or sale with a planned disturbance of equal to or greater than 1 acre and less than 5 acres.

PA DEP issues two types of NPDES permits for Stormwater Discharges Associated with Construction Activities – a General Permit (PAG-2) and an Individual Permit. PAG-2 covers most projects; however, an Individual Permit is needed for projects in "special protection" watersheds (high quality, exceptional value, and exceptional value wetlands). Copies of the NPDES permit application forms, instructions, and other related documents are available through PA DEP's website (www.dep.state.pa.us).

Each local municipality and county involved shall be notified, pursuant to Act 14, P.L. 834, to the effect that an application for the NPDES has been filed with PA DEP and the documentation of this notification included in the application submitted. No permit application fee is required for any application submitted by the Department. The NPDES shall be processed by the Engineering District through the County Conservation District, or PADEP, according to the established procedure. If construction of the project can not be completed within the time limit normally specified in a permit, a longer time limit to cover the entire construction period should be requested when the permit application is submitted.

**3.** An NPDES permit is not required for those highway projects which involve a total project earth disturbance area of less than 1.0 acre. However, the erosion and sediment pollution control measures and plans must comply with PA DEP's Chapter 102 regulations.

**4.** Best Management Practices (BMPs) must be utilized for all earth disturbances, regardless of area. Standards for the BMPs are contained in Publication 584, *PennDOT Drainage Manual*, Chapter 12.

**5.** A written E&SPC Plan must be prepared for projects that disturb 5000 $ft^2$ or more. (Note: Two additional conditions which may require a written plan are listed in PA Code Section 102.4(b)(2).)

**6.** An Erosion and Sediment Control Permit is required for roadway maintenance projects that disturb 25 acres or more.

**7.** Special protection BMPs are required when earth disturbance activities may result in a discharge into a water classified under Chapter 93 of the PA Code as High Quality (HQ) or Exceptional Value (EV), including EV wetlands.

**8.** The current standard special provisions for the E&SPC, as indicated in the Department's Contract Management System, should be included in all applicable contract proposals.

**9.** The necessary E&SPC practices must be fully implemented and monitored during the construction of the highway project.

**10.** One copy of the E&SPC Plan should be sent by the Engineering District to the Central Office, Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section for information and review at the time the plan is submitted to the County Conservation District.

**11.** The County Conservation Districts have been delegated responsibilities for PA DEP's Erosion and Sediment Control Program. Under this program, authority is delegated to Conservation Districts at three different levels: Level I, Level II, and Level III. Level I delegation (four counties) includes providing information on PA DEP's Erosion and Sediment Control Program, the review and processing of Erosion and Sediment Control Permit applications, and the review of Erosion and Sediment Control Plans. Level II delegation (51 counties) includes Level I responsibilities, plus responsibilities of complaint investigation and site inspections. Level III delegation (10 counties) includes Level I and II responsibilities, plus enforcement responsibilities such as administrative hearings, equity actions, summary or misdemeanor actions, and assessment of civil penalties.

In addition to the Erosion and Sediment Control Program, 60 Level II and III Conservation Districts are also delegated responsibilities for processing National Pollutant Discharge Elimination System (NPDES) Permits for Stormwater Discharges Associated with Construction Activities. (Note: Philadelphia County does not have a County Conservation District.)

**12.** During construction, it is encouraged that PA DEP's Area Office staff be contacted to assist in implementing the erosion and sedimentation control measures and facilities. All significant changes, additions and/or deletions to the plans approved with a permit which will affect erosion and sediment pollution controls shall be approved by PA DEP prior to construction.

**13.** Generally, individual PennDOT construction projects will be issued one NPDES permit for the entire project, and this permit will apply inclusively to borrow and spoil areas.

**14.** NPDES permits are issued during the final design phase.

**15.** After spoil and borrow areas are identified, and before any earth moving activities occur in them, E&SPC Plans must be submitted and approved. Once approved, these E&SPC Plans automatically become amendments to the project's original NPDES permit.

**16.** Since there is only one NPDES permit issued to PennDOT for the entire project, if this permit is violated and subsequently suspended or revoked, that action will affect the entire project.

## 13.7 ANTIDEGRADATION AND POST CONSTRUCTION STORMWATER MANAGEMENT POLICY

**A. Background.** PennDOT performs a broad spectrum of activities in order to maintain and improve the state's roadway system. Highway improvement projects involve, to varying degrees, altering the existing landscape through a combination of clearing, compaction, and impervious cover. These activities disrupt the natural hydrologic processes that reduce surface runoff, such as interception and infiltration. It has been well-documented that the development of land into less pervious areas generally leads to an increase in stormwater runoff volume, higher peak flows, higher average temperature of runoff, collection of a larger mass of pollutants (due to lack of infiltration capacity), and an increased flooding hazard for downstream waterways. All of these factors contribute to degradation – changes in the physical, chemical, and biological properties – of the receiving waters.

That being said, not all projects are created equal in terms of their potential to impact receiving waters. Many land development projects involve the clearing of forests and meadows, and developing productive farmlands. On the other hand, the vast majority of PennDOT projects involve improvements within an existing legal right-of-way, which has already been largely disturbed in order to construct the highway facility. Thus, PennDOT improvement and maintenance projects tend to have less of an effect on runoff characteristics than other types of development projects. However, there are effects associated with most non-maintenance activities, and those effects are generally proportional to the amount of additional impervious area being proposed.

Among Pennsylvania's water quality standards are antidegradation requirements, which are described in Section 93.4a of the PA Code. The antidegradation requirements are aimed at protecting the existing instream uses of surface waters, in addition to maintaining and protecting the water quality of High Quality (HQ) and Exceptional Value (EV) waters. Stormwater runoff is considered a point source discharge which has the potential to impact existing uses and water quality, so it is regulated by PA DEP.

Three key measures are used to assess the potential for impacts from stormwater runoff – volume, rate, and quality. The goal of post construction stormwater management (PCSM) is to prevent or minimize any increase in the quantity (rate and volume) of runoff while also minimizing the factors affecting the quality. The best way to achieve antidegradation is to mimic the natural, pre-development hydrologic conditions, which are usually dominated by infiltration and evapotranspiration (ET – see definitions). This is a two-fold solution because stormwater management strategies that address quantity normally also address quality. However, the inherent characteristics of highway projects sometimes limit the options for volume reduction. Therefore, it is also important to have a combination of strategies that reduce the amount of runoff being generated.

PCSM is required whenever a project (1) requires an NPDES construction stormwater permit (Section 13.7.B.2), or (2) is located in a watershed with an approved Act 167 stormwater management plan. PennDOT recognized that a policy on antidegradation and PCSM was needed in order to establish guidelines for addressing project-induced changes in runoff. This policy is a tool for achieving a target, which is consistency with Pennsylvania's antidegradation regulations and federal NPDES requirements. The guidelines that are provided were developed with the most common types of PennDOT construction projects and circumstances in mind. However, it is important to keep in mind that there will be projects with circumstances that require considerations beyond those recommended for these typical situations. The following sections describe the specifics of the policy.

**B. Policy on Antidegradation and Post Construction Stormwater Management.** This policy outlines PennDOT's proactive approach to protecting the surface waters of the Commonwealth from degradation. Most of the information in this section is related to the implementation of a standardized approach for selecting PCSM best management practices (BMPs) on projects. However, this is just one component of an overall program to enable PennDOT to adapt to current practices and maintain consistency with evolving stormwater requirements. PennDOT will use a comprehensive "$E^5$" strategy for addressing stormwater management issues, which is consistent with PennDOT's MS4 permit. The goal is to integrate each of the $E^5$ components into the overall design process in order to achieve a program that is sustainable and efficient. The $E^5$ strategy includes:

- **E**ncouraging low impact practices for preventing runoff;
- **E**valuating site characteristics and BMP needs early in the design process;
- **E**ngaging PA DEP through pre-application meetings;
- **E**stablishing a process to evaluate new technologies, assess the performance of existing ones in the field, and update/expand the BMP toolbox; and
- **E**ducating PennDOT staff, consultants, and contractors on stormwater policy and implementation.

This comprehensive approach to stormwater management is needed in order to address the many challenges presented by runoff from PennDOT's facilities. In Pennsylvania, the three primary concerns related to the effects of runoff on water resources from roadway facilities are:

- Stream channel erosion and flooding resulting from increases in runoff rate and volume;
- Water quality impacts to streams and groundwater aquifers from particulates, floatables, hydrocarbons, and deicing materials; and
- Thermal impact on streams caused by heat transfer from pavement to runoff and loss of riparian buffer vegetation.

Chapter 7 of the PA Stormwater BMP Manual (PA DEP, 2006), herein referred to as the "BMP Manual," lists a number of additional common pollutant constituents in highway runoff. Many, if not most of these constituents occur in relatively small concentrations and are usually addressed when the increases in the rate and volume of runoff are mitigated. The items listed above are the primary concerns related to potential water resources impacts and are discussed below in more detail.

**1.** Increases in Runoff Rate and Volume. It is well documented that a direct relationship exists between the imperviousness of a watershed and the impairment of its surface waters. Unmitigated increases in the rate and volume of runoff discharging from developing areas have a cumulative effect, which has been shown to cause flooding and erosion of streams. Increases in the rate and volume of runoff are mostly dependent on the amount of impervious area replacing pervious area, the amount of disturbance, and the time it takes for the runoff to concentrate and leave the site. Some types of projects add relatively little (or no) impervious area and require minimal disturbance, while other types of projects create large areas of impervious cover and disturbance. Increased discharges can often be prevented in the former case by implementing qualitative and non-structural measures; whereas the latter case usually requires structural measures for peak flow and volume mitigation. Because there is a wide range of activities affecting stormwater and an array of potential BMP solutions, it is necessary to group the activities and BMPs in order to create a standard approach that applies to most PennDOT projects. This approach is described in detail in Section 13.7.C.

The peak rate and volume control achieved through application of the BMP Manual guidance results in treatment of a major fraction of pollutants associated with particulates from impervious surfaces, in addition to flood and stream channel protection during most storms. It should be noted, however, that solutes will continue to be transported in runoff throughout the storm, regardless of its magnitude.

**2.** Winter Maintenance Materials. Chlorides and other soluble chemicals in deicing materials and salts can spike concentrations in groundwater. In addition, the fine sediments that make up anti-skid materials can be carried into an adjacent stream or accumulate over and clog an infiltration facility. The BMP Manual and PennDOT's MS4 permit list several good housekeeping approaches that PennDOT is working on to minimize pollutant loadings from winter maintenance materials, including

- Monitoring and minimizing the volume of winter maintenance materials used;
- Protecting salt storage and loading areas from weather influences; and
- Cleaning around the area where materials are dispensed immediately after deicing operations have ceased.

**3.** Thermal Impact. In warm months, heat transferred from stormwater runoff to cold-water streams can be a potential source of thermal impacts. This type of effect is pronounced in urban areas. Runoff is heated as it passes over impervious surfaces with large heat storage due to solar radiation. As the magnitude of impervious surfaces and open water ponds or basins increase, or when riparian areas (i.e., vegetated buffer zones) decrease, there is a potential for increasing summer stream temperatures. Other studies have shown similar effects in the winter, except that impervious areas cool the runoff below the stream's ambient temperature. Thermal impacts are also particularly important for surface waters that have a fishery classification of Cold Water Fishes or Trout Stocking; this includes waters that are High Quality waters due to an existing or designated use as a Class A wild trout stream by the PA Fish and Boat Commission. PA DEP and PennDOT have developed strategies to reduce potential thermal impacts, which include the following:

- Limit the use of curb and gutter sections as much as practicable;
- Limit the use of storm sewers as much as practicable;
- Consider alternative methods of energy dissipation at culvert and storm sewer outfalls;
- Discharge storm sewers into non-EV wetland areas or vegetated swales as much as practicable;
- Consider vegetated islands in-lieu of concrete islands; and
- Maintain naturally occurring vegetation (i.e., buffer zones, including wetland and riparian) along streams, rivers and other surface waters for shading and thermal protection.

Two additional factors that should be considered when evaluating a project's potential for thermal impacts are (1) the distance from the impervious areas to the surface water and (2) the size of the surface water relative to the amount of runoff generated by the impervious areas. Generally speaking, the longer the travel time through vegetated or shaded areas, the cooler the runoff will be when it eventually reaches the surface water. Although the use of vegetated swales for stormwater conveyance is preferred, storm sewers are buried and generally stay cool; thus, a significant amount of heat loss can take place in a long sewer run before the runoff reaches the surface water. The size of the receiving surface water is an important factor due to mixing phenomena. Large highway projects that are adjacent to headwaters have the potential to adversely affect the temperature regime because runoff from the highway may produce a significant percentage of the total surface flow in the headwater. In this type of situation, it is particularly important to address potential thermal impacts using the strategies outlined above. However, it is more likely that the runoff produced by the road during a storm is insignificant compared to the flow in the receiving surface water. Additionally, the water quality criteria do not preclude the allowance of a reasonable mixing zone if there is no significant effect on the ambient temperature of the stream outside the mixing zone.

**C. Project Categories.** The most common types of construction projects that PennDOT engages in are grouped into three categories – bridges, highway restoration, and new construction – and presented in Table 13.5. Descriptions for each type of project are provided in the table. PCSM levels, which are located in the right-hand column of the table, are determined by:

- the potential for generating increased stormwater discharges (volume or rate) as a result of the activity;
- the potential for causing thermal impacts to receiving surface waters; and
- the potential for discharging high concentrations of pollutants (e.g., salt storage facilities).

The projects in Table 13.5 are assigned a PCSM level, from 1 to 3, which represents a scale of low potential (Level 1) to high potential (Level 3) for the items listed above. For example, a project involving a highway interchange reconfiguration (Level 3) has a greater potential for generating increased runoff than a project proposing to add a center-turning lane to a local intersection (Level 2).

In addition to factors listed above, the sensitivity of the area or the watershed receiving runoff from the project is an important consideration in the analysis of increased runoff impacts. In fact, a project should be considered PCSM Level 4, regardless of the type of project it is, when it has the potential to discharge into one of the following sensitive areas, which are noted in Table 13.6:

- HQ or EV waters, or EV wetlands,
- stormwater-impaired surface waters,
- combined sewer systems, and
- surface waters containing critical habitat for threatened or endangered species.

Each of the four PCSM levels corresponds to a different set of stormwater BMPs, which is called a "BMP toolbox." The BMPs within that toolbox may be used to prevent or control runoff from that particular project after the BMPs in the lower level toolboxes have been considered. The lower level BMPs are generally focused on minimizing the potential impacts from runoff by applying preventative design and construction measures, which are applicable on most projects. There may be circumstances that warrant the use of BMPs from a higher-level toolbox (e.g., a Level 2 project that uses BMPs in the Level 3 toolbox). In these cases, the PennDOT project manager should be consulted.

## TABLE 13.5
## PCSM LEVELS FOR PROJECTS LOCATED IN NON-SENSITIVE AREAS

| Type of Project | | Description | PCSM Level |
|---|---|---|---|
| Bridges | New or Replacement over Water | Total bridge length is 200 feet or less, or at least 75% of total bridge length is over water for longer bridges. | 1 |
| | | Bridges longer than 200 feet and more than 25% of length over land. | 2 |
| | Replacement over Land | Similar to 3R widening. | 2 |
| | New over Land | Bridge over pervious area is similar to new road alignment; if new bridge over existing impervious, subtract impervious area below the bridge. | 3 |
| Highway Restoration (3R) | Pavement | Replace portions, overlay, or mill and resurface the roadway's surface. | 1 |
| | Widening | Increase the width of the existing travel lanes (no new lanes added) and shoulders, or extension of acceleration/deceleration ramps in existing shoulder areas. | 2 |
| | Shoulders | Resurface, stabilize, upgrade (dirt or gravel to paved), or widen the existing shoulders within the existing footprint. | 1 |
| | Intersection | Nominal channelization of intersections and addition of turning lanes. | 2 |
| | Alignment | Change the roadway by either reducing or eliminating horizontal and vertical curves. | 2 |
| | Pull-offs | New, as part of a larger project or by itself. | 2 |
| | Other | Replace and/or repair guide rail, signs, traffic signals, and drainage systems to their original specifications; various minor safety improvements. | 1 |
| New Construction | Major Widening | Addition of one or more travel lanes, including acceleration and deceleration lanes, to an existing road. | 3 |
| | New Alignment | New roadway corridor. | 3 |
| | Interchange | Reconfiguration of ramps, lane modification within interchange area, etc. | 3 |
| | Facilities | New stockpile sites, park-and-ride lots, rest stops, etc. | 3 |

## TABLE 13.6
## PCSM LEVELS FOR PROJECTS LOCATED IN SENSITIVE AREAS

| Type of Area | Description | PCSM Level |
|---|---|---|
| HQ/EV waters or EV wetlands | Any portion of a project having a potential to discharge into waters with existing or designated HQ or EV uses per 25 PA Code 93, or EV wetlands per 25 PA Code 105. | 4 |
| Impaired watershed | Any portion of a project discharging into a watershed identified by PA DEP as having impairments due to stormwater. | 4 |
| Combined sewer systems | Any portion of a project discharging into a combined sewer system. | 4 |
| Threatened and endangered species and critical habitat | Any portion of a project that has the potential to have an adverse effect, either directly or indirectly, on threatened or endangered Federal or Pennsylvania species, or critical habitat for threatened or endangered species (e.g., bog turtle wetlands). | 4 |

**1.** PCSM Level 1. These types of projects involve restoring an existing roadway to its original condition; pervious areas are generally not being converted into impervious areas. Level 1 projects do not measurably change the post-construction rate, volume, or quality (including temperature) of runoff from the site. The BMPs listed in Table 13.7 should be employed and the designer should attempt to maintain pre-development stormwater conditions. Also refer to the E&S procedures and BMPs outlined in PennDOT's Drainage Manual for designing measures to prevent polluted discharges from the construction site. If one or more of the BMPs in Table 13.7 can be used for a substantial portion of a project, calculations for peak flow, volume, and water quality are usually not required for Level 1 projects.

Level 1 Target – Minimal disturbance.

## TABLE 13.7
## LEVEL 1 BMP TOOLBOX

| Stormwater BMP | Reference[1] | Application |
|---|---|---|
| Minimize compaction | [8] Ch 5.6.2 | Designate areas for construction vehicle traffic to prevent unintended compaction |
| Preserve trees and re-vegetate using native species | [8] Ch 5.6.3 | Preserve trees by clearing only those that are safety hazards and that are necessary for construction; preserve riparian buffers; clearly mark overall limits of disturbance; re-vegetation of abandoned alignment; re-vegetate temporary staging areas |
| Maintenance of dual-purpose E&S/PCSM BMPs | [7] Ch 12 | Proper maintenance and conversion of E&S control facilities, such as sediment basins, into permanent PCSM facilities, such as infiltration basins |
| Restoration of temporary staging areas | [8] Ch 6.7.3 | Restore areas used for temporary staging or storage of materials by replacing or supplementing the soil and re-vegetating the disturbed areas |

1 – List of References: [7] PennDOT, 2007; [8] PA DEP, 2006

**2.** PCSM Level 2. Level 2 projects typically involve a minor addition of impervious area relative to existing conditions and do not generally change the direction of runoff or the potential for pollutants in the runoff. For example, widening existing travel lanes or shoulders for improved safety does not increase the volume of traffic; thus, the amount of potential pollutants deposited and the amount of deicing materials used on the road are not expected to increase. A relatively small volume of additional runoff is generated by the new impervious area, in part because the pervious areas within the right-of-way are highly compacted and exhibit runoff qualities similar to impervious areas. The primary focus of a Level 2 project analysis should be to compare the existing and proposed runoff characteristics. In many cases, the existing road and right-of-way will contain very few, if any, BMPs that significantly contribute to improving water quality and reducing runoff volume. The additional runoff can often be dealt with using non-structural and restoration BMPs when the roadway runoff does not discharge directly to surface waters.

## TABLE 13.8
## LEVEL 2 BMP TOOLBOX

| Stormwater BMP | | Reference[1] | Application |
|---|---|---|---|
| Non-Structural | Street sweeping | [9] Ch 11<br>[8] Ch 5.9.1 | Most effective in urban areas for removing debris and sediment on roads; bridges over HQ/EV waters |
| | Impervious disconnection | [8] Ch 5.8.2 | Disconnect road from storm sewer; eliminate curb/gutter where possible and provide curb cuts to allow flow into parallel BMPs |
| | Slope roughening | N/A | Includes surface roughening, grooving, tracking, stepping, etc.; use on slopes to reduce erosion potential and increase ET |
| | Pavement width reduction | [8] Ch 5.7.1 | Use minimum allowable pavement widths; consider design exceptions where adjacent road sections are narrow |
| Structural – Restoration | Riparian buffers | [8] Ch 6.7.1 | Reestablish buffer areas along stream; minimum 10.5 m (35 ft) width from top of bank |
| | Landscaping and planting | [8] Ch 6.7.2 | Use non-invasive native species vegetation in lawn areas and on slopes, to enhance water uptake and the storage of certain pollutants in plant tissue. Use sod-forming grasses adjacent to the roadway shoulders and for vegetated swales to serve as filters for suspended solids and metals. |
| | Soil amendments | [9] Ch 13<br>[8] Ch 6.7.3 | Replace poorly draining soils in swales or other areas receiving runoff with a permeable/organic mix of soil |
| Structural | Vegetated swales | [9] Ch 14 | Convert ordinary shoulder swales and rock-lined ditches to vegetated swales (see BMP descriptions); use check dams; supplement with subsurface storage if necessary |
| | Bioretention | [9] Ch 5<br>[8] Ch 6.4.5 | Convert median areas on low-volume roads and intersections to vegetated areas or replant existing vegetated areas with species that offer greater ET |
| | Vegetated filter strip | [8] Ch 6.4.9 | Receives sheet flow directly from pavement edge; used on embankment slopes of fill sections and adjacent to flat sections |
| | Constructed wetlands / Wet ponds | [8] Ch 6.6.1<br>[8] Ch 6.6.2 | Retrofitting an existing dry detention basin only |

1 – List of References: [8] PA DEP, 2006; [9] Transportation Research Board, 2006

The structural BMPs listed in Table 13.8 can be used where they can be retrofitted within the existing footprint without affecting safety, and where the roadway facility would normally discharge directly into a conveyance system or surface water. Examples of swale retrofitting include: replacing earth material and/or vegetation in swales to encourage evapotranspiration and/or infiltration; adding an organic layer (i.e., compost) to encourage bioretention; replanting with species that offer greater evapotranspiration opportunities (i.e., larger root systems); and retrofitting ditches with check dams to provide storage in the channel. The vegetation for filter strips may be comprised of (1) turf grasses, (2) meadow grasses, shrubs, and native vegetation, including trees, and (3) indigenous areas of woods and vegetation. The BMP references [1, 6, 7, 8, 9, 11] should be consulted for information on increasing the capacity and efficiency of the structural BMPs. In addition, a combination of BMPs is preferred over a single BMP treatment because they can compliment each other and provide a more effective means of treatment.

<u>Level 2 Target</u> – Where existing swales and median areas can be retrofitted with structural BMPs without adversely affecting safety, BMPs should be designed to (1) capture 50 mm (2.0 in) of runoff from all impervious areas contributing to the BMPs; (2) permanently remove the first 25 mm (1.0 in) of runoff from new impervious areas by assimilating through infiltration and/or evapotranspiration; and (3) infiltrate the first 13 mm (0.5 in) of runoff from new impervious areas. Where retrofitting existing swales and medians is not feasible, the designer should maximize the use of non-structural and restoration-type BMPs that encourage and/or enhance evapotranspiration in order to attempt to maintain pre-development stormwater runoff conditions. Peak discharge rates should be calculated where the use of structural BMPs is not feasible and a measurable difference between pre- and post-construction rates is anticipated.

The Level 2 target is in alignment with Control Guideline 2 (CG-2) in the BMP Manual. Level 2 projects exceeding 0.40 ha (1.0 ac) of disturbance should apply the above guidelines, even though the BMP Manual recommends limiting the application of CG-2 to 0.40 ha (1.0 ac) of disturbance. Disturbance to 0.40 ha (1.0 ac) of clustered land has a high potential to affect an adjacent surface water receiving runoff from the site. Given this scenario, the ratio of receiving waters to disturbed area is 1-to-1. On the other hand, a 3R project that proposes 0.6 m (2 ft) of shoulder widening on both sides of the road would have to be 3.2 km (2 mi) long to equal 0.40 ha (1.0 ac) of disturbed area. Assuming that there are five small tributaries per 1.6 km (1 mi) for this particular project, the ratio of receiving waters to disturbed area (and added impervious area) is 10-to-1. Although the actual number of receiving waters varies from project to project, these types of ratios are typical and provide justification for the recommended PCSM target for Level 2 projects in this policy.

**3.** PCSM Level 3. These projects typically involve a significant increase in an existing roadway's footprint or, as in a new alignment, significant changes in topography and cover. By altering the landscape, these projects generally produce higher volumes and rates of runoff. The structural BMPs in Table 13.9 should be considered for integration into the design of the stormwater management and drainage systems. Most of these BMPs reduce runoff volume through a combination of infiltration and evapotranspiration, while all of the BMPs have some capacity for peak reduction and water quality.

Level 1 and 2 BMPs should be examined first before Level 3 BMPs are considered. In addition, incorporate low impact design concepts such as (1) maintaining natural drainage divides, (2) preserving naturally vegetated areas, (3) grading to encourage sheet flow, and (4) directing runoff into or across vegetated areas.

<u>Level 3 Target</u> – Reduce the post-construction runoff peak rate to the pre-construction peak rate for the 1-year through 100-year storm events. Reduce the post-construction runoff volume to the pre-construction runoff volume for the 2-year 24-hour storm event and smaller. The plans must also comply with the water quality requirements established by 25 PA Code 93.

## TABLE 13.9
## LEVEL 3 BMP TOOLBOX

| Stormwater BMP | Reference[1] | Application |
|---|---|---|
| Vegetated swales | [9] Ch 14<br>[8] Ch 6.4.8 | Shoulder swales, medians, top of cut ditches, storm sewer outlet channels; use check dams to increase volume capacity; plant with salt-tolerant vegetation such as creeping bentgrass and switchgrass |
| Bioretention | [9] Ch 5 | Divided highway medians; can combine with infiltration trench to increase volume capacity |
| Bioslopes | [9] Ch 6 | Embankments with engineered soil media; similar to vegetated filter strip except filtering occurs below the surface |
| Dry extended detention basin | [7] Ch 14<br>[8] Ch 6.6.3 | Traditional detention basins; use where infiltration is not feasible and wet ponds are undesirable (safety concerns, etc.) |
| Infiltration trench | [9] Ch 9<br>[8] Ch 6.4.4 | Design as part of a storm sewer system using perforated pipes: virtually no release of small storm events and normal conveyance of large events; can incorporate with vegetated swales; limited use in karst topography |
| Infiltration basin | [8] Ch 6.4.2 | Use in conjunction with an extended stormwater detention for peak flow detention; limited use in karst topography; ideal in interchanges |
| Infiltration berm | [8] Ch 6.4.10 | Locate between roadway and adjacent surface water; place parallel to contours on 4:1 or flatter slopes; can be combined with an infiltration trench; limited use in karst topography |

1 – List of References: [7] PennDOT, 2007; [8] PA DEP, 2006; [9] Transportation Research Board, 2006;

**4.** PCSM Level 4. Level 2 or 3 projects that have the potential to discharge into surface waters that (1) have existing or designated HQ or EV uses (including EV wetlands), (2) have impairments due to stormwater, (3) are connected to combined sewer systems, or (4) have the potential to have an adverse effect on threatened or endangered species, or critical habitat for such species, are elevated to PCSM Level 4. Level 4 BMPs in Table 13.10 should be considered only after BMPs for Levels 1 through 3 are applied, where appropriate, to address the runoff from the additional impervious surfaces. Generally, PCSM BMPs that address quantity (rate and volume) also address quality. To demonstrate this determination, water quality requirements will be met when there is no net change in the pre/post runoff volume comparison for the 2-year 24-hour storm event, rate is controlled for the 1-year through 100-year storm events, and the nitrate removal efficiency of the proposed BMPs has been documented (see FAQ #6).

If the approved BMPs in this policy cannot accomplish the non-discharge alternative (a no net change in runoff for rate, volume, and quality), then Antidegradation Best Available Combination of Technologies (ABACT) BMPs need to be incorporated. ABACT BMPs include practices that, in combination, provide (1) cost-effective treatment, (2) land disposal, (3) pollution prevention, and (4) stormwater reuse technology approaches. In the Antidegradation Analysis Section of the NPDES permit, which applies only to Special Protection waters, the applicant must describe how these items have been satisfied. All but the last item, stormwater reuse technology approaches, can be satisfied using the BMPs described in this policy. Except for possibly PennDOT buildings, park-and-ride lots, and maintenance facilities, stormwater reuse is not feasible for PennDOT projects. Table 13.11 lists the BMPs in this policy according to which ABACT category they can be applied. Prior approval from the PennDOT project manager is required for using BMPs that are not listed in this table. Manufactured products, such as water quality inlets and underground detention units, require special approval from the Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section, and will be assessed on a project-by-project basis.

## TABLE 13.10
## LEVEL 4 BMP TOOLBOX

| Stormwater BMP | Reference[1] | Application |
|---|---|---|
| Constructed wetlands / Wet ponds | [8] Ch 6.6.1<br>[8] Ch 6.6.2 | Significant detention of peak flow rates is needed and the contributing drainage area is large; retrofit existing detention basins or construct new in open median or interchange areas |
| Permeable pavement | [9] Ch 10<br>[8] Ch 6.4.1 | Limited to park-and-ride sites and parking lots |
| Manufactured products: subsurface storage, water quality inlets, etc. | [9] Ch 6.6.3<br>[9] Ch 6.6.4 | Subsurface storage products are designed to temper peak runoff events through infiltration and/or discharge rate reduction. Storm sewer inlet structures or inserts are designed to minimize the discharge of solids, floatables, and oil/grease pollutants. Regular maintenance of these products is necessary and is an important factor in assessing the feasibility of using one of these products. |

1 – List of References: [8] PA DEP, 2006; [9] Transportation Research Board, 2006

Level 4 Target – Reduce the post-construction runoff peak rate to the pre-construction peak rate for the 1-year through 100-year storm events. Reduce the post-construction runoff volume to the pre-construction runoff volume for the 2-year 24-hour storm event and smaller. The plans must also comply with the water quality requirements established by 25 PA Code 93.

## TABLE 13.11
## BMPS BY ABACT CATEGORY

| Treatment BMPs | Land Disposal | Pollution Prevention |
|---|---|---|
| Vegetated swale | Bioslope | Street sweeping |
| Bioretention | Bioretention | Impervious disconnection |
| Constructed wetland | Vegetated filter strip | Slope roughening |
| Wet pond | Impervious disconnection | Pavement width reduction |
| Infiltration trench | | Riparian buffers |
| Infiltration basin | | Landscaping and planting |
| Infiltration berm | | Soil amendments |
| Permeable pavement | | |

**D. Act 167 Plans and Municipal Ordinances.** In Pennsylvania, Act 167 stormwater management plans provide a model set of ordinances to municipalities for regulating stormwater discharges from developing areas, which are based on extensive studies of the watershed's runoff characteristics. Because the watersheds being studied reach across many municipal boundaries, counties oversee the development of the plans. Once a plan is approved by PA DEP, the municipalities within that watershed must adopt and enforce ordinances that are at least as restrictive as the model ordinance in the Act 167 plan.

PennDOT must be consistent with the standards of watershed-based stormwater management plans approved by PA DEP and implemented under the Storm Water Management Act (1978 Act 167); however, PennDOT is not required to comply with individual local ordinances, including ordinances adopted under an Act 167 plan. PennDOT does, however, strive to maintain good relations with local municipalities and, at PennDOT's discretion, wishes to be consistent with local ordinances when feasible and practicable. Municipal stormwater ordinances should not be used to design stormwater facilities on a project unless specifically directed by the PennDOT project manager.

Consistency with an Act 167 plan does not necessarily mean that the antidegradation requirements for an NPDES permit have been satisfied. From 1980 to 2003, Act 167 plans that were developed focused on controlling the peak rate of discharge to protect downstream persons and property. Act 167 plans developed since 2003 have targeted a broader range of stormwater runoff issues related to development including: minimizing increases in runoff volume, controlling peak discharge rates, maintaining groundwater recharge, and protecting water quality. The former addresses one component of antidegradation and PCSM, while the latter addresses most of the issues. Volume control and water quality requirements of the NPDES permit will usually govern because the majority of existing plans do not include volume and water quality standards. On the other hand, the peak discharge standards in an Act 167 plan may be more restrictive than NPDES requirements and would thereby govern. In any case, the more restrictive requirements between the NPDES permit and the PA DEP-approved Act 167 plan govern the design of PCSM for PennDOT projects.

**E. Applicable Laws.** A number of Commonwealth and federal laws directly related to stormwater management affect the way PennDOT manages runoff from its roadways and facilities.

**1.** Federal Clean Water Act, Section 402. This section is referred to as the NPDES permit, which requires a permit for the discharge of any pollutant into navigable waters.

**2.** Federal NPDES Regulations at 40 CFR Part 122. Contains provisions for implementing the NPDES program.

**3.** PA Storm Water Management Act. Known as Act 167, this law requires counties to develop stormwater management plans for each watershed within their county. The purpose of this act is to manage stormwater runoff in order to preserve and restore the flood carrying capacity of streams (thereby preventing flooding), preserve the hydrologic balance of the watershed, and protect and conserve groundwater resources and groundwater recharge areas. Any project funded by the Commonwealth must be conducted in a manner consistent with the Act 167 plan that has been approved by PA DEP. Act 167 plans normally contain provisions for peak rate reduction and improving water quality.

**4.** PA Clean Streams Law. Establishes the general authority for the PA DEP in establishing standards for the protection, maintenance and restoration of the Commonwealth's water resources.

**5.** 25 PA Code 92. This chapter sets forth permitting, monitoring, and compliance requirements with regard to the PA DEP implementation of the NPDES program. The PA DEP permit process for the NPDES Permit for Stormwater Discharges Associated with Construction Activities is promulgated, in part, through this regulation.

**6.** 25 PA Code 93. Chapter 93 establishes requirements to protect designated and existing water quality uses of surface waters. It also provides for the implementation of antidegradation requirements for activities that have the potential to discharge to Special Protection watersheds (HQ and EV). For special protection waters, non-discharge alternatives must be evaluated that are environmentally sound and will (1) minimize accelerated erosion and sedimentation during the earth disturbance activity, and (2) achieve no net change from pre-development to post-development volume, rate and concentration of pollutants in water quality. Where no environmentally sound and cost-effective non-discharge alternatives exist, Chapter 93 requires that the applicant demonstrate that the discharge will maintain and protect the existing quality of receiving surface waters. This is accomplished when a new, additional or increased discharge uses the Antidegradation Best Available Combination of Technologies (ABACT). The NPDES permit application form includes an Antidegradation Analysis Module for evaluating impacts to designated and existing uses in HQ and EV watersheds.

**7.** 25 PA Code 96. The purpose of this chapter is to establish the process for achieving and maintaining water quality standards.

**8.** 25 PA Code 102. This chapter of the PA Code addresses requirements for earth disturbances, including the application of erosion and sediment control as it relates to construction and maintenance projects

**9.** 25 PA Code 105. Section 105.17 defines EV wetlands. Section 105.18a outlines the requirements that must be met in order for PA DEP to grant a Chapter 105 (water obstructions and encroachments) permit. The requirement that is most directly related to stormwater discharges applies to wetlands and provides, "The project will not cause or contribute to pollution of groundwater or surface water resources or diminution of resources sufficient to interfere with their uses."

**F. Definitions.**

**1.** Additional Impervious Surfaces. Refers to the difference between post-development and pre-development impervious surfaces.

**2.** Best Management Practices (BMPs). Schedules of activities, prohibitions of practices, maintenance procedures and other management practices to prevent or reduce pollution to surface waters of the Commonwealth. The function of many stormwater BMPs is to prevent or minimize increases in runoff rate and volume caused by changes in the landscape.

**3.** Combined Sewer Systems (CSSs). A single pipe sewer system designed, permitted, and constructed to convey both sewage and stormwater during periods of excess precipitation (runoff).

**4.** Degradation. For HQ and EV watersheds, degradation is an adverse effect that results in a negative change in the existing water quality of the receiving surface water. For non-HQ and non-EV watersheds, it is a negative change in the existing or designated in-steam water use or the level of water quality necessary to protect the use.

**5.** Evapotranspiration (ET). The sum of evaporation and plant transpiration of water. Evapotranspiration accounts for a significant portion of the rainfall that is lost (not returned to streams via surface runoff) in Pennsylvania watersheds. The amount of water that is lost by evapotranspiration is influenced mostly by the types of vegetation and land use in a watershed. Because water transpired through leaves comes from the roots, plants with deep reaching roots can more constantly transpire water. Thus, herbaceous plants transpire less than woody plants because herbaceous plants usually lack a deep taproot. Also, woody plants keep their structure over long winters while herbaceous plants must grow up from seed in the spring in seasonal climates, and will contribute almost nothing to evapotranspiration in the spring.

**6.** Impaired Stream. A stream that does not meet the water quality criteria for its designated or existing use.

**7.** Infiltration. The process by which surface water penetrates through the ground surface into the soil. The soil texture and structure, vegetation types and cover, water content of the soil, soil temperature, and rainfall intensity all play a role in controlling infiltration rate and capacity. For example, coarse-grained sandy soils have large spaces between each grain and allow water to infiltrate quickly. Vegetation creates more porous soils by both protecting the soil from pounding rainfall, which can close natural gaps between soil particles, and loosening soil through root action. This is why forested areas have the highest infiltration rates of any vegetative types.

**8.** Long Term Control Plan. A plan developed by municipalities and/or municipal authorities designed to mitigate the impact of combined sewer system discharges and meet water quality standards.

**9.** Municipal Separate Storm Sewer System (MS4). Certain small municipal separate storm sewer systems in urbanized areas, as defined in 40 CFR Part 122, that discharge stormwater into surface waters of the Commonwealth (including intermittently flowing streams and drainage channels) are required to have the discharges authorized by an NPDES stormwater permit. The MS4 classification includes a conveyance or system of conveyances (including roads with drainage systems, streets, catch basins, curbs, gutters, ditches, man-made channels or storm drains) primarily used for collecting and conveying stormwater runoff.

**10.** Net Change. Refers to the change from pre-development to post-development conditions.

**11.** Non-discharge Alternative. For activities requiring coverage under an NPDES Permit for Stormwater Discharges Associated with Construction Activities, means no "net change" in existing stormwater runoff conditions (volume, rate, and quality) per watershed. Non-discharge alternative does not mean that there can be no discharge from the site.

**12.** Pre-development. Refers to runoff condition that exists onsite immediately before the planned project occurs. Pre-development is not intended to be interpreted as the period before any human-induced land disturbance activity has occurred.

**13.** Post Construction Stormwater Management (PCSM). The term "post-construction" is used to differentiate PCSM from discharges during construction. Erosion and sediment (E&S) pollution control plans are required for most construction projects to show that runoff from disturbed areas during construction is properly managed. PCSM deals with runoff from the project after the earth disturbance is completed and the site has been stabilized.

**14.** Surface Waters. Perennial and intermittent streams, rivers, lakes, reservoirs, ponds, wetlands, springs, natural seeps and estuaries.

**15.** Thermal Impact. Per 25 PA Code 93, thermal degradation is a two degree (or more) change during a one-hour period in mean water temperature of the receiving surface water. The water quality criteria do not preclude the allowance of a reasonable mixing zone if there is no significant effect on the ambient temperature of the stream outside the mixing zone.

**16.** Total Maximum Daily Load (TMDL). The amount of pollutant loading that a waterbody can assimilate and meet water quality standards. The TMDL process is a planning tool to develop pollution reduction goals that will improve impaired waters to meet water quality standards.

**G. Limitations.** There are a number of factors that may preclude the use of a BMP, even if it otherwise appears to be applicable. The most common factors limiting their use include karst topography, high groundwater table, limiting soil zones, shallow depth to bedrock, and compacted soils. A few of these factors are described below. It should be noted that the presence of limiting factors does not exempt a project from analyzing the post-construction stormwater conditions and potential impacts to receiving waters.

**1.** Structural Infiltration BMPs. The use of structural infiltration systems is challenging in cold-climate states such as Pennsylvania. Frozen soils can dramatically reduce, or stop, the rate of infiltration, chlorides may pose a risk to groundwater, and sand used as abrasives on roads may clog infiltration practices. Consequently, designers need to make modifications to these BMPs to make them effective in cold climates. Minimum soil infiltration rates should be increased (from base criteria) to account for the clogging potential from road abrasives and somewhat for the reduced infiltration rates during the winter season. Additional design guidelines for infiltration systems can be found in Appendix C of the BMP Manual. When infiltration practices are used next to a road or pavement, they should be set back in order to avoid potential frost heave conditions. Infiltrated water can contribute to ice lenses that form beneath the road surface, aggravating frost heave and potentially causing damage. The maximum ponding elevation in a facility should be no higher than the minimum subgrade elevation of the road. Setback restrictions can be avoided by using other measures to protect pavement. For example, pavement can be insulated or underlain with a very thick gravel to protect against frost damage.

Roadway runoff generates high levels of suspended solids and should not be discharged directly to infiltration systems without first reducing sediment loads. Structural infiltration BMPs are appropriate for roadway systems but must be designed in conjunction with a pre-treatment measure (structural or non-structural) that reduces the amount of sediment and other particulate matter in roadway runoff prior to infiltration. There are a variety of options that will reduce sediment loads, including:

- Vegetated systems such as grassed swales, filter strips, and bioretention;
- During construction, sediment filter bags on inlets and various other E&S BMPs; and
- Maintenance measures such as street sweeping and vacuuming.

Using one or more of these measures before discharging to an infiltration BMP will minimize the accumulation of sediment that could lead to failure of an infiltration BMP. All measures for sediment reduction require regular maintenance.

**2.** Karst Topography. Karst terrain is characterized by sinkholes, depressions, caves, and underground drainage, and is generally underlain by soluble rocks such as limestone and dolomite. Thick sequences of carbonate bedrock underlie a sizeable area in central and southeastern Pennsylvania [9]. Because natural filtration through soil is limited in karst areas, pollutants in highway stormwater runoff can directly infiltrate underground sources of drinking water and environments that are habitats for sensitive species. Although there is an abundance of literature concerning karst groundwater quality, relatively little research has been conducted addressing the specific impacts of highway runoff to groundwater in karst areas.

It is important to evaluate the appropriateness of structural infiltration BMPs in karst areas on a project-by-project basis. In general, areas with less than 300 mm (4 ft) of soil over carbonate bedrock should be avoided, and ponding depths in infiltration systems should be shallow. Infiltration trenches are not recommended in areas with pronounced karst topography due to the potential for sinkhole formation and groundwater contamination. These limitations should not preclude infiltration altogether. Structural infiltration BMPs may be provided where runoff can be spread over a large area with a shallow maximum ponding depth. This should be done on existing grades, if possible, to avoid excavation and maintain sufficient soil depth above the bedrock. Where infiltration is not feasible, maximize the use of non-structural BMPs and consider structural BMPs with high evapotranspiration characteristics, such as bioretention. Additional information on the use of BMPs in karst areas can be found in Chapter 7 of the BMP Manual.

**H. Special Considerations.**

**1.** Building and Maintenance Facilities. PennDOT should consider alternative stormwater solutions at PennDOT buildings and maintenance facilities, since these areas have less limiting factors than roadway systems. For example, porous pavement and other subsurface infiltration methodologies may be considered on park-and-ride sites and parking areas. Dry wells and other subsurface infiltration methodologies may be considered for building roof drains.

**2.** Combined Sewer Systems. Combined sewer systems (CSSs) can be found in cities and towns throughout Pennsylvania, including Pittsburgh, Harrisburg, and Philadelphia. These systems were designed to collect stormwater runoff, domestic sewage, and industrial wastewater all in the same pipe. Most of the time, combined sewer systems transport all of their wastewater to a sewage treatment plant. However, during periods of heavy rainfall or melting snow the volume of wastewater can exceed the capacity of the CSS pipes, and excess wastewater empties directly into nearby streams, rivers, or other water bodies. New construction of CSS systems is prohibited, and the old CSS infrastructure in Pennsylvania is gradually being replaced with separate stormwater and sewer systems. The volume and quality of PennDOT stormwater discharges to CSSs can contribute to water quality impacts to receiving surface waters. At a minimum, peak discharge rates into a CSS should not increase as a result of a project, and practicable alternatives that reduce discharges into a CSS should be considered. PennDOT designs should evaluate conditions and alternatives that facilitate the removal of headwater streams from local collection and conveyance systems. PennDOT projects located in CSS communities should evaluate and incorporate, where feasible, water quality improvement designs to minimize runoff volume and pollutant content, including solids, floatables, and oil/grease. PennDOT will coordinate and evaluate its project design proposals to be consistent with local Long Term Control Plans and its objectives.

**I. Non-Structural BMP Descriptions.** This section includes brief descriptions of each of the non-structural PCSM measures in the BMP toolboxes. These descriptions should supplement the technical guidance that can be found in the BMP Manual and other similar publications listed under References in Section 13.7.L.

**1.** Minimize Compaction. The post-construction runoff from a project can be reduced by minimizing the amount of area that is compacted. Compaction of a previously undisturbed area can significantly reduce the infiltration capacity of that soil. This non-structural BMP can be applied to almost every project. Compaction is normally a planned construction activity, but it can also occur unintentionally, such as by the weight of construction vehicles. Well-planned staging of construction activities can reduce the need to disturb uncompacted areas outside of the construction footprint. Areas specifically designated for staging and temporary construction measures should be described in the E&S plans and clearly marked in the field by the contractor. Additional information on minimizing compaction can be found in Section 5.6.1 and 5.6.2 of the BMP Manual.

**2.** Preserve Trees and Re-vegetate Using Native Species. Clearing of forested areas, including riparian buffers, should be limited to only those areas that are essential for construction operations. Well-planned staging of construction activities can reduce the need to disturb wooded areas outside of the construction footprint. Similar to minimizing compaction, this non-structural BMP can be applied to almost every project. Highway projects involving new alignments sometimes involve abandoning existing sections of highway. These areas may provide opportunities to offset the stormwater-related impacts of the new alignment. By removing pavement and planting the abandoned areas with native vegetation, the abandoned areas can be made to resemble pre-existing conditions. Additional details including costs and plant references can be found in Section 5.6.3 of the BMP Manual.

**3.** Street Sweeping. Street sweeping is an effective non-structural BMP for removing pollutants before they are carried away by runoff into storm sewers or an adjacent stream. Applications may be limited to projects with highly impervious surroundings and few opportunities for vegetative or structural BMPs. It is effective in removing all three of the representative pollutants in the BMP Manual: TSS, TP, and TN. Sweeping frequencies and cleaning routes should be chosen to optimize overall sweeping efficiencies. For example, sweeping should be assessed before any regional wet season to remove accumulated sediments. Certain conditions, such as streets with high traffic volumes and streets with high erosion zones, may also warrant increased sweeping frequencies. The maintenance manager in the District where the project is located should be consulted prior to submitting a permit where this BMP is proposed.

**4.** Impervious Disconnection. A number of potential stormwater impacts can be reduced or eliminated by installing BMPs in between impervious areas and storm sewers. Direct connection is primarily an issue with curbed roadways, where runoff is forced into catch basins, which are part of the storm sewer collection system. This common type of design quickly and efficiently removes runoff from the roadway to prevent ponding hazards. The problem with this system is that it usually results in (1) a decreased time of concentration, (2) an increase the peak flow rate, (3) an increase in the total runoff volume, and (4) no removal of pollutants from the runoff. Two ways to achieve disconnection are to (1) eliminate curbs and gutters, and (2) redirect road and driveway runoff into grassed swales or other vegetated systems designed to receive stormwater. Where curb and gutter cannot be eliminated for safety, right-of-way, or other practical reasons, carefully designed curb cuts may be used to allow runoff to spill into an adjacent vegetated BMP.

**5.** Slope Roughening. Known as a time of concentration ($T_c$) practice, slope roughening increase the time it takes for runoff to flow across a site to the drainage point or a BMP. Slowing runoff velocity potentially reduces erosion and increases the potential for infiltration. This BMP can include slope terracing, surface roughening, contouring, benching, and other similar methods of creating stabilized irregularities in graded slopes. Instead of allowing runoff to sheet flow down an embankment, these surface features (1) reduce erosion potential by slowing down the flow, (2) create pockets of small depressions that capture and reduce the total volume of runoff, and (3) encourage infiltration on the slope. When applied to slopes at bridge sites, the turbulence that this BMP creates aids in oxygenating the runoff before it discharges into the stream. Surface roughening has traditionally been used as an E&S measure to reduce erosion potential and prepare a slope to receive vegetation. Slopes steeper than 2:1 should be benched or stepped.

**6.** Pavement Width Reduction. PennDOT has standard pavement widths for various road classifications. Whenever a proposed design uses shoulder or lane widths that are less than the design standards, it should be noted in the PCSM plan. This is a self-crediting BMP, meaning that by not using the additional pavement width, the total volume of runoff is proportionally reduced. It is a good idea to document the amount of additional runoff that was not generated by using a design exception in the PCSM plan.

**J. Structural BMP Descriptions.** This section includes brief descriptions and technical information summaries of each of the structural PCSM measures in the BMP toolboxes. Many of these BMPs can be used in series, commonly referred to as a "treatment train", or combined with other BMPs to improve the system's efficiency. The first three BMPs listed in this section are structural-restoration BMPs. These BMPs can be used to return disturbed areas to more natural, vegetated areas with high infiltration and/or evapotranspiration potential. The remaining BMPs in this section are engineered measures for reducing runoff; their descriptions in this section include a technical summary that can be used as a quick reference. This information may be useful in the planning stages of design, but the technical guidance that can be found in the BMP Manual and other similar publications listed under References in Section 13.7.L should be used to design the BMPs.

**1.** Riparian Buffer Restoration. Riparian buffers are areas adjacent to streams, ponds, etc., that protect those water resources from pollution, prevent bank erosion, provide wildlife food and cover, and shade the adjacent water, moderating temperatures for aquatic species. Buffers are transition areas between aquatic and upland environments. PennDOT projects that are adjacent to bodies of water with depleted riparian buffers may consider restoration as a structural BMP. Riparian buffers are complicated natural features that require a diverse group of expertise to effectively design restoration strategies. Restoration design should be coordinated with PA DEP early in project development.

**2.** Landscaping and Planting. Landscape restoration is the general term used for actively sustainable landscaping practices that are implemented outside riparian (or other specially protected) buffer areas. Landscape restoration includes the restoration of forest (i.e. reforestation) and/or meadow and the conversion of turf to meadow. In a truly sustainable site design process, this BMP should be considered only after the areas of development that require landscaping and/or revegetation are minimized. The remaining areas that do require landscaping and/or revegetation should be driven by the selection and use of vegetation (i.e., native species) that does not require significant chemical maintenance by fertilizers, herbicides, and pesticides.

**3.** Soil Amendments. Soil amendments, which include both soil conditioners and fertilizers, make the soil more suitable for the growth of plants and increase water retention capabilities. Compost amendments and soils for water quality enhancement are also used to enhance native or disturbed and compacted soils. These measures change the physical, chemical, and biological characteristics of the soil allowing it to more effectively reduce runoff volume and filter pollutants. Vegetated swales and grass filter strips can be treated with soil amendments to improve performance and increase their permeability. A variety of techniques are included as potential soil amendments including aerating; fertilizing; and adding compost, other organic matter, or lime to the soil.

**4.** Vegetated Swale. Vegetated swales are one of the most commonly used BMPs along roads because of their ability to fit within limited right-of-way space while providing both drainage and PCSM functions. Vegetated swales are broad, shallow, typically trapezoidal channels that receive runoff from adjacent impervious surfaces and are designed to slow it down, promote infiltration, and filter pollutants and sediments in the process of conveying the runoff. Vegetated swales can receive runoff from concentrated sources (e.g., pipe outfalls), as well as from lateral sheet flow along the length of the channel. They are well suited for use along roads, either as swales in a cut section of a shoulder or in the median receiving runoff from both sides of a divided highway. They can also be used for storm sewer outlet channels and top of cut ditches.

## FIGURE 13.2
## VEGETATED SWALE SUMMARY

| | | | |
|---|---|---|---|
| Location | Median<br>Swale in cut section | Top of slope ditch |  |
| Effectiveness | Water quality<br>Volume<br>Peak discharge | High<br>Medium<br>Medium | |
| Key Design Elements | • DA ≤ 2 ha (5 acres)<br>• Min. 600 mm (24 in) between bottom and bedrock/seasonal high GWT<br>• Longitudinal slopes from 1%-6%<br>• Use 150-300 mm (6-12 in) high check dams to increase retention<br>• Side slopes from 3:1 to 5:1<br>• Bottom width 0.6-2.4 m (2-8 ft) | | Vegetated swale along roadside |

The simplest form of a vegetated swale consists of a band of dense vegetation that can include a variety of trees, shrubs, and/or grasses. Under the vegetated surface layer is approximately 600 mm (24 in) of permeable soil (minimum 13 mm/hr (0.5 in/hr) infiltration rate) containing a high level of organic matter. An acceptable variation is known as a dry swale, which is essentially a vegetated swale with an infiltration trench. Check dams can also be used to reduce velocities in channels that have a longitudinal slope greater than 3 percent. Check dams used in swales parallel to the roadway must be designed such that the maximum ponding elevation in the swale does not exceed the adjacent subgrade elevation. Turf reinforcement mats can be used to provide enhanced stabilization within the channel to prevent erosion. Salt-tolerant vegetation, such as creeping bentgrass and switchgrass, should be considered in areas with regular deicing of roads in the winter.

Examples of retrofitting existing swales (Level 2 toolbox) include: replacing or modifying poorly draining soils in the swale; adding an organic layer (i.e., compost) to encourage bioretention; replanting with species that offer greater evapotranspiration opportunities; and retrofitting ditches with check dams to provide storage in the channel. A rock-lined ditch that discharges directly into a surface water may be a good candidate for retrofitting with a turf reinforcement mat and vegetation. If it is not practicable to construct swales on both sides of the road, the capacity of the swale can be increased to capture more runoff on one side of the road while releasing all of the runoff from the other side.

**5.** Bioretention. Bioretention is a method of treating stormwater by pooling water on the surface and allowing filtering and settling of suspended solids and sediment at the mulch layer, prior to entering the plant/soil/microbe complex media for infiltration and pollutant removal. Bioretention cells, also called raingardens, cause retention of runoff through exfiltration into the subsoil (if subsoil has adequate permeability), subsurface storage below the underdrain (if present), and evapotranspiration by vegetation. Detention storage is provided through a combination of surface ponding with control structures and subsurface storage in soil and gravel layers above the underdrain. Common areas of application for highway projects include medians, areas adjacent to local/urban roads and intersections, and parking or median islands. Several examples of road and parking application are shown in the BMP Manual.

## FIGURE 13.3
## BIORETENTION SUMMARY

<table>
<tr><td>Location</td><td>Median<br>Swale in cut section</td><td>Top of slope ditch</td><td rowspan="3"></td></tr>
<tr><td>Effectiveness</td><td>Water quality<br>Volume<br>Peak discharge</td><td>High<br>Medium<br>Medium</td></tr>
<tr><td rowspan="2">Key Design Elements</td><td colspan="2" rowspan="2">• DA ≤ 0.2 ha (0.5 acres)<br>• Min. 600 mm (24 in) between bottom and bedrock/seasonal high GWT<br>• Native, perennial vegetation<br>• Provide overflow system</td></tr>
<tr><td>Bioretention along roadside</td></tr>
</table>

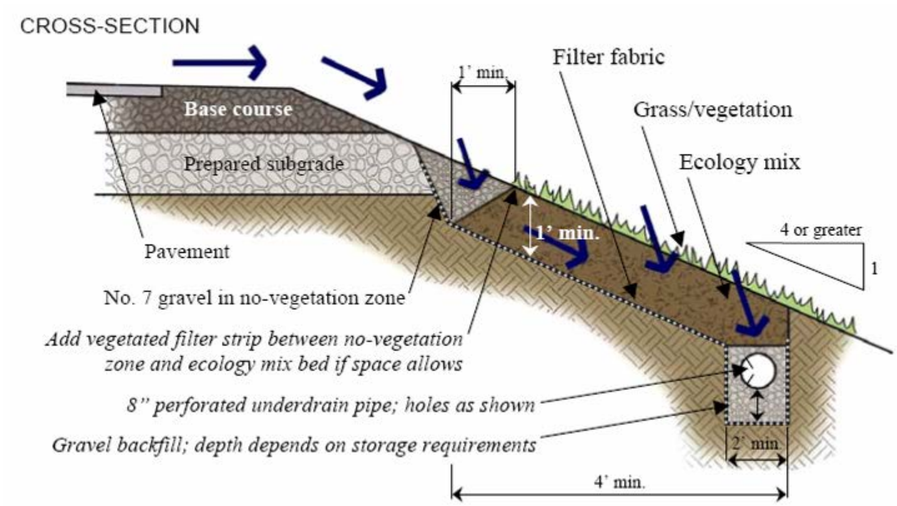
**6.** Vegetated Filter Strip. Vegetated filter strips are a common and often overlooked BMP. They are gently sloping, densely vegetated areas that filter, slow, and infiltrate sheet flowing stormwater. They are essentially buffers between runoff from impervious areas and a receiving body of water. Filter strips can be best utilized along roads and next to parking areas where runoff flows off the pavement via sheet flow and into a filter strip. This scenario is possible for roads at grade or in a fill condition; it does not work for a section in cut. The effectiveness of filter strips can be improved by adding a pervious berm at the toe of the slope. Check dams can also be implemented on filter strip slopes exceeding 5 percent. Level spreaders can be used to spread flow over a larger area so as to not create a point-source discharge.

## FIGURE 13.4
## VEGETATED FILTER STRIP SUMMARY

| | | |
|---|---|---|
| Location | Adjacent to road/shoulder or parking lot |  |
| Effectiveness | Water quality: High<br>Volume: Low/Medium<br>Peak discharge: Low | |
| Key Design Elements | • Contrib. DA slope ≤ 5%<br>• Filter strip slope < 5% preferred; 8% max.<br>• Min. width should be ≥ width of DA<br>• Effectiveness is a function of slope, vegetative cover, and soil type<br>• Check dams can be used on slopes > 5% | Vegetated filter strip in median |

**7.** Bioslope. Bioslopes (also called "ecology embankments") are embankments that treat runoff by rapid filtering through an engineered soil media commonly known as an ecology mix. Bioslopes use a variety of physical, chemical, and biological processes to improve water quality. Bioslopes are similar to vegetated filter strips, but instead of filtering runoff via sheet flow through thatch and surface soils, runoff is rapidly infiltrated into a gravel trench and then filtered via subsurface flow through the ecology mix. A bioslope is usually indistinguishable from ordinary embankments, and its footprint is usually contained within the embankment.

## FIGURE 13.5
## BIOSLOPE SCHEMATIC




Bioslopes cause retention of runoff through exfiltration into the subsoil (if subsoil has adequate permeability), storage in the gravel trench below the underdrain (if present), and evapotranspiration by vegetation. Credit for volume reduction should not be taken for any portions of the bioslope footprint that are above compacted soils. Bioslopes have minimal detention storage because they do not allow ponding and because the ecology mix drains rapidly. However, peak discharges are still reduced because of movement across the vegetated surface, percolation through the ecology mix, and infiltration into the subsoil (if subsoil has adequate permeability).

## FIGURE 13.6
## BIOSLOPE SUMMARY

| | |
|---|---|
| Location | Median embankment<br>Side slope |
| Effectiveness | Water quality High<br>Volume Medium<br>Peak discharge Medium |
| Key Design Elements | • Side slope 4:1 to 7:1 preferred; 3:1 max.<br>• Max. 4% longitudinal gradient<br>• Max. slope length is 9 m (30 ft)<br>• Plant with a native grass mix |

Bioslope application on embankment

**8.** Infiltration Trench. An infiltration trench is an excavated trench lined with filter fabric and backfilled with stone. These systems encourage stormwater infiltration into subsurface soils and work well in space-limited applications. Stormwater can enter a trench via sheet flow from open-section roadways or by channelized flow from swales or storm drain outlets. When located adjacent to roadways, the subsurface drainage direction should be to the downhill side (away from pavement subbase), or located lower than the impervious subbase layer. Proper measures should be taken to prevent water infiltrating into the pavement subbase. Infiltration trenches may be used in conjunction with vegetated swales, roadway drainage systems, or both (i.e., a swale over a pipe running between inlets). A common application is to place a flat run of continuously perforated storm sewer in an infiltration trench. The design storm is conveyed through the system the same way it would through a normal storm sewer; however, smaller rain events have time to drain through the perforations and into the gravel bed. Pretreatment of runoff prior to discharging into the infiltration trench is recommended in order to increase the life and effectiveness of the facility. Sediment traps in the storm sewer inlets (inlet invert is 150-300 mm (6-12 in) below pipe invert) and vegetated filters are examples of pretreatment.

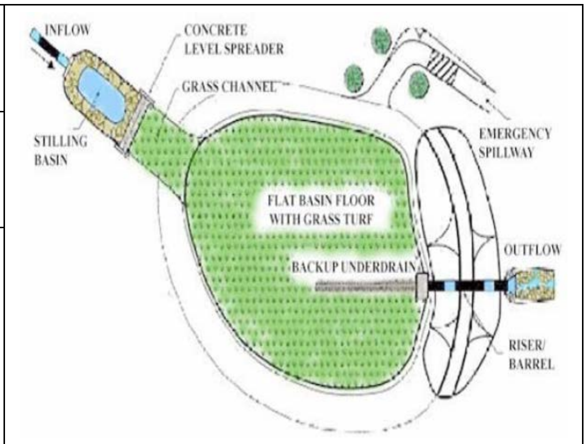
## FIGURE 13.7
## INFILTRATION TRENCH SUMMARY

| | |
|---|---|
| Location | Median<br>Shoulder swales<br>Between curb and sidewalk |
| Effectiveness | Water quality Medium<br>Volume Medium<br>Peak discharge Medium |
| Key Design Elements | • DA ≤ 2 ha (5 ac).<br>• Min. 600 mm (24 in) between bottom and bedrock/seasonal high GWT<br>• Min. 1.5 m (5 ft) from edge of road<br>• Include underdrain if infiltration rate is < 25 mm/h (1 in/h)<br>• Trench invert Elev. < than road subgrade Elev. |

Curb opening (impervious disconnection) into an infiltration trench

**9.** Infiltration Basin. Infiltration basins are shallow, impounded areas designed to temporarily store and infiltrate stormwater runoff. Sizes and shapes can vary from a single large basin to multiple, smaller basins throughout a project site. Infiltration basins reduce the volume of stormwater runoff by infiltration and evapotranspiration. Poor soils may be amended by adding sand or gravel to the surface layer to increase the permeability.

## FIGURE 13.8
## INFILTRATION BASIN SUMMARY

<table>
<tr><td>Location</td><td>Median<br>Interchange areas<br>Rest stop/park-and-ride lot</td><td rowspan="3">
</td></tr>
<tr><td>Effectiveness</td><td>Water quality — Medium<br>Volume — Low<br>Peak discharge — Medium/High</td></tr>
<tr><td rowspan="2">Key Design Elements</td><td rowspan="2">• Uncompacted subgrade<br>• Retain increase in 2-yr storm runoff volume<br>• Min. 600 mm (24 in) between bottom and bedrock/seasonal high GWT<br>• 5:1 max.impervious-to-infiltration area</td></tr>
<tr><td>Conceptual Infiltration Basin</td></tr>
</table>

Traditional stormwater management basins can be combined with infiltration basin concepts to provide peak flow detention for larger storms and the required volume control. The combined detention/infiltration basin can be utilized at the discharge points of drainage systems or placed in large median areas where positive basin outflow is provided and subbase drainage is not impeded. During the winter months, there will be many occasions when the soil beneath an infiltration basin is frozen and long-duration ponding will occur; therefore, infiltration basins must be placed in areas where this does not create a safety hazard. When runoff containing salt-based deicers is directed to an infiltration basin, soil may become less fertile and less capable of supporting vegetation. Using salt-tolerant plants and incorporating mulch into the soil can help to mitigate this problem. Infiltration basins should not be used to store snow from highways or parking lots because the sand in the snow can clog the basin, and the chlorides and other pollutants can contaminate the groundwater.

**10.** Infiltration Berm. An infiltration berm is a mound of compacted earth with sloping sides that is usually located along (i.e., parallel to) a contour in a moderately sloping area. Berms create shallow depressions that collect and temporarily store stormwater runoff, allowing it to infiltrate into the ground and recharge groundwater. Berms are ideal in areas where runoff is free to discharge over slopes. The berm can be installed parallel to the road and intercept runoff prior to being discharged into adjacent areas or bodies of water. Berms can be constructed on disturbed slopes and revegetated as part of the construction process. Infiltration berms may also be constructed in combination with a subsurface infiltration trench at the base of the berm to increase the retention capacity.

## FIGURE 13.9
## INFILTRATION BERM SUMMARY

| | | |
|---|---|---|
| Location | Side slope |  |
| Effectiveness | Water quality — Medium/High<br>Volume — Low/Medium<br>Peak discharge — Medium | |
| Key Design Elements | • Constructed parallel to contours<br>• Min. 600 mm (24 in) between bottom and bedrock/seasonal high GWT<br>• 600 mm (24 in) max. height<br>• Side slope 4:1 max.<br>• Can be retrofitted on slopes w/o causing significant disturbance | Infiltration berm |

**11.** Wet Ponds. Wet ponds, also known as retention basins, are stormwater basins that include a substantial permanent pool for water quality treatment and additional capacity above the permanent pool for temporary runoff storage. Wet ponds are effective for pollutant removal and peak rate mitigation, but do not achieve significant groundwater recharge and volume reduction. Unlike infiltration basins, the permanent pool is a key feature and infiltration is discouraged. Wet ponds should have low permeability soils at the bottom and, where possible, be excavated close to or below the groundwater table. Interchanges are usually ideal for wet ponds because the basin is surrounded by pavement and receives runoff from all directions. Trees and other types of vegetation should be planted around the perimeter to keep the water in the pond cool and reduce potential thermal impacts. In populated areas, wet ponds may not be desired because of potential mosquito issues. Wet ponds are generally not the preferred BMP when the facility discharges directly into temperature-sensitive water (such as those with temperature TMDLs). Extended detention facilities should (1) be designed with a minimal permanent pool; (2) preserve existing shade trees and plant fast growing trees along the shoreline, but not on the constructed embankment; (3) align ponds in a north-south direction; and (4) avoid excessive riprap and concrete channels that impart heat to runoff.

## FIGURE 13.10
## WET POND SUMMARY

| | | |
|---|---|---|
| Location | Median<br>Interchange areas<br>Rest stop/park-and-ride lot |  |
| Effectiveness | Water quality — Medium<br>Volume — Low<br>Peak discharge — High | |
| Key Design Elements | • 2-4 ha (5-10 acres) min. DA needed<br>• Need a natural high GWT<br>• Average depth 0.9-1.8 m (3-6 ft); 2.4 m (8 ft) max.<br>• Relatively impermeable soils or engineered liner<br>• Sediment forebay at inlet<br>• Vegetation type and location is critical | Wet pond with sediment forebay |

**12.** Constructed Wetlands. Constructed wetlands (CWs) are shallow marsh systems planted with emergent vegetation that are designed to treat stormwater runoff. They can provide considerable aesthetic and wildlife benefits, but require a relatively large amount of space and an adequate source of inflow to maintain the permanent water surface. CWs improve runoff quality through settling, filtration, uptake, chemical and biological decomposition, volatilization, and adsorption. They are effective at removing many common stormwater pollutants including suspended solids, heavy metals, total phosphorus, total nitrogen, toxic organics, and petroleum products. Peak rate is primarily controlled through the transient storage above the normal water surface. Although not typically considered a volume-reducing BMP, CWs can achieve some volume reduction through evapotranspiration, especially during small storms. CWs are a good option for retrofitting existing detention basins.

## FIGURE 13.11
## CONSTRUCTED WETLAND SUMMARY

<table>
<tr><td>Location</td><td>Median<br>Interchange areas<br>Rest stop/park-and-ride lot</td><td rowspan="3"><br>Constructed wetland next to highway</td></tr>
<tr><td>Effectiveness</td><td>Water quality High<br>Volume Low<br>Peak discharge High</td></tr>
<tr><td>Key Design Elements</td><td>• 2-4 ha (5-10 acres) min. DA needed or sustained base flow<br>• 2:1 length to width ratio<br>• Relatively impermeable soils or engineered liner<br>• Sediment forebay at inlet<br>• Can be combined with wet pond design</td></tr>
</table>

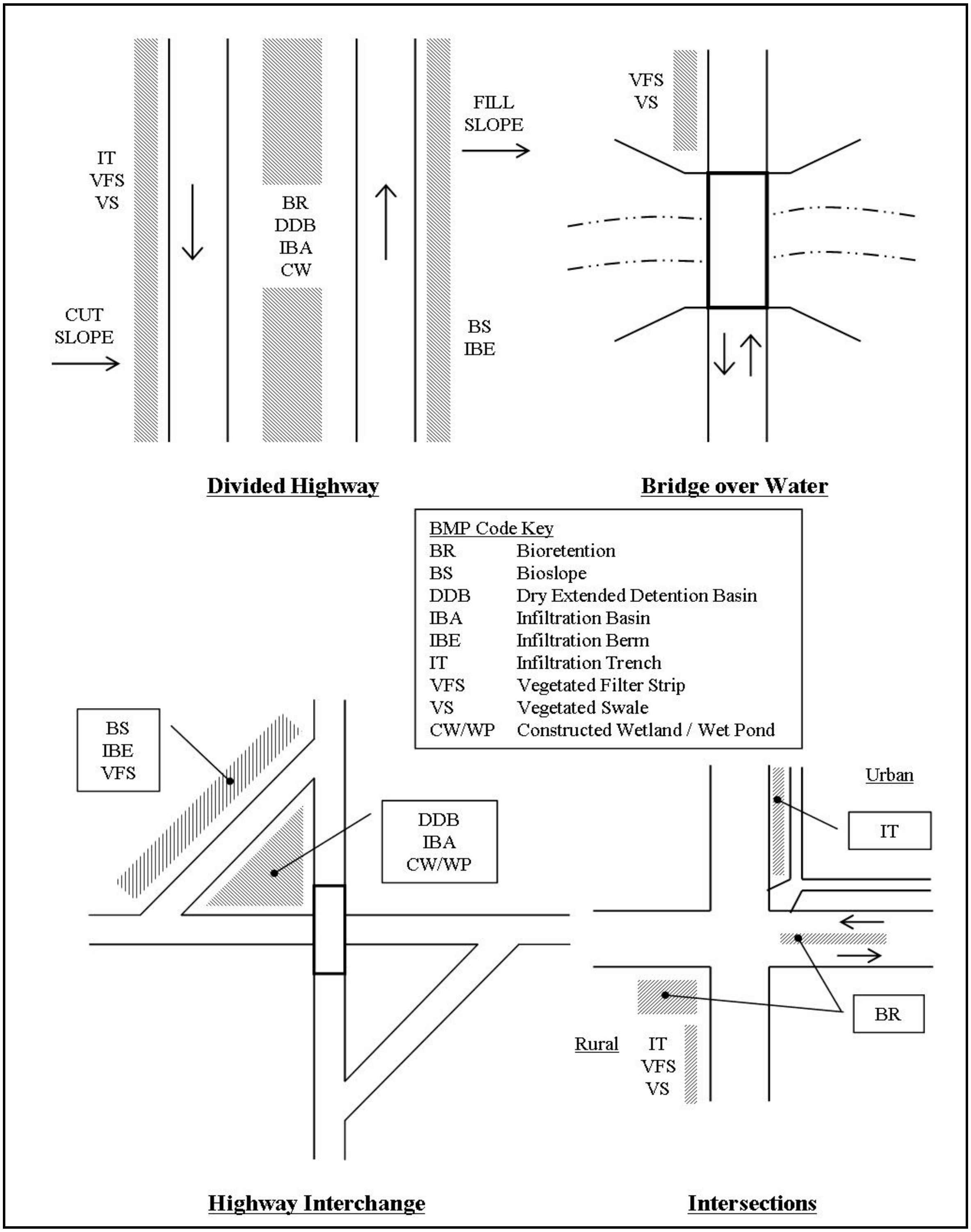
**13.** Permeable Pavement. Permeable pavement consists of a pervious surface course underlain by a uniformly graded stone bed that provides temporary storage for peak rate control and promotes infiltration. In northern climates, pervious pavements have less of a tendency to form black ice and often require less plowing. The surface course may consist of porous asphalt, porous concrete, or various porous structural pavers laid on uncompacted soil. Permeable pavements are best suited for areas that will not be subject to high traffic volumes or high rates of travel speed. Paver blocks are not suitable for high rate travel speeds because of the block design, and the open graded asphalt and concrete in permeable pavements does not wear well in travel lanes. Proper construction is critical for permeable pavement to function properly and, therefore, must be undertaken in such a way as to prevent (1) compaction of underlying soil, (2) contamination of stone subbase with sediment and fines, (3) tracking of sediment onto pavement, and (4) drainage of sediment-laden waters onto pervious surface or into constructed bed. Permeable pavement can provide significant stormwater benefits as long as the pavement surface is kept free of debris and sediment. Maintenance involves removing sediments from the pavement by means of a vacuum truck. Sweeping may actually exacerbate the problem by working sediment down into the porous surface.

## FIGURE 13.12
## PERMEABLE PAVEMENT SUMMARY

| | | | |
|---|---|---|---|
| Location | Park-and-rides<br>Parking lots<br>Pull offs | Walking paths<br>Sidewalks |  |
| Effectiveness | Water quality<br>Volume<br>Peak discharge | Medium<br>Medium/High<br>Medium/High | |
| Key Design Elements | • 300-900 mm (12-36 in) typical infiltration bed depth<br>• Uncompacted subgrade<br>• Frequent maintenance required to prevent pavement surface clogging<br>• Backup drainage system needed | | Porous pavement parking lot |

Figure 13.13 depicts four typical types of PennDOT projects and the structural BMPs that would most often be applicable for each type of project. This figure does not preclude the use of a BMP in any of these areas if adequate design documentation is provided.

**FIGURE 13.13**
**COMMON STRUCTURAL BMP APPLICATIONS**



**K. Frequently Asked Questions.**

**1.** ***What is the difference between stormwater management that may discharge to Special Protection waters, or EV wetlands, and all other waters?*** In Special Protection watersheds, or EV wetlands, there can be no measurable change in the rate or volume of runoff from site. For all other waters, there can be no loss in the existing or designated use from a change in the post-construction runoff. The process of analyzing and using non-discharge alternatives, and antidegradation best available control technologies (ABACT), must be documented in HQ and EV watersheds, or EV wetlands. The PA DEP NPDES construction permit includes an Antidegradation Analysis Module so that the applicant can provide information that demonstrates non-degrading discharges.

**2.** ***Are wetlands and streams treated the same in terms of PCSM requirements?*** For the most part, yes, since they are both considered surface waters. However, a project can also indirectly impact a wetland without even discharging stormwater to it by cutting off the wetland's hydrologic input. The source of hydrology for adjacent, downstream wetlands should be evaluated to ensure that the project does not have adverse impacts. In addition, wetlands can be classified as EV. For example, if a wetland is critical habitat for a threatened or endangered species, that wetland is considered an EV wetland.

**3.** ***Do all 3R projects require an NPDES construction permit?*** Not all projects exceed one acre of disturbance with a point-source discharge to surface waters, which is the threshold for requiring an NPDES construction permit. In fact, most maintenance projects only disturb a small area outside of the existing roadway footprint and, therefore, do not require a permit. A permit is not required for any project that does not result in a construction activity consisting of 0.4-2.0 ha (1-5 ac) of earth disturbance with a point source discharge to surface waters, or for a construction activity that consists of 2.0 ha (5 ac) or more of earth disturbance.

**4.** ***A project has between one and five acres of disturbance, but all of the runoff leaves the site via sheet flow. Does the project require an NPDES construction permit?*** No, only when there is a point-source (end of pipe, channel, etc.) discharge with between one and five acres of disturbance is a permit required. However, an E&S plan must be developed and submitted to the applicable county conservation district.

**5.** ***Is a PCSM analysis required when the project does not require an NPDES construction permit and it is not located in an approved Act 167 plan watershed?*** No, there is no law, per se, that requires PCSM in the absence of an NPDES permit and Act 167 plan. However, PennDOT's MS4 permit outlines BMPs to be used for maintenance facilities and practices. Even if a PCSM plan is not required, the low-impact design concepts and non-structural BMPs described in this policy should be evaluated on a project-by-project basis.

**6.** ***Is it acceptable to leave parts of the NPDES permit application blank, or can questions be addressed by simply writing "not applicable?"*** No. Any application for NPDES Permits for Stormwater Discharges Associated with Construction Activities, regardless of the type of project or applicant, requires that all sections and parts of the application be completed.

**7.** ***Chapter 8 of PA DEP's Stormwater BMP Manual provides for water quality calculations – when do these calculations have to be completed for PennDOT projects?*** PCSM plans for Level 3 and 4 projects require a water quality analysis, even if the targets for rate and volume have been met. Infiltration generally satisfies PA DEP's reduction requirements for two of the three representative pollutants: total suspended solids (TSS) and total phosphorus (TP). However, infiltration does not necessarily remove solute from runoff before it enters groundwater flow. PA DEP uses a representative solute, nitrate, as an indicator for solute removal. The designer must use Flow Chart D and the associated worksheets in Chapter 8 of the BMP Manual to document consistency with the pollutant removal guidelines. Since Level 1 and 2 projects should have minimal increases in rate and runoff, and no change in the types or sources of pollutants; therefore, these calculations are not required for Level 1 and 2 projects. Worksheet 10 from Chapter 8 of the PA DEP BMP Manual should be completed for Level 3 and 4 projects.

**8.** ***What information should the PCSM section of an NPDES permit application submission contain?*** The PCSM plan should contain all of the information listed in the NPDES permit application checklist (note that General and Individual permits have different checklists), which is attached to the permit application form. Worksheets 1-5, which are attached to the application package, must be completed for all NPDES permit applications, regardless of the PCSM Level. Worksheet 7 from Chapter 8 of the PA DEP BMP Manual must be completed for Level 2 projects, and Worksheet 10 must be completed for all Level 3 and Level 4 projects. Also note that the seal of a qualified licensed professional (Engineer, Land Surveyor, Professional Geologist or Landscape Architect) is required on PCSM plans for engineered structural BMP calculations and specifications.

**9.** ***The Summary Data Table in the NPDES permit application requires calculations demonstrating the net change in peak discharge rate and volume of runoff. Is it necessary to complete this table for all projects that require an NPDES permit, and what design event should be indicated in the table?*** Yes, the table must be completed for every NPDES permit, and the data in the table must be clearly explained so that the reviewer can recognize how the data was derived and that data demonstrates that rate and volume of stormwater runoff are mitigated. For Level 1 and Level 2 projects, the Summary Data Table should be completed using the targets defined in Section 14.2, which are similar to CG-2, and the appropriate backup calculations should be provided.

Level 3 and Level 4 projects must demonstrate peak rate control for up to the 100-year event, and volume mitigation for the 2-year event using the targets defined in Section 14.2, which are similar to CG-1. The Summary Data Table should be completed for the 2-year storm event, and peak rate control calculations should be provided based on the Act 167 Plan, or for the 2, 10, 25, 50 and the 100-year storm events when an Act 167 Plan has not been approved by the Department.

**10.** ***Do peak discharge rates and runoff volumes have to be mitigated at each source of disturbance and before runoff goes beyond PennDOT's right-of-way?*** No. Peak rate control must be demonstrated at each point at which discharge from the project reaches the receiving surface water. Areas in between the point where discharge leaves PennDOT's right-of-way and the receiving surface water must be analyzed for erosion potential and flooding impacts. Volume control must be demonstrated within the respective watershed, and analogous when comparing the pre and post drainage areas.

**11.** ***What information should be contained in the thermal impact analysis section of the NPDES permit?*** Although documentation must be provided with every PCSM plan, thermal impacts are primarily an issue when a project significantly increases impervious area and the resulting runoff is directly connected (i.e., ditch, storm sewer, etc.) to a cold water, headwater stream, or when the activity results in the removal of vegetation within the floodway/stream corridor. The strategies developed by PA DEP and PennDOT in Section 14.1.C are examples of BMPs that can help reduce thermal impacts. The general idea is to break any direct connection between the impervious area and the surface water, and reduce impervious areas, where practicable. In most cases, a narrative discussing the BMPs located between the impervious surface and surface water will be sufficient.

**L. References and Additional Guidance.** A number of publications are available that provide design, cost, and maintenance information on BMPs for PCSM. The publications listed below were referenced to develop this policy and are good resources for information.

**1.** Atlanta Regional Commission (2001). *Georgia Stormwater Management Manual.*

**2.** Dane County Conservation District. *Predicting the Impact of Urban Development on Stream Temperature Using a Thermal Urban Runoff Model (TURM).* Dane County Conservation District, Wisconsin.
Donaldson, B.M. (2004). *Highway Runoff in Areas of Karst Topography.* Virginia Transportation Research Council, Charlottesville, Virginia.

**3.** Fennessey, Lawrence, A.J., Ph.D., P.E. (2003). "Defining Natural Land Areas Critical for Stormwater Control in Karst Regions." *Proceedings of the 2003 Pennsylvania Stormwater Management Symposium.*

**4.** FHWA (2003). *Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring.* Federal Highway Administration, U.S. Department of Transportation.

**5.** LID Center (2006). *Low Impact Development Design Manual for Highway Runoff Control.* Transportation Research Board, Washington, DC.

**6.** New Jersey Department of Environmental Protection (2004). *New Jersey Stormwater Best Management Practices Manual.* New Jersey Department of Environmental Protection, Trenton, NJ.

**7.** PennDOT (2010). *PennDOT Drainage Manual*. Publication 584, Pennsylvania Department of Transportation, Bureau of Project Delivery.

**8.** PA DEP (2006). *Pennsylvania Stormwater Best Management Practices Manual*. Pennsylvania Department of Environmental Protection, Bureau of Watershed Management.

**9.** Transportation Research Board (2006). *Evaluation of Best Management Practices for Highway Runoff Control.* NCHRP Report 565, Transportation Research Board, Washington, DC.

**10.** Virginia DCR (1999). *Virginia Stormwater Management Handbook.* Volumes 1 and 2, First Edition, Division of Soil and Water Conservation, Virginia Department of Conservation and Recreation.

**11.** Washington State DOT (2006). *Highway Runoff Manual.* Washington State Department of Transportation.

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# CHAPTER 14

## COST ESTIMATING

### 14.0 INTRODUCTION

Cost Estimates that are to be provided by design agencies as part of the Preliminary Engineering Report are to be set up in accordance with the following format. The cost estimate for final design shall be the standard Form 407.

The procedures used in the preparation of the cost estimate are as follows:

**1.** Individual estimates are to be provided for each anticipated construction section. These shall also be combined into a total estimate.

**2.** Unit prices and an explanation of their basis are to be included as a separate item in the report.

**3.** All back-up data used to develop unit prices and Form D-405, Work Sheet for Cost Estimate, are to be supplied to the District, but not as a part of the Study Report.

**4.** It is expected that the estimate be developed from the best available information such as models using computerized historical bid data. For example, a cost per kilometer for guide rail may be used in a Preliminary Engineering Report while a specific breakdown of items shall appear in the Form 407.

**5.** The cost estimate format is a guide and it may have to be modified for special cases.

**6.** The cost estimate should be based on the anticipated letting date of the project.

Related material can be located in Publication 352, *Estimating Manual*.

**COST ESTIMATE**

**__________ County Sta __________ To Sta __________**
**SR __________ Section __________ Length ________________**

**Project Description: ________________________________________**

**____________________________________________________**

**____________________________________________________**

| | | | |
|---|---|---|---|
| 1. | Pavement, Base and Shoulder | | ________________ |
| 2. | Grading and Drainage | | |
| | (a) | Grading | ________________ |
| | (b) | Drainage and Minor Structures | ________________ |
| 3. | Grade Separation Structures | | |
| | (a) | Location | ________________ |
| | (b) | | ________________ |
| | (c) | | ________________ |
| 4. | Interchanges | | |
| | (a) | Location | ________________ |
| | (b) | | ________________ |
| | (c) | | ________________ |
| 5. | Other Bridges and Tunnels | | |
| | (a) | Location | ________________ |
| | (b) | | ________________ |
| | (c) | | ________________ |
| 6. | Retaining Walls | | ________________ |
| 7. | Highway Hardware (Guide Rail, Median Barrier, Right-of-Way Fence, Signing, Lighting, etc.) | | ________________ |
| 8. | Frontage Roads and Service Roads | | |
| | (a) | Location | ________________ |
| | (b) | | ________________ |
| | (c) | | ________________ |
| 9. | Environmental Considerations | | |
| | (a) | Erosion Control | ________________ |
| | (b) | Landscaping | ________________ |
| | (c) | Safety Rest Areas | ________________ |
| | (d) | Protection of 4(f) Lands | ________________ |
| | (e) | Etc. | ________________ |
| 10. | Mobilization | | ________________ |
| 11. | Maintenance and Protection of Traffic | | ________________ |
| **SUBTOTAL** | | | |
| 12. | Contingencies (Normally 10% of Lines 1 to 10) | | ________________ |
| **SUBTOTAL** (Total Construction Cost) | | | |
| 13. | Right-of-Way (Acquisition, Relocation and Demolition) | | ________________ |
| 14. | Utilities | | ________________ |
| 15. | Engineering | | ________________ |
| **TOTAL PROJECT COST** | | | ________________ |

D-405

**WORK SHEET FOR COST ESTIMATE**

COMPILED BY: ______________________

DATE: ______________________

| COUNTY | S.R. & SEC. | F.A.I. RTE. | STATION | TO STATION | LENGTH |
|---|---|---|---|---|---|
| | | | | | |

**PROJECT DESCRIPTION:**

| ITEM | UNIT | QUANTITY | UNIT COST | SUB-TOTAL | TOTAL $1,000 |
|---|---|---|---|---|---|
| 1. BASE: SURFACING: SHOULDERS | | | | | |
| A. ______________ PAVEMENT | | | | | |
| B. SUB-BASE | | | | | |
| C. PAVED SHOULDERS | | | | | |
| D. SHOULDERS | | | | | |
| E. SUBGRADE | | | | | |
| F. MEDIAN PAVEMENT | | | | | |
| G. SIDEWALK | | | | | |
| H. | | | | | |
| | | | | TOTAL | |
| 2. A GRADING | | | | | |
| (1) EXCAVATION | | | | | |
| (2) BORROW | | | | | |
| (3) CLEARING & GRUBBING | | | | | |
| B DRAINAGE & MINOR STRUCTURES | | | | | |
| | | | | | |
| | | | | TOTAL | |
| 3 GRADE SEPARATIONS (WITHOUT RAMPS) | | | | | |
| TYPE ____________________ | | | | | |
| A. STRUCTURE | | | | | |
| B. CROSSROAD ADJUSTMENTS (INCLUDES ALL COSTS INCIDENT TO CHANGES IN CROSSROADS) | | | | | |
| C. | | | | | |
| | | | | TOTAL | |
| 4 INTERCHANGE: COMPLETE* (* DO NOT INCLUDE ANY MAIN LINE QUANTITIES) | | | | | |
| A. PAVEMENT | | | | | |
| B. SUB-BASE | | | | | |
| C. SHOULDERS | | | | | |
| D. EXCAVATION | | | | | |
| E. BORROW | | | | | |
| F. STRUCTURES | | | | | |
| G. DRAINAGE | | | | | |
| H. SLOPE TREATMENT | | | | | |
| I. ROADSIDE IMPROVEMENT | | | | | |
| J. CROSSROAD ADJUSTMENT | | | | | |
| K. GUARD RAIL | | | | | |
| L. MEDIAN BARRIER | | | | | |
| M. R/W FENCE | | | | | |
| N. CURBS | | | | | |
| O. SUBGRADE | | | | | |
| P. LIGHTING | | | | | |
| Q. SIGNING | | | | | |
| R. TRAFFIC CONTROL DEVICES | | | | | |
| S. | | | | | |
| | | | | TOTAL | |
| 5 OTHER BRIDGES: TUNNELS | | | | | |
| TYPE ____________________ | | | | | |
| A. | | | | | |
| B. | | | | | |
| C. | | | | | |
| D. | | | | | |
| | | | | TOTAL | |
| 6 WALLS | | | | | |
| A. | | | | | |
| B. | | | | | |
| C. | | | | | |
| | | | | TOTAL | |
| 7 HIGHWAY HARDWARE (MAIN LINE ONLY) | | | | | |
| A. GUARDRAIL: COMPLETE | | | | | |
| B. LIGHTING | | | | | |
| C. SIGNS | | | | | |
| D. R/W FENCE (TYPE ______________________) | | | | | |
| E. TRAFFIC CONTROL DEVICES | | | | | |
| F. MEDIAN BARRIER | | | | | |
| | | | | TOTAL | |
| 8 FRONTAGE ROADS & SERVICE ROADS | | | | | |
| A. | | | | | |
| B. | | | | | |
| C. | | | | | |
| | | | | TOTAL | |
| 9 ENVIRONMENTAL CONSIDERATIONS | | | | | |
| A. EROSION CONTROL | | | | | |
| B. LANDSCAPING | | | | | |
| C. REST AREAS | | | | | |
| D. SCENIC OVERLOOKS | | | | | |
| E. TEMPORARY WATER POLLUTION CONTROL | | | | | |
| F. | | | | | |
| | | | | TOTAL | |
| 10 MOBILIZATION | | | | TOTAL | |
| 11 MAINTENANCE & PROTECTION OF TRAFFIC | | | | TOTAL | |
| SUB-TOTAL, ITEMS 1 TO 11 INCLUSIVE | | | | | |
| 12 CONTINGENCIES (10% OF ITEM 1 TO 11) | | | | TOTAL | |
| SUB-TOTAL (TOTAL CONSTRUCTION COSTS) | | | | | |
| 13 RIGHT OF WAY | | | | | |
| A. LAND ACQUISITION | | | | | |
| B. RELOCATION PAYMENTS | | | | | |
| C. DEMOLITION | | | | | |
| | | | | TOTAL | |
| 14 UTILITY ADJUSTMENTS | | | | | |
| 15 ENGINEERING | | | | | |
| TOTAL ESTIMATED COST | | | | | |

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# CHAPTER 15

## GUIDELINES FOR DESIGN OF LOCAL ROADS AND STREETS

### 15.0 INTRODUCTION

The policy of the Department regarding the formulation of highway design criteria and procedures relative to the design of local roads and streets shall conform to Publication 70M, *Guidelines for Design of Local Roads and Streets*.

Because of the relatively low traffic volumes and the extensive length, design standards for local roads and streets are of comparatively low order as a matter of practicality. However, to provide the requisite traffic mobility and safety together with the essential economy in construction, maintenance and operations, they shall be planned, located and designed to be suitable for predictable traffic operations and shall be consistent with the development and culture abutting the right-of-way.

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# CHAPTER 16

## BICYCLE FACILITIES

### 16.0 INTRODUCTION

With an increase in the use of bicycles for commuting, for recreation and for other travel purposes, a wide variety of bicycle-related projects and programs are being developed and implemented. Provisions of adequate facilities as part of the overall transportation system enhance and encourage safe bicycle travel. This Chapter presents the guidelines for the development and design of bikeways and the procedures for the processing of a bikeway construction project after the Planning, Programming and Budgeting phase through the Final Design phase. Also included are guidelines for the issuance of Bikeway Occupancy Permits for bikeways located within the Department's right-of-way.

The development and design of bikeways within the Department's right-of-way and/or utilizing State or Federal funds for construction should reflect the criteria presented in the Association of State Highway and Transportation Officials' (AASHTO) *Guide for the Development of Bicycle Facilities** and the Department's "Bicycle and Pedestrian Checklist" found in Publication 10X, Design Manual, Part 1X, *Appendices to Design Manuals 1, 1A, 1B, and 1C*, Appendix S. One important factor that should be considered in the design, especially when attempting to utilize existing roadways and streets, is the safety of bicyclists, pedestrians and motorists. Safety should not be compromised.

The following represent the definition of terms, frequently used throughout this Chapter, that are applicable to the planning, design and operation of bicycle facilities. Additional definitions of basic terms are presented in the AASHTO Bicycle Guide:

**1.** Bicycle Facilities. A general term denoting improvements and provisions made by public agencies to accommodate or encourage bicycling, including parking facilities, maps, all bikeways and shared roadways not specifically designated for bicycle use.

**2.** Bike Lane or Bicycle Lane. A portion of a roadway which has been designated by striping, signing and pavement markings for the preferential or exclusive use of bicyclists.

**3.** Bike Path or Bicycle Path. A bikeway physically separated from motorized vehicular traffic by an open space or barrier and either within the highway right-of-way or within an independent right-of-way.

**4.** Shared Roadway. Any roadway upon which a bicycle lane is not specifically designated but which may be legally used by bicycles. Signs only are installed along shared roadways.

**5.** Non-Motorized Vehicle. Any human-powered or horse-drawn apparatus under the jurisdiction of the PA Vehicle Code. The emphasis for this Chapter is on bicycles, which are regulated by the PA Vehicle Code as a vehicle, subject to the statutes contained therein.

### 16.1 PLANNING AND DEVELOPMENT OF BIKEWAY CONSTRUCTION PROJECTS

Bicycle transportation planning and development represents more than just planning for bikeways and should consider many alternatives to provide for safe and efficient bicycle travel. Planning for bicycle facilities should be conducted in conjunction with planning for other modes of transportation. It should begin with observing and gathering data on the existing conditions to provide an inventory of the physical factors that affect bicycle transportation. Also, existing laws that affect bicycling and education and enforcement programs should be examined. The inventory of existing conditions can be used to modify and/or refine bicycle-use goals and objectives and to develop a plan of proposed improvements for bicycle travel.

* Hereinafter referred to as the AASHTO Bicycle Guide.

To select the type, location and priority of a particular facility, the following factors should be considered:

**1.** Physical barriers to bicycle travel (widths, overhead obstructions, bridge restrictions).

**2.** Assessing the reduction, prevention or alleviation of bicycle accident problems.

**3.** Integrating bicycle facilities properly into a multi-modal transportation environment.

**4.** Providing frequent and convenient bicycle access and adequate access for emergency, maintenance and service vehicles.

**5.** Considering the context sensitive orientation of a bikeway facility.

**6.** Considering security along remote bicycle paths and the possibility of theft or vandalism at parking locations.

**7.** Reviewing any delays or frequent stops required by bicyclists along the bikeway facility since this may cause them to avoid the route or disregard traffic controls.

**8.** Evaluating and eliminating, if possible, any conflicts between bicyclists, motorists and pedestrians involving highway design.

**9.** Providing for a bikeway pavement surface quality that shall accommodate bicyclists, commensurate with the type of facility.

**10.** Truck and bus traffic, motorhomes and trailers that may cause special problems for bicyclists due to their aerodynamic effect and width.

**11.** On-street motor vehicle parking that affects bicycle safety through car door openings and angle parking spaces.

**12.** For bikeway facilities on roadways, traffic volumes, speeds of motor vehicles and the roadway width should be considered.

**13.** The decision to implement a bikeway plan should be made with a conscious, long-term commitment to a proper level of maintenance and any required improvements.

**14.** Bicycle facilities and programs that reflect local laws and ordinances to encourage bicyclists to operate in a manner consistent with Pennsylvania Title 75, PA Vehicle Code and the adopted "Pennsylvania Bicycle Driver's Manual".

**15.** Providing bridges that afford bicyclists safe access and movement across barriers.

**16.** Since a high proportion of bicycle accidents occur at intersections, select intersection facilities to minimize bicycle/motor vehicle conflict points.

For additional information relative to bicycle facility planning, refer to the AASHTO Bicycle Guide and the Department's "Bicycle and Pedestrian Checklist" found in Publication 10X, Design Manual, Part 1X, *Appendices to Design Manuals 1, 1A, 1B, and 1C*, Appendix S.

## 16.2 DESIGN OF BICYCLE FACILITIES

The controlling design feature for all bicycle facilities is the location; i.e., whether it is on the roadway or is on an independent alignment. Roadway improvements such as bike lanes are dependent on the roadway's design while bike paths are located on independent alignments and their design is dependent on many factors such as the performance capabilities of the bicyclist and the bicycle.

Most highways have not been designed with bicycle travel in mind; however, there are many methods to safely improve most roadways to accommodate bicycle traffic while also improving safety for motorized road users and pedestrians. Roadway conditions should be examined and, where necessary, safe drainage grates, railroad-highway grade crossing angles and crossing surface material, smooth pavement surfaces and traffic control devices responsive to bicycle traffic should be provided. In addition, the desirability of adding facilities such as bicycle lanes, bicycle routes, shoulder improvements and wide curb lanes should be considered. Raised pavement markings and raised barriers can cause steering difficulties for bicyclists and should not be used to delineate bike lanes.

Bicycle tolerable shoulder rumble strips should be considered for installation instead of shoulder rumble strips that can pose problems for bicyclists who utilize paved shoulders for travel. For additional guidance on these types of rumble strips, refer to the Publication 46, *Traffic Engineering Manual*.

Bike lanes should be considered when it is desirable to delineate available roadway space for preferential use by bicyclists and motorists and to provide for more predictable movements by each. Bike lanes should always be one-way facilities and carry traffic in the same direction as adjacent motor vehicle traffic. Two-way bike lanes on one side of the roadway are unacceptable because they promote riding against the flow of motor vehicle traffic and are in direct violation of the PA Vehicle Code. Figure 16.1 indicates three usual locations for a bike lane relative to the roadway.

Bike lanes tend to complicate both bicycle and motor vehicle turning movements at intersections. Since they encourage bicyclists to keep to the right and motorists to keep to the left, both operators are somewhat discouraged from merging in advance of turns. At intersections, bicyclists proceeding straight through and motorists turning right may cross paths. Striping and signing configurations which encourage these crossings in advance of the intersection, in a merging fashion, are generally preferable to those that force the crossing in the immediate vicinity of the intersection.

The AASHTO Bicycle Guide, Chapter 2, Figures 6 and 11 present examples of pavement marking details for bike lanes approaching motorists' right-turn-only lanes. Where there are numerous left-turning bicyclists, a separate turning lane, as indicated in Part 9 of the FHWA's Manual on Uniform Traffic Control Devices (MUTCD), should be considered. The design of bike lanes should also include appropriate signing at intersections to reduce the number of conflicts. General guidance for pavement marking of bike lanes is contained in the MUTCD.

Bike paths represent facilities located on exclusive rights-of-way and with minimal cross flow by motor vehicles. Bike paths should be thought of as extensions of the highway system that are intended for the exclusive or preferential use of bicycles. There are many similarities between design criteria for bike paths and for highways, such as determining horizontal alignment, sight distance requirements, signing and pavement markings. On the other hand, some criteria such as horizontal and vertical clearance requirements, grades and pavement structure are dictated by the operating characteristics of bicycles which are substantially different from those of motor vehicles. The designer should always be aware of the similarities and the differences between bicycles and motor vehicles and of how these similarities and differences influence the design of bike paths. The AASHTO Bicycle Guide, Chapter 2, Figure 17 indicates a typical bike path cross section on a separated right-of-way.

The following represent general design elements, design controls and other elements which should be considered to provide an adequate and safe bike path facility:

**1.** Paved width, operating width and vertical clearance to obstructions.
**2.** Design speed of bicyclists.
**3.** Horizontal alignment and superelevation.
**4.** Grades on bike paths.
**5.** Adequate stopping sight distances.
**6.** Intersection design considerations.
**7.** Adequate signing and marking.
**8.** Pavement structure.
**9.** Structures required to provide continuity.
**10.** Drainage of pavement and adjacent areas.
**11.** Fixed-source lighting luminaires and standards.

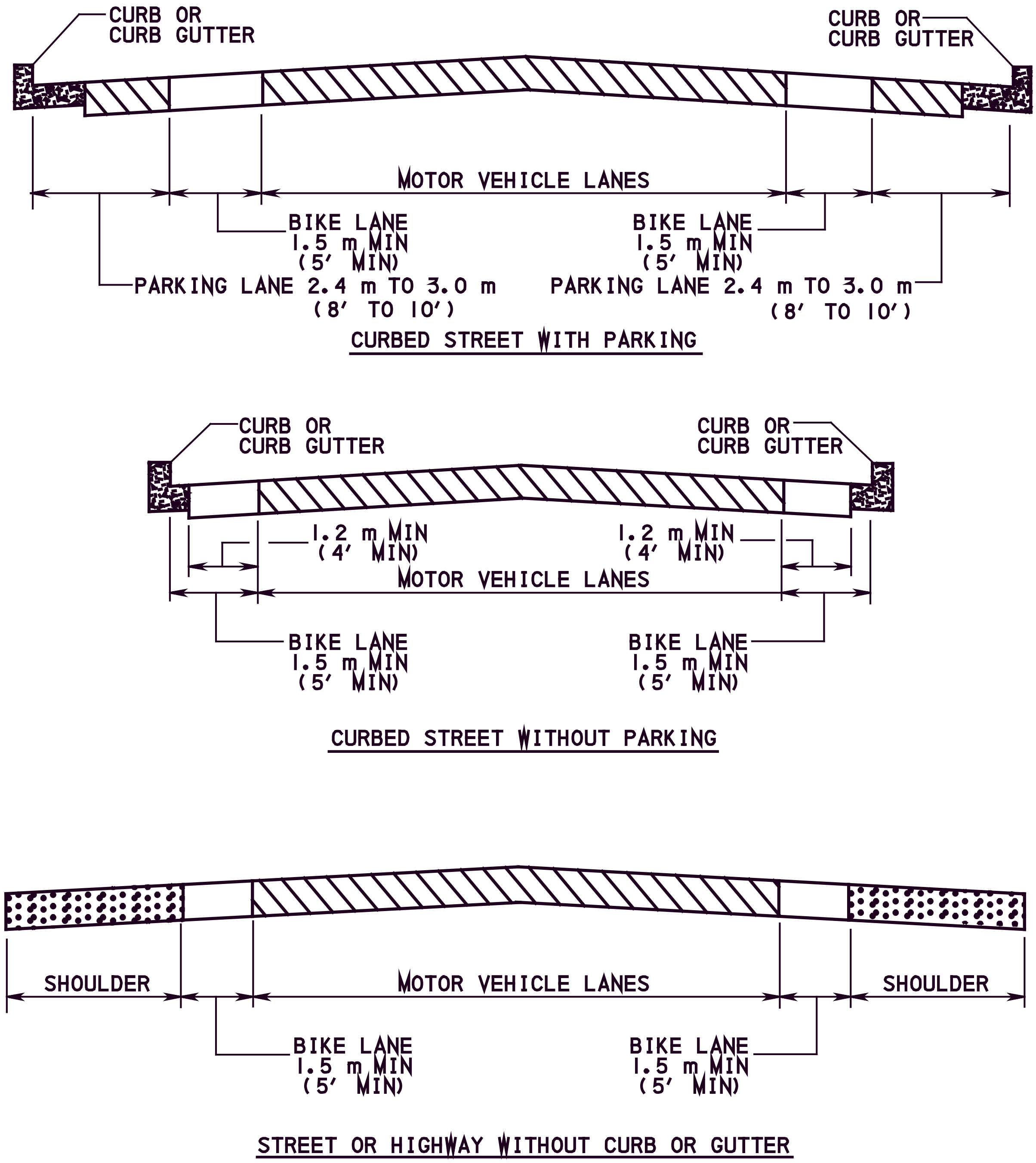


FIGURE 16.1
TYPICAL BIKE LANE CROSS SECTIONS

DM2_16M.DGN

**12.** Restriction of motor vehicle traffic.
**13.** Multi-use bike paths.

The guidelines presented in the AASHTO Bicycle Guide and the Department's "Bicycle and Pedestrian Checklist" found in Publication 10X, Design Manual, Part 1X, *Appendices to Design Manuals 1, 1A, 1B, and 1C*, Appendix S should be used in the design and construction of bike lanes and separate bike paths that accommodate the operating characteristics of "bicycles".

## 16.3 OPERATION AND MAINTENANCE OF BICYCLE FACILITIES

The costs involved with the operation and maintenance of bicycle compatible facilities should be considered and budgeted for when planning a facility since neglected maintenance can render bicycle facilities unrideable and the facilities can become a liability. A smooth surface, free of potholes and debris, should be provided and maintained. Signs and pavement markings should be inspected regularly and kept in good condition. For bike paths, attention should be given to maintaining the full paved width. Trees, shrubs and other vegetation should be controlled by trimming or removal to provide adequate clearances and sight distances. If snow removal is required, it should be in the form of plowing since deicing agents and abrasives can damage bicycles or lower skid resistance. The agency responsible for the control, maintenance and policing of the bicycle facility should be established prior to construction. For additional information relative to the operation and maintenance of bicycle facilities, refer to the AASHTO Bicycle Guide.

## 16.4 BIKEWAY FUNDING PROCEDURES

Bikeways that are located outside of the Department's right-of-way and do not involve Federal funds do not require any action by the Department. Bikeways that are located within the Department's right-of-way and do not utilize Motor License or Federal funds shall require approval from the Central Office, Bureau of Project Delivery. Bike paths which are located within the right-of-way limits for Interstate and Other Limited Access highway facilities shall require approval from both the Bureau of Project Delivery and the FHWA. All bikeways located within the Department's right-of-way shall require a Bikeway Occupancy Permit (see Section 16.6). A log shall be kept by the District Executive of <u>all</u> approvals.

All bikeway construction projects that utilize Federal funds shall require processing for approval through the Program Management Committee (PMC) and the Bureau of Project Delivery whether they are inside or outside of the Department's right-of-way. Those bikeways utilizing Federal funding participation shall be consistent with the terms of the 1987 Surface Transportation and Uniform Relocation Assistance Act (STURAA); the Intermodal Surface Transportation Efficiency Act of 1991; Transportation Equity Act for the 21st Century (TEA-21); Title 23, USC, Section 217; and 23 Code of Federal Regulations (CFR), Part 652, Pedestrian and Bicycle Accommodations and Projects. For independent bikeways, <u>only</u> those projects which serve a transportation-related function are eligible for Federal funds. Incidental facilities, whether recreational or transportation-related, <u>may</u> be eligible for Federal funds. On highways without full access control, where a bridge and/or the roadway is being replaced or rehabilitated, and where bicycles are permitted to operate, consideration will be given to reconstruction to safely accommodate bicycle passage. Also, any bikeway utilizing either Federal or Motor License funds shall be incorporated into the Commonwealth's State Transportation Improvement Program (STIP) of projects. The construction phase of all bikeway projects should also be included in the Department's obligation plan. In addition to the STIP, Act 120 requirements should be satisfied for projects located on a State Route (SR).

## 16.5 PROCEDURES FOR PROCESSING BIKEWAY CONSTRUCTION PROJECTS

Bikeway construction projects, regardless of bikeway type, can be categorized as either an independent bikeway construction project, which is a project to construct only a bicycle facility, or an incidental bikeway construction project, which is a project to construct a bicycle facility concurrently with a highway project or as a separate stage of construction. An incidental bikeway project should be processed with and as part of the accommodating project. Independent bikeway construction projects should be processed as follows:

**1.** The District Office shall direct and assist the sponsor of the bikeway project in preparing the required programming-related documents (see Figure 16.2). The following information which, for an area with a Metropolitan Planning Organization (MPO), should also include the documentation verifying that the project is endorsed by the MPO and is on the Transportation Improvement Program (TIP). Items A, B, C, D, E, F and K in Figure 16.2 shall be sent as a "package" to the Center for Program Development and Management (CPDM) for presentation to the Program Management Committee (PMC) for funding approval. Provisions in current programming strike-off letters pertaining to the Department's Bicycle Program and Funding Policy shall be followed. The remainder of the items listed shall be provided to the Bureau of Project Delivery for review during Final Design. Items A, D, E, F and J are required for programming Federal and State funds.

**2.** The sponsor shall submit four (4) copies of the following to the District Executive: (1) completed programming-related documents listed in 1 above, (2) resolutions on Cost Sharing, if applicable and (3) maintenance and policing responsibilities. The Department shall only be responsible for maintenance when the bikeway shares our roadway; this normally does not include signing and pavement markings or snow removal. However, on shared roadway projects, where no physical separation exists between the bikeway and roadway, the Department shall maintain the roadway edge striping and provide snow removal of the shoulder area. An agency other than the Department should agree to maintenance responsibility prior to construction of the facility.

**3.** The District Office shall submit one (1) copy of the programming-related documents and resolutions mentioned in 1 and 2 above to the CPDM for funding approval by the PMC.

**4.** Upon notification of PMC approval, the District Office shall submit a Form D-4232 to the CPDM for the appropriate preliminary design phase. Refer to Publication 10, Design Manual, Part 1, *Transportation Program Development and Project Delivery Process,* Chapter 5, Section 5.5 for proper Form D-4232 processing. The District Office shall arrange an environmental and engineering scoping field view for the project by contacting the Highway Design and Technology Section, Highway Delivery Division, Bureau of Project Delivery. The District Traffic Engineer and appropriate Central Office personnel, along with FHWA personnel, if applicable, shall be invited to attend. The primary purpose of the scoping field view shall be to identify the project limits, the scope of the environmental and engineering studies and the public involvement requirements.

**5.** After the scoping field view, the District Office or municipality shall conduct the engineering and environmental studies and the public involvement activities as defined during the scoping field view. Sufficient engineering shall be performed to assess the environmental impacts and to solicit public input.

**6.** Environmental documentation required for the construction of bicycle facilities should adhere to PENNDOT's NEPA handbooks (CEE, EA, EIS) and the Section 4(f) Handbook. If park property is required for the construction of the bicycle facility, the Negative Declaration may be applicable; however this determination must be made by FHWA.

Section 6(f) (monies obtained from the Department of the Interior's Land and Water Conservation Fund) consultation process must include FHWA. Coordination is necessary with the Pennsylvania Department of Conservation and Natural Resources, Bureau of Recreation and Conservation and the Department of the Interior (DOI), National Park Service. Coordination with DOI must be done by FHWA.

**7.** The Bureau of Project Delivery shall obtain approval of all required documents from the FHWA, if required, and transmit such to the District Executive.

**8.** Subsequent to the receipt of Design approval, the District Office shall take the proper steps to notify the sponsor to initiate the final design, utilizing Federal funding, if applicable, and the preparation of plans and legal agreements for the reimbursement of construction costs and for the maintenance responsibility. The reimbursement agreement should be executed prior to initiation of the project phase for which Federal reimbursement is requested (preliminary engineering and construction). Upon completion, the Plans, Specifications and Estimate (PS&E) shall be submitted to the Bureau of Project Delivery in accordance with the procedures for approval and authorization to advertise as directed in Publication 10C, Design Manual, Part 1C, *Transportation Engineering Procedures*. The plans should show all construction details including the location of signing and pavement markings for the bikeway.

| PROGRAMMING-RELATED DOCUMENT ITEMS | TYPES OF BIKEWAY PROJECTS | | | |
|---|---|---|---|---|
| | **BIKE PATH* ON NEW OR EXISTING R/W** | **BIKE LANE* REQUIRING ADDITIONAL R/W** | **BIKE LANE* WITHIN EXISTING R/W** | **SHARED* ROADWAY** |
| (A) Location Map | X | X | X | (1) |
| (B) Strip Map, 1:2000 (1"=200') Scale | X | X | X | (1) |
| (C) Detail Map, 1:500 (1"=50') Scale or Larger for Areas of Required R/W, Intersections, Points of Conflict | X | X | X | (1) |
| (D) Cost and Quantities | X | X | X | X |
| (E) Present and Future Expected Use | X | X | X | X |
| (F) Support Facilities | X | — | — | — |
| (G) Analysis of Turning Movements and Capacity at Intersections | (2) | X | X | X |
| (H) Bikeway Profile and Typical Sections | X | X | (1) | (1) |
| (I) Consideration of: | | | | |
| 1. Drainage Requirement | X | X | X | (2) |
| 2. Auto on Street Parking Requirement | — | X | X | — |
| 3. Mass Transit Operation Effects | — | X | X | X |
| 4. Alternative Locations | X | — | — | — |
| (J) Maintenance Agreements | X | X | X | (2) |
| (K) Overall Plan Relating Bikeway Project Existing or Proposed Areawide System with Due Consideration to Contiguous Routes | X | X | X | X |

*For definitions, see Section 16.0.
X = Required item.
(1) = Use latest highway plans.
(2) = If applicable.

## FIGURE 16.2
## PROGRAMMING RELATED DOCUMENTS
## REQUIRED FOR BIKEWAY CONSTRUCTION PROJECTS

**9.** The Bureau of Project Delivery shall process the PS&E submission as a normal project as outlined in Department directives. A municipality may choose to let and award the project if the requirements of Publication 39, *Procedures for the Administration of Locally Sponsored Projects*, are met.

The District Office shall ensure that the following are properly advertised as directed in Publication 10C, Design Manual, Part 1C, *Transportation Engineering Procedures*: (1) the availability of all environmental documents, (2) all opportunities for and holding of public hearings and public meetings and (3) request for and receipt of Design approval.

For non-construction-type bikeway projects, the above listed procedures may be modified, as appropriate, to expedite project development. When construction involves minor signing and pavement markings or typical shoulder modifications, or when construction of facilities are other than standard roadway items, such as storage racks, etc., the procedures for minor projects in Publication 10C, Design Manual, Part 1C, *Transportation Engineering Procedures*, may be utilized.

## 16.6 BIKEWAY OCCUPANCY PERMIT

All bikeways located within the Department's right-of-way should have a Bikeway Occupancy Permit (Form TE-700) as shown in Figure 16.3 and should meet the requirements of the AASHTO Bicycle Guide. Bikeway Occupancy Permits for the establishment of bikeways within the Department's right-of-way, except Interstate and Limited Access right-of-way, shall be issued by the District Executive. For those bikeway projects occupying Interstate or Limited Access right-of-way, approval from the Bureau of Project Delivery and the FHWA shall be required prior to issuing the permit. The Bikeway Occupancy Permit should be modified accordingly to fit the needs of each bikeway construction project.

Proposed bikeway projects not utilizing Federal and/or Motor License funds should have a Bikeway Occupancy Permit issued by the District Executive if they are to be located within the Department's right-of-way. Prior to issuance of the Bikeway Occupancy Permit, municipalities and/or counties should submit to the District Office, for approval, the required documentation as specified in Section 16.5 and the maintenance agreements. The District Office should maintain a minimum of one copy of the fully-executed permit for record purposes. Bikeway Occupancy Permits shall only be issued for those bikeways which have an approved study "package" and are in conformance with the AASHTO Bicycle Guide and Publication 10X, Design Manual, Part 1X, *Appendices to Design Manuals 1, 1A, 1B, and 1C*, Appendix S, Bicycle and Pedestrian Checklist. For clarity, the location map required in the study "package" should accompany the permit.

The Bikeway Occupancy Permit should describe the entire bikeway route. If more than one State Route is involved, these should also be listed. For continuity and clarity, if local road segments are utilized for a portion of the bikeway route, they should also be listed. The State Routes and/or local roads should be listed in sequential order starting from one end and progressing to the other end of the bikeway route. In addition to the listing of the routes, the limits and identification of segments of each route in the bikeway route should also be indicated in the "From" and "To" columns and should include stations and reference points (intersecting State Routes or local roads, as an example) at each point. Segment and segment offset information are not applicable to local roads. In the "Type of Bikeway" column, indicate if the bikeway is a bike path, bike lane or shared roadway. This column should only be filled out for the State Routes involved. The next two columns only pertain to the bike paths and bike lanes and should only be filled out for the State Routes involved. The description and location should specify the bikeway width, which side or sides of the roadway are involved, whether pavement or a portion of the shoulder is utilized and any other pertinent information necessary to properly locate the bikeway route.

As an example of a bike lane, the description location should be: "1.2 m (4 ft) bike lane on pavement, measured from curb, both sides". As an example of a bike lane on a shoulder area, the descriptive location should be: "1.2 m (4 ft) bike lane on outer 1.2 m (4 ft) portion of the right shoulder". The type of separation which is necessary for bike lanes or bike paths should be specified as traffic line paint, curb, sidewalks, earth strip, etc.

As specified in Section 16.5, indicate any "special conditions" (environmental or otherwise) conditional to granting approval of the permit. Representatives from the Bureau of Project Delivery shall be available, upon request, to review complex bikeway problems.

## 16.7 SIGNING, SIGNALIZATION AND MARKING

All bikeway facilities should be properly signed and marked for identification and to convey instructions to either bicyclists, motorists, or both, in accordance with the MUTCD. The uniform application of traffic control devices should be used to encourage proper bicyclist behavior.

**INTENTIONALLY BLANK**

| **TE-700 (10/88)**<br>**(Reproduced Locally)** | **BIKEWAY OCCUPANCY PERMIT** | **PERMIT NO.________** |
|---|---|---|

WHEREAS, It is desired to designate Bikeways on or along certain Highways as shown on the sketch attached hereto and made a part hereof, and

WHEREAS, It is desired to have such Bikeways established and marked in accordance with the standards, rules and regulations of the Pennsylvania Department of Transportation.

NOW THEREFORE, BE IT RESOLVED;

That the following routes are hereby established for Bikeways:

| ROUTE VIA | FROM | TO | TYPE OF BIKEWAY | DESCRIPTIVE LOCATION | TYPE OF SEPARATION (IF ANY) |
|---|---|---|---|---|---|

Said Bikeway to be established and maintained under and subject to the following items and conditions:

(a) The ____________ of ___________ County of ____________ shall be responsible for the policing*, maintenance (including snow removal), and proper traffic signing and marking of the bikeway.

> *Including the enactment of a local ordinance to ban all motorized vehicles other than maintenance vehicles and snowmobiles when snow conditions and local ordinances permit.

(b) The Department maintains the right to cancel this permit upon thirty (30) day written notification to the permittee.

(c) Shall provide and annually repair the necessary signs and markings in accordance with the standards as prescribed by the Secretary of Transportation.

(d) The Bikeway hereby established shall be discontinued and all signs and markings thereon shall be removed therefrom if changes in physical or traffic conditions make such Bikeway impracticable or hazardous in the judgement of the Secretary of Transportation.

**Sheet 1 of 2**

**FIGURE 16.3**
**BIKEWAY OCCUPANCY PERMIT**

SPECIAL CONDITIONS OF APPROVAL

A certified copy of this resolution shall be sent to the Deputy Secretary for Highway Administration, and upon his approval, the aforesaid Bikeway shall be deemed to have been authorized in accordance with the terms thereof.

ATTEST:

____________________________ ____________________________

Chief Clerk Mayor

____________________________

Secretary

I hereby certify the foregoing to be a true and correct copy of resolution of the ________ of _______ duly adopted at a meeting of said body on the _________ day of __________ , ___________ .

____________________________

Chief Clerk

(SEAL)

The establishment of the aforesaid Bikeway is hereby approved in accordance with the terms and conditions expressed in the foregoing resolution.

Date: _______ , _______ .

____________________________

District Executive
Engineering District ___

______________________________________

Deputy Secretary for Highway Administration

**Sheet 2 of 2**

**FIGURE 16.3**
**BIKEWAY OCCUPANCY PERMIT**
**(CONTINUED)**

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# CHAPTER 17

## EMERGENCY ESCAPE RAMPS

### 17.0 INTRODUCTION

Where long, descending grades exist or where topographic and location controls require such grades on new alignment, the design and construction of an emergency escape ramp at an appropriate location is desirable to provide a location for out-of-control vehicles, particularly trucks, to slow and stop away from the main traffic stream. Out-of-control vehicles are generally the result of a driver losing braking ability either through overheating of the brakes due to mechanical failure or failure to downshift at the appropriate time. The loss of stopping capability of a heavy vehicle on a downgrade resulting in an "out-of-control" situation is a relatively infrequent event. The results of that event, however, in many cases are spectacular and very costly in both lives lost and property damage.

Even the best road design cannot fully compensate for the "out-of-control" problem in mountainous terrain, and vehicle performance standards can provide for heavy vehicle control on long and/or steep downgrades only when the use of gear shifting and braking are properly combined to reduce speeds.

Static signing and stopping areas (turnouts or pull off areas) located before severe downgrades, to be used for voluntary or mandatory brake inspections and for cooling of brakes to restore their stopping capabilities, are the methods most commonly used to provide proper information to the drivers and provide an opportunity for checking the operation of the equipment prior to descent. In addition, information about the grade ahead and the location of escape ramps can be provided by diagrammetric signing. Refer to Publication 212, *Official Traffic Control Devices*.

The Department has constructed and maintains emergency escape ramps throughout the Commonwealth. Reports and evaluations indicate that these escape ramps have reduced property damage and more importantly have saved lives. The design criteria presented in this chapter have been developed by the Department through research by The Pennsylvania State University. The goal of this research project was to understand the physical characteristics of the stopping mechanism and to provide a means for adequately designing and maintaining gravel arrester beds. Full-scale testing was performed at operational gravel arrester beds within the state as well as at two research gravel arrester beds located at The Pennsylvania Transportation Institute's (PTI) Research Facility.

Additional information and details can be obtained from The Pennsylvania Transportation Institute, *A Field and Laboratory Study to Establish Truck Escape Ramp Design Methodology*, Report No. FHWA-PA-86-034+83-23, October 1988 and the AASHTO Green Book.

### 17.1 DYNAMICS OF A VEHICLE

The effectiveness of gravel arrester beds in stopping runaway vehicles results from the interaction between vehicle motion and gravel movement. The motion can be predicted if the forces acting on the vehicle can be predicted because Newton's law gives the deceleration if the forces and masses of the vehicle are known.

Resistance forces that act on every vehicle and affect the vehicle's speed include engine, braking and tractive resistance forces. Engine and braking resistance forces can be ignored in the design of emergency escape ramps because the ramp should be designed for the worst case; that is, the vehicle is out of gear and the brake system has failed. Tractive resistance forces contain four subclasses: inertial, aerodynamic, rolling and gradient. Inertial and negative gradient resistance forces act to maintain motion of the vehicle while rolling, positive gradient and air resistance forces act to retard its motion. The 2004 AASHTO Green Book, Chapter 3, Exhibit 3-65 illustrates the action of the various resistance forces on a vehicle in motion.

Inertial resistance force can be described as a force that resists movement in a vehicle at rest or keeps a vehicle in motion, unless the vehicle is acted upon by some external force. Inertial resistance force must be overcome to either increase or decrease the speed of a vehicle. Rolling and positive gradient resistance forces are available to overcome the inertial resistance force. Rolling resistance force is a general term used to describe the resistance to motion at the area of contact between a vehicle's tires and the roadway surface and is only applicable when a vehicle is in motion. It is influenced by the type and displacement characteristics of the surfacing material of the roadway.

Gradient resistance force is due to the effect of gravity and is expressed as the force needed to move the vehicle through a vertical distance. For gradient resistance force to provide a beneficial force on an escape ramp, the vehicle must be moving upgrade against gravity. In the case where the vehicle is descending a grade, gradient resistance force is negative, thereby reducing the forces available to slow and stop the vehicle. It is influenced by the total mass (weight) of the vehicle and the magnitude of the grade.

The remaining component of tractive resistance force is aerodynamic resistance force. Air causes a significant resistance at speeds above 80 km/h (50 mph) and is negligible under 30 km/h (20 mph). The effect of aerodynamic resistance has been neglected in determining the length of the arrester bed in this chapter.

## 17.2 NEED AND LOCATION

Each grade has its own unique characteristics. Highway alignment, gradient, length and descent speed contribute to the potential for out-of-control vehicles. For existing highways, operational problems on a downgrade will often be reported by law enforcement officials, truck drivers or the general public. A field review of a specific grade may reveal damaged guide rail, gouged pavement surfaces or spilled oil indicating locations where drivers of heavy vehicles had difficulty negotiating a downgrade. For existing facilities, an escape ramp should be provided as soon as a need is established. Crash experience (or, for new facilities, use crash experience on similar facilities) and truck operations on the grade combined with engineering judgment are used frequently to determine the need for a truck escape ramp. Often the impact of potential runaway trucks on adjacent activities or population centers will provide sufficient reason to construct an escape ramp. Likewise, for Interstate highways on extended lengths of maximum or near maximum descending grades, emergency escape ramps should be added where an evaluation indicates they are required.

Unnecessary escape ramps should be avoided. For example, a second escape ramp should not be needed just beyond the curve that created the need for the initial ramp.

While there are no universal guidelines available for new and existing facilities, a variety of factors should be considered in selecting the specific site for an escape ramp. Each location presents a different array of design needs; factors that should be considered include topography, length and percent of grade, potential speed, economics, environmental impact and crash experience. Ramps should be located to intercept the greatest number of runaway vehicles, such as at the bottom of the grade and at intermediate points along the grade where an out-of-control vehicle could cause a catastrophic crash.

A technique for new and existing facilities available for use in analyzing operations on a grade, in addition to crash analysis, is the *Grade Severity Rating System*. The system uses a predetermined brake temperature limit (260 °C (500 °F)) to establish a safe descent speed for the grade. It also can be used to determine expected brake temperatures at 0.8 km (0.5 mi) intervals along the downgrade. The location where brake temperatures exceed the limit indicates the point that brake failures can occur, leading to potential runaways.

Escape ramps generally may be built at any practical location where the main road alignment is tangent. They should be built in advance of horizontal curves that cannot be negotiated safely by an out-of-control vehicle and in advance of populated areas. Escape ramps should exit to the right of the roadway. On divided multilane highways, where a left exit may appear to be the only practical location, difficulties may be expected by the refusal of vehicles in the left lane to yield to out-of-control vehicles attempting to change lanes.

Although crashes involving runaway trucks usually can occur at various sites along a grade, locations having multiple crashes should be analyzed in detail. Analysis of crash data pertinent to a prospective site should include evaluation of the section of highway immediately uphill including the amount of curvature traversed and distance to and radius of the adjacent curve.

An integral part of the evaluation should be the determination of the maximum speed that an out-of-control vehicle could attain at the proposed site. This highest obtainable speed can then be used as the minimum design speed for the ramp. The 130 to 140 km/h (80 to 90 mph) entry speed, recommended for design, is intended to represent an extreme condition and therefore should not be used as the basis for selecting locations of escape ramps. Although the variables involved make it impractical to establish a maximum truck speed warrant for location of escape ramps, it is evident that anticipated speeds should be below the range used for design. The principal factor in determining the need for an emergency escape ramp should be the safety of the other traffic on the roadway, the driver of the out-of-control vehicle and the residents along and at the bottom of the grade. An escape ramp, or ramps if the conditions indicate the need for more than one, should be located wherever grades are of a steepness and length that present a substantial risk of runaway trucks and topographic conditions will permit construction.

## 17.3 TYPES OF EMERGENCY ESCAPE RAMPS

Emergency escape ramps have been classified in a variety of ways. Three broad categories used to classify ramps are gravity, sandpile and arrester bed. Within these broad categories, four basic emergency escape ramp designs predominate. These designs are the sandpile and three types of arrester beds, classified by grade of the arrester bed: descending grade, horizontal grade and ascending grade. Typical escape ramps are shown in the 2004 AASHTO Green Book, Chapter 3, Exhibits 3-67 and 3-68.

The gravity ramp has a paved or densely compacted aggregate surface, relying primarily on gravitational forces to slow and stop the runaway. Rolling resistance forces contribute little to assist in stopping the vehicle. Gravity ramps are usually long and steep and are constrained by topographic controls and costs. While a gravity ramp stops forward motion, the paved surface cannot prevent the vehicle from rolling back down the ramp grade and jackknifing without a positive capture mechanism. Therefore, the gravity ramp is the least desirable of the escape ramp types.

Sandpiles, composed of loose, dry sand dumped at the ramp site, are usually no more than 120 m (400 ft) in length. The influence of gravity is dependent on the slope of the surface. The increase in rolling resistance is supplied by loose sand. Deceleration characteristics of sandpiles are usually severe and the sand can be affected by weather. Because of the deceleration characteristics, the sandpile is less desirable than the arrester bed. However, at locations where inadequate space exists for another type of ramp, the sandpile may be appropriate because of its compact dimensions.

Descending-grade arrester-bed escape ramps are constructed parallel and adjacent to the through lanes of the highway. These ramps use loose aggregate in an arrester bed to increase rolling resistance to slow the vehicle. The gradient resistance acts in the direction of vehicle movement. As a result, the descending-grade ramps can be rather lengthy because the gravitational effect is not acting to help reduce the speed of the vehicle. The ramp should have a clear, obvious return path to the highway so drivers who doubt the effectiveness of the ramp will feel they will be able to return to the highway at a reduced speed.

Where the topography can accommodate, a horizontal-grade arrester-bed escape ramp is another option. Constructed on an essentially flat gradient, the horizontal-grade ramp relies on the increased rolling resistance from the loose aggregate in an arrester bed to slow and stop the out-of-control vehicle, since the effect of gravity is minimal. This type of ramp is longer than the ascending-grade arrester bed.

The most commonly used escape ramp is the ascending-grade arrester bed. Ramp installations of this type use gradient resistance to its advantage, supplementing the effects of the aggregate in the arrester bed, and in general, reducing the length of ramp needed to stop the vehicle. The loose material in the arresting bed increases the rolling resistance, as in the other types of ramps, while the gradient resistance acts downgrade, opposite to the vehicle movement. The loose bedding material also serves to hold the vehicle in place on the ramp grade after it has come to a safe stop.

Each of the ramp types is applicable to a particular situation where an emergency escape ramp is desirable and should be compatible with established location and topographic controls at possible sites. The procedures used for analysis of truck escape ramps are essentially the same for each of the categories or types identified. The rolling resistance factor for the surfacing material used in determining the length needed to slow and stop the runaway safely is the difference in the procedures.

## 17.4 ELEMENTS OF DESIGN

The principal factor in determining the need for an emergency escape ramp should be the safety of the other traffic on the roadway, the driver of the out-of-control vehicle and the residents along and at the bottom of the grade.

To safely stop an out-of-control vehicle, the length of an escape ramp should be sufficient to dissipate the kinetic energy of the moving vehicle. A "last chance" device at the end of the ramp, such as a mound or a row of barrels, should be considered when the consequences of leaving the end of ramp are serious.

There are numerous elements which affect the performance of emergency escape ramps. The depth, length and slope as well as the gradation, density and type of material are important factors in the performance of an arresting bed.

Resistance forces limit the maximum speed of an out-of-control vehicle. Speeds in excess of 130 to 140 km/h (80 to 90 mph) will rarely, if ever, be attained. For the escape ramp to be effective, it must stop the largest vehicle expected to use the ramp; generally a truck, such as a WB-15 (WB-50) or a WB-18 (WB-60).

Access to the ramp should be made obvious by exit signing, with sufficient sight distance in advance, to allow the driver of an out-of-control vehicle time to react, so as to minimize the possibility of missing the ramp. Advance signing is needed to inform drivers of the existence of an escape ramp and to prepare drivers well in advance of the decision point so that they will have enough time to decide whether or not to use the escape ramp. Regulatory signs near the entrance should be used to discourage other motorists from entering, stopping, or parking at or on the ramp. The path of the ramp should be delineated to define ramp edges and provide nighttime direction. Illumination of the approach and ramp is desirable.

Design recommendations for emergency escape ramps are divided into the following subsections: (1) Basic Bed Length, (2) Barrels, (3) Mounds, (4) Length Design with Combination of Bed, Mounds and Barrels, (5) Bed Design and (6) Incidental Items.

**A. Basic Bed Length.** The basic bed length (L) required without mounds or barrels is given by a third-order equation:

$$L = A + BV + CV^2 + DV^3 \qquad \text{(Eq. 17-1)}$$

where:

| | | |
|---|---|---|
| L | = | Basic bed length (m (ft)). |
| V | = | Entry speed (km/h (mph)). |
| A,B,C,D | = | Constants given in Table 17.1. |

The above equation is used to calculate the basic bed length for entry speeds up to 140 km/h (90 mph). However, the values of the constants used with the equation are different. In Table 17.1, a set of values is given for entry speeds from 50 to 100 km/h (30 to 60 mph) and another set of values for entry speeds from 101 to 140 km/h (61 to 90 mph).

To calculate L, the entry speed and bed grade are chosen, and then the constants can be determined from Table 17.1.

**METRIC EXAMPLE:** To find the length required for an entry speed of 100 km/h at 0% grade and 10% grade, the constants are first found from Table 17.1.

| 0% grade | | | 10% grade | | |
|---|---|---|---|---|---|
| $A_0$ | = | 0.992 202 49 | $A_{10}$ | = | -1.804 566 84 |
| $B_0$ | = | 0.032 091 92 | $B_{10}$ | = | 0.118 240 57 |
| $C_0$ | = | 0.005 095 26 | $C_{10}$ | = | 0.003 723 85 |
| $D_0$ | = | 0.000 047 68 | $D_{10}$ | = | 0.000 031 98 |

By substituting these values into Equation 17-1, lengths of 103 m for a bed with 0% grade and 79 m for a bed with 10% grade are found. As shown here, if conditions dictate a shorter bed length, the grade of the bed is required to be steeper.

**1.** Graphs for Designing the Bed Length. Figure 17.1 is a plot of Equation 17-1 using the values from Table 17.1 and thus can be used as an alternative to Equation 17-1 for designing bed length. In the example given above, the 100 km/h line would be followed to the 0% grade curve where the length of 103 m is indicated. For a 10% slope, the 100 km/h line would be followed to the 10% grade curve, where the length of 79 m, is shown.

The basic bed length is also given in Table 17.2 which results from using Equation 17-1 and the constants from Table 17.1. The basic bed length is given for entry speeds of 2 km/h increments from 50 to 140 km/h. This table is to be used as a quick reference during preliminary design and for review of final plans for emergency escape ramps.

**ENGLISH EXAMPLE:** To find the length required for an entry speed of 60 mph at 0% grade and 10% grade, the constants are first found from Table 17.1.

| 0% grade | | | 10% grade | | |
|---|---|---|---|---|---|
| $A_0$ | = | 3.2552575 | $A_{10}$ | = | -5.92049487 |
| $B_0$ | = | 0.16944534 | $B_{10}$ | = | 0.62431019 |
| $C_0$ | = | 0.04329616 | $C_{10}$ | = | 0.03164279 |
| $D_0$ | = | 0.00065202 | $D_{10}$ | = | 0.00043730 |

By substituting these values into Equation 17-1, lengths of 310 ft for a bed with 0% grade and 240 ft for a bed with 10% grade are found. As shown here, if conditions dictate a shorter bed length, the grade of the bed is required to be steeper.

**1.** Graphs for Designing the Bed Length. Figure 17.1 is a plot of Equation 17-1 using the values from Table 17.1 and thus can be used as an alternative to Equation 17-1 for designing bed length. In the example given above, the 60 mph line would be followed to the 0% grade curve where the length of 310 ft is indicated. For a 10% slope, the 60 mph line would be followed to the 10% grade curve, where the length of 260 ft, is shown.

The basic bed length is also given in Table 17.2 which results from using Equation 17-1 and the constants from Table 17.1. The basic bed length is given for entry speeds of 2 mph increments from 30 to 90 mph. This table is to be used as a quick reference during preliminary design and for review of final plans for emergency escape ramps.

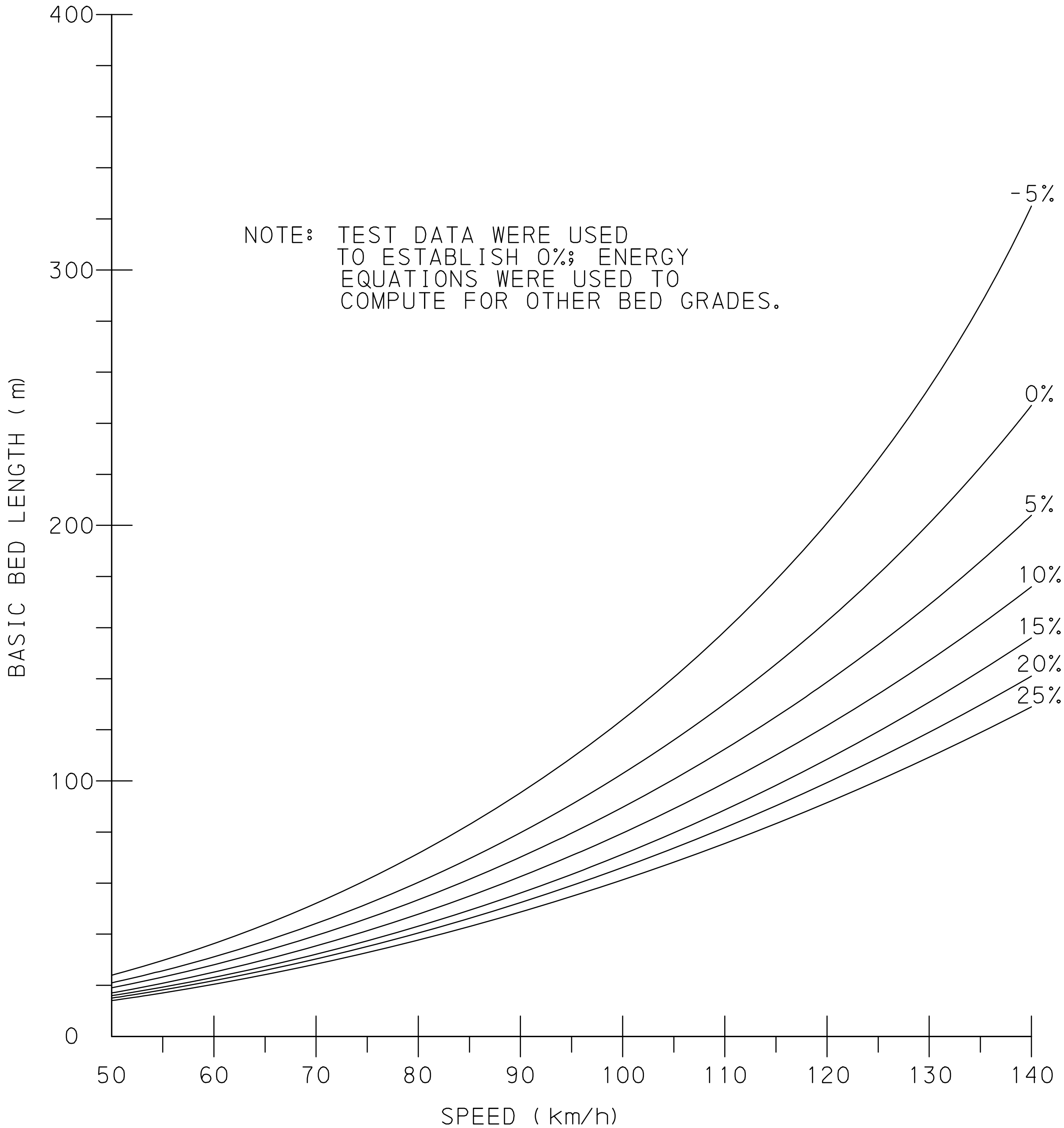


FIGURE 17.1 (METRIC)
EFFECT OF GRADE ON RIVER GRAVEL BED

DM2_17M.DGN

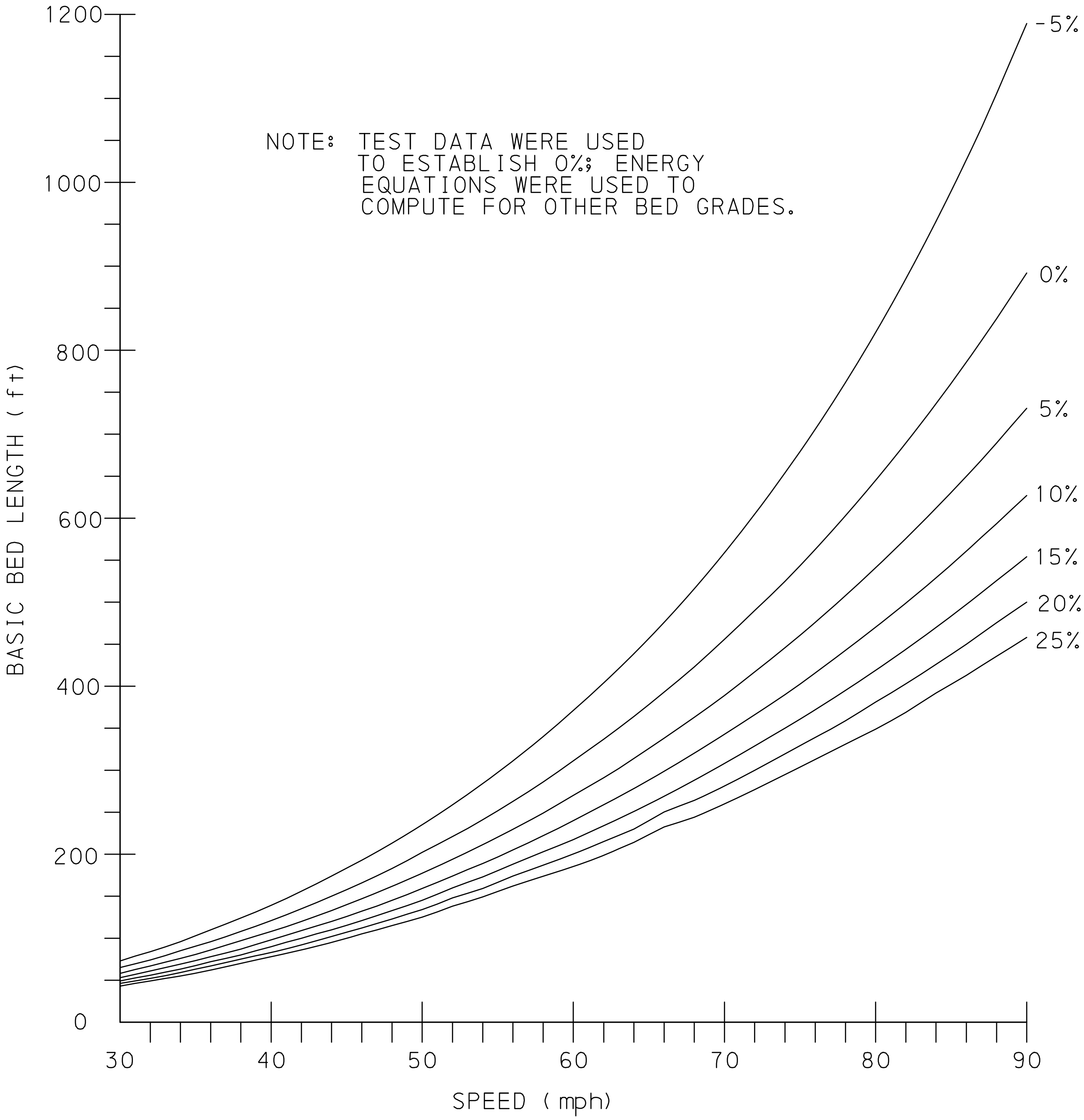


FIGURE 17.1 (ENGLISH)
EFFECT OF GRADE ON RIVER GRAVEL BED

DM2_17M.DGN

## TABLE 17.1 (METRIC)
## VALUES FOR CONSTANTS USED TO CALCULATE BASIC BED LENGTH IN EQUATION 17-1

| CONSTANT | 50 TO 100 km/h | | | | | | |
|---|---|---|---|---|---|---|---|
| | PERCENT GRADE OF BED | | | | | | |
| | -5 | 0 | 5 | 10 | 15 | 20 | 25 |
| **A** | -15.172 944 00 | 0.992 202 49 | -4.921 267 79 | -1.804 566 84 | 0.492 795 03 | 1.457 464 15 | 7.102 965 24 |
| | | | | | | | |
| **B** | 0.782 196 97 | 0.032 091 92 | 0.264 322 13 | 0.118 240 57 | -0.010 606 62 | -0.039 982 48 | -0.303 254 64 |
| | | | | | | | |
| **C** | -0.006 001 88 | 0.005 095 26 | 0.001 874 60 | 0.003 723 85 | 0.005 658 15 | 0.005 612 71 | 0.009 278 71 |
| | | | | | | | |
| **D** | 0.000 120 66 | 0.000 047 68 | 0.000 049 02 | 0.000 031 98 | 0.000 015 32 | 0.000 012 06 | -0.000 008 81 |
| | | | | | | | |

| CONSTANT | 101 TO 140 km/h | | | | | | |
|---|---|---|---|---|---|---|---|
| | PERCENT GRADE OF BED | | | | | | |
| | -5 | 0 | 5 | 10 | 15 | 20 | 25 |
| **A** | -282.525 459 84 | -86.921 166 05 | -22.415 263 66 | -23.581 269 96 | -30.226 931 56 | -4.254 939 42 | -3.029 281 62 |
| | | | | | | | |
| **B** | 8.624 979 66 | 2.744 483 34 | 0.794 359 49 | 0.736 911 89 | 0.836 898 03 | 0.177 542 32 | 0.093 922 63 |
| | | | | | | | |
| **C** | -0.083 083 36 | -0.023 107 90 | -0.003 412 29 | -0.002 057 50 | -0.002 419 34 | 0.002 973 24 | 0.003 926 11 |
| | | | | | | | |
| **D** | 0.000 374 69 | 0.000 146 79 | 0.000 066 36 | 0.000 049 74 | 0.000 042 33 | 0.000 022 58 | 0.000 015 36 |
| | | | | | | | |

## TABLE 17.1 (ENGLISH)
## VALUES FOR CONSTANTS USED TO CALCULATE
## BASIC BED LENGTH IN EQUATION 17-1

| CONSTANT | 30 TO 60 mph | | | | | | |
|---|---|---|---|---|---|---|---|
| | PERCENT GRADE OF BED | | | | | | |
| | -5 | 0 | 5 | 10 | 15 | 20 | 25 |
| **A** | -49.78 | 3.2552575 | -16.14589169 | -5.92049487 | 1.61678158 | 4.78170653 | 23.30369173 |
| | | | | | | | |
| **B** | 4.13 | 0.16944534 | 1.39562086 | 0.62431019 | -0.05600296 | -0.21110752 | -1.60118449 |
| | | | | | | | |
| **C** | -0.051 | 0.04329616 | 0.01592913 | 0.03164279 | 0.04807917 | 0.04769312 | 0.07884436 |
| | | | | | | | |
| **D** | 0.00165 | 0.00065202 | 0.00067035 | 0.00043730 | 0.00020949 | 0.00016497 | -0.00012045 |
| | | | | | | | |

| CONSTANT | 61 TO 90 mph | | | | | | |
|---|---|---|---|---|---|---|---|
| | PERCENT GRADE OF BED | | | | | | |
| | -5 | 0 | 5 | 10 | 15 | 20 | 25 |
| **A** | -926.9208 | -285.1744293 | -73.54089126 | -77.36637125 | -99.16972295 | -13.9597750 | -9.93858798 |
| | | | | | | | |
| **B** | 45.53989258 | 14.49087202 | 4.19421811 | 3.8908948 | 4.41882161 | 0.93742345 | 0.49591149 |
| | | | | | | | |
| **C** | -0.70598725 | -0.19635557 | -0.02899535 | -0.01748326 | -0.02055797 | 0.02526466 | 0.03336147 |
| | | | | | | | |
| **D** | 0.00512399 | 0.00200734 | 0.00090754 | 0.00068014 | 0.00057884 | 0.00030885 | 0.00021004 |
| | | | | | | | |

**TABLE 17.2 (METRIC)**
**BASIC BED LENGTH FOR ENTRY**
**SPEED FOR SOME BED GRADES**

| ENTRY SPEED (km/h) | BASIC BED LENGTH (m) | | | | | | |
|---|---|---|---|---|---|---|---|
| | PERCENT GRADE OF BED | | | | | | |
| | -5 | 0 | 5 | 10 | 15 | 20 | 25 |
| 50 | 24 | 21 | 19 | 17 | 16 | 15 | 14 |
| 52 | 26 | 23 | 21 | 19 | 17 | 16 | 15 |
| 54 | 29 | 25 | 23 | 20 | 19 | 18 | 16 |
| 56 | 31 | 27 | 24 | 22 | 20 | 19 | 18 |
| 58 | 34 | 29 | 26 | 24 | 22 | 20 | 19 |
| 60 | 36 | 32 | 28 | 26 | 24 | 22 | 20 |
| 62 | 39 | 34 | 30 | 27 | 25 | 23 | 22 |
| 64 | 42 | 36 | 33 | 29 | 27 | 25 | 23 |
| 66 | 45 | 39 | 35 | 31 | 29 | 27 | 25 |
| 68 | 48 | 42 | 37 | 34 | 31 | 28 | 27 |
| 70 | 52 | 45 | 40 | 36 | 33 | 30 | 28 |
| 72 | 55 | 48 | 42 | 38 | 35 | 32 | 30 |
| 74 | 59 | 51 | 45 | 40 | 37 | 34 | 32 |
| 76 | 63 | 54 | 48 | 43 | 39 | 36 | 34 |
| 78 | 67 | 57 | 50 | 45 | 41 | 38 | 36 |
| 80 | 71 | 61 | 53 | 48 | 44 | 40 | 38 |
| 82 | 75 | 64 | 56 | 51 | 46 | 43 | 40 |
| 84 | 80 | 68 | 60 | 53 | 49 | 45 | 42 |
| 86 | 84 | 72 | 63 | 56 | 51 | 47 | 44 |
| 88 | 89 | 76 | 66 | 59 | 54 | 50 | 46 |
| 90 | 95 | 80 | 70 | 62 | 57 | 52 | 49 |
| 92 | 100 | 84 | 73 | 65 | 59 | 55 | 51 |
| 94 | 106 | 89 | 77 | 69 | 62 | 57 | 53 |
| 96 | 111 | 93 | 81 | 72 | 65 | 60 | 56 |
| 98 | 117 | 98 | 85 | 76 | 68 | 63 | 58 |
| 100 | 124 | 103 | 89 | 79 | 71 | 66 | 61 |
| 102 | 130 | 108 | 94 | 83 | 75 | 69 | 64 |
| 104 | 137 | 114 | 98 | 87 | 78 | 72 | 66 |
| 106 | 144 | 119 | 102 | 91 | 82 | 75 | 69 |
| 108 | 152 | 125 | 107 | 95 | 85 | 78 | 72 |
| 110 | 160 | 131 | 112 | 99 | 89 | 81 | 75 |
| 112 | 168 | 137 | 117 | 103 | 93 | 85 | 78 |
| 114 | 176 | 143 | 122 | 107 | 96 | 88 | 81 |
| 116 | 185 | 150 | 127 | 112 | 100 | 92 | 85 |
| 118 | 194 | 156 | 133 | 116 | 104 | 95 | 88 |
| 120 | 204 | 163 | 138 | 121 | 109 | 99 | 91 |

## TABLE 17.2 (METRIC)(CONTINUED)
## BASIC BED LENGTH FOR ENTRY SPEED FOR SOME BED GRADES

| ENTRY SPEED (km/h) | BASIC BED LENGTH (m) | | | | | | |
|---|---|---|---|---|---|---|---|
| | PERCENT GRADE OF BED | | | | | | |
| | -5 | 0 | 5 | 10 | 15 | 20 | 25 |
| 122 | 213 | 171 | 144 | 126 | 113 | 103 | 95 |
| 124 | 224 | 178 | 150 | 131 | 117 | 107 | 98 |
| 126 | 235 | 186 | 156 | 136 | 121 | 110 | 102 |
| 128 | 246 | 194 | 163 | 141 | 126 | 115 | 106 |
| 130 | 258 | 202 | 169 | 147 | 131 | 119 | 109 |
| 132 | 270 | 210 | 176 | 152 | 135 | 123 | 113 |
| 134 | 283 | 219 | 182 | 158 | 140 | 127 | 117 |
| 136 | 296 | 228 | 189 | 164 | 145 | 132 | 121 |
| 138 | 310 | 238 | 197 | 170 | 150 | 136 | 125 |
| 140 | 325 | 247 | 204 | 176 | 156 | 141 | 129 |
| 142 | 340 | 257 | 212 | 182 | 161 | 146 | 133 |
| 144 | 355 | 267 | 219 | 188 | 167 | 150 | 138 |
| 146 | 372 | 278 | 227 | 195 | 172 | 155 | 142 |
| 148 | 389 | 289 | 236 | 202 | 178 | 160 | 147 |
| 150 | 406 | 300 | 244 | 209 | 184 | 165 | 151 |
| 152 | 425 | 312 | 253 | 216 | 190 | 171 | 156 |
| 154 | 444 | 324 | 261 | 223 | 196 | 176 | 161 |
| 156 | 464 | 336 | 270 | 230 | 202 | 182 | 165 |
| 158 | 484 | 349 | 280 | 238 | 209 | 187 | 170 |
| 160 | 505 | 362 | 289 | 245 | 215 | 193 | 175 |
| 162 | 527 | 375 | 299 | 253 | 222 | 199 | 181 |
| 164 | 550 | 389 | 309 | 261 | 229 | 204 | 186 |
| 166 | 574 | 403 | 319 | 270 | 236 | 210 | 191 |
| 168 | 598 | 418 | 329 | 278 | 243 | 217 | 196 |
| 170 | 623 | 433 | 340 | 287 | 250 | 223 | 202 |
| 172 | 650 | 448 | 351 | 295 | 258 | 229 | 207 |
| 174 | 677 | 464 | 362 | 304 | 265 | 236 | 213 |
| 176 | 705 | 481 | 373 | 314 | 273 | 242 | 219 |
| 178 | 733 | 497 | 385 | 323 | 281 | 249 | 225 |
| 180 | 763 | 514 | 397 | 332 | 289 | 256 | 231 |
| 182 | 794 | 532 | 409 | 342 | 297 | 263 | 237 |
| 184 | 826 | 550 | 422 | 352 | 306 | 270 | 243 |
| 186 | 858 | 569 | 434 | 362 | 314 | 277 | 249 |
| 188 | 892 | 588 | 447 | 373 | 323 | 284 | 255 |
| 190 | 927 | 607 | 461 | 383 | 332 | 292 | 262 |

## TABLE 17.2 (ENGLISH)
## BASIC BED LENGTH FOR ENTRY SPEED FOR SOME BED GRADES

| ENTRY SPEED (mph) | BASIC BED LENGTH (ft) | | | | | | |
|---|---|---|---|---|---|---|---|
| | PERCENT GRADE OF BED | | | | | | |
| | **-5** | **0** | **5** | **10** | **15** | **20** | **25** |
| 30 | 73 | 65 | 58 | 53 | 49 | 46 | 43 |
| 32 | 84 | 74 | 67 | 61 | 56 | 52 | 49 |
| 34 | 96 | 85 | 76 | 69 | 63 | 59 | 55 |
| 36 | 110 | 96 | 86 | 78 | 72 | 67 | 62 |
| 38 | 124 | 108 | 97 | 87 | 80 | 75 | 70 |
| 40 | 139 | 121 | 108 | 98 | 90 | 83 | 78 |
| 42 | 156 | 135 | 120 | 109 | 100 | 92 | 86 |
| 44 | 174 | 150 | 133 | 120 | 110 | 102 | 95 |
| 46 | 193 | 166 | 147 | 132 | 121 | 112 | 105 |
| 48 | 213 | 183 | 162 | 145 | 133 | 123 | 115 |
| 50 | 235 | 202 | 177 | 159 | 145 | 134 | 125 |
| 52 | 259 | 221 | 194 | 174 | 158 | 146 | 136 |
| 54 | 284 | 241 | 211 | 189 | 172 | 158 | 148 |
| 56 | 311 | 263 | 230 | 205 | 186 | 172 | 160 |
| 58 | 340 | 286 | 249 | 222 | 201 | 185 | 172 |
| 60 | 371 | 311 | 270 | 240 | 217 | 200 | 185 |
| 62 | 404 | 337 | 291 | 259 | 234 | 215 | 199 |
| 64 | 439 | 364 | 314 | 278 | 251 | 230 | 214 |
| 66 | 476 | 393 | 338 | 299 | 269 | 247 | 229 |
| 68 | 516 | 423 | 363 | 320 | 288 | 264 | 244 |
| 70 | 559 | 456 | 389 | 343 | 308 | 281 | 260 |
| 72 | 605 | 490 | 417 | 366 | 329 | 300 | 277 |
| 74 | 654 | 525 | 446 | 390 | 350 | 319 | 294 |
| 76 | 706 | 563 | 476 | 416 | 372 | 339 | 313 |
| 78 | 762 | 603 | 508 | 443 | 395 | 359 | 331 |
| 80 | 821 | 645 | 541 | 470 | 419 | 381 | 351 |
| 82 | 885 | 690 | 576 | 499 | 444 | 403 | 371 |
| 84 | 954 | 736 | 612 | 529 | 470 | 426 | 392 |
| 86 | 1027 | 786 | 650 | 561 | 497 | 450 | 413 |
| 88 | 1105 | 837 | 689 | 593 | 525 | 475 | 435 |
| 90 | 1189 | 892 | 731 | 627 | 554 | 500 | 458 |
| 92 | 1279 | 949 | 774 | 662 | 584 | 526 | 482 |
| 94 | 1375 | 1009 | 819 | 699 | 615 | 554 | 506 |
| 96 | 1477 | 1073 | 866 | 737 | 647 | 582 | 532 |
| 98 | 1586 | 1139 | 915 | 776 | 681 | 611 | 558 |
| 100 | 1702 | 1209 | 966 | 817 | 715 | 641 | 584 |

## TABLE 17.2 (ENGLISH)(CONTINUED)
## BASIC BED LENGTH FOR ENTRY
## SPEED FOR SOME BED GRADES

| ENTRY SPEED (mph) | BASIC BED LENGTH (ft) | | | | | | |
|---|---|---|---|---|---|---|---|
| | PERCENT GRADE OF BED | | | | | | |
| | -5 | 0 | 5 | 10 | 15 | 20 | 25 |
| 102 | 1824 | 1282 | 1019 | 859 | 750 | 672 | 612 |
| 104 | 1953 | 1358 | 1074 | 903 | 787 | 703 | 640 |
| 106 | 2088 | 1438 | 1131 | 948 | 825 | 736 | 669 |
| 108 | 2228 | 1521 | 1190 | 995 | 864 | 770 | 699 |
| 110 | 2372 | 1608 | 1252 | 1043 | 904 | 805 | 730 |
| 112 | 2521 | 1699 | 1316 | 1093 | 945 | 840 | 762 |
| 114 | 2671 | 1792 | 1382 | 1145 | 988 | 877 | 794 |
| 116 | 2824 | 1890 | 1451 | 1198 | 1032 | 915 | 828 |
| 118 | 2976 | 1990 | 1521 | 1253 | 1077 | 954 | 862 |
| 120 | 3128 | 2093 | 1595 | 1309 | 1124 | 994 | 897 |

**B. Barrels.** Impact attenuator barrels can be used to help decelerate trucks where insufficient space is available for proper bed length. The following three equations give the change in speed, average deceleration load and time to travel the 0.9 m (3 ft) through a row of barrels:

$$V_f = DV_e$$

**METRIC:**

$$g = 0.004\,298\,8\,(D^2 - 1)V_e^2 \qquad \text{(Eq. 17-2)}$$

$$t = 6.584 / (D + l)V_e$$

**ENGLISH:**

$$g = 0.011134\,(D^2 - 1)V_e^2$$

$$t = 4.091 / (D + l)V_e$$

where:

$V_f$ = Exit speed after barrel row (km/h (mph)).
$V_e$ = Entry speed into barrel row (km/h (mph)).
D = Factor given in Table 17.3.
g = Deceleration, g.
t = Time to travel length of barrels (s).

**METRIC EXAMPLE:**
Three or more barrels across by four rows deep, would permit an additional reduction of 50 km/h when combined with the last 4.4 m of the bed for a 36 300 kg vehicle and would cause a 4.7-g load. Otherwise, 21 m of bed without the barrel barrier would be required to achieve the same results at 0% grade. Because of the larger deceleration loads at speeds above 70 km/h, a design as given in Figure 17.2 is suggested to reduce the maximum to below 9-g. This design is good for vehicles traveling as fast as 100 km/h. If speeds are higher, the designer should follow the procedures given in the next section, on barrel curves, to design the appropriate configuration.

**ENGLISH EXAMPLE:**
Three or more barrels across by four rows deep, would permit an additional reduction of 30 mph when combined with the last 14 ft of the bed for a 80,000 lb vehicle and would cause a 4.7-g load. Otherwise, 65 ft of bed without the barrel barrier would be required to achieve the same results at 0% grade. Because of the larger deceleration loads at speeds above 45 mph, a design as given in Figure 17.2 is suggested to reduce the maximum to below 9-g. This design is good for vehicles traveling as fast as 60 mph. If speeds are higher, the designer should follow the procedures given in the next section, on barrel curves, to design the appropriate configuration.

**1.** Graphs for Designing the Barrel Array. The equations given in the previous section are presented graphically in Figure 17.3. This figure presents, in the same manner as that used in the Energite System manual for the inertial barrier system, the design for a 36 300 kg (80,000 lb) vehicle using 0.64 $m^3$ (22.6 $ft^3$) barrels filled with river gravel (AASHTO No. 57). Sand should not be used in the barrels since sand would contaminate the gravel bed. The maximum deceleration forces acceptable for a vehicle's occupants are 12-g. The figure gives deceleration force levels up to 12-g. However, a deceleration force of 9-g is desirable for design. To use Figure 17.3, the same procedure is followed as was used to determine the bed length.

A vehicle impacting a three by three barrel array at 50 km/h (30 mph) can be considered as an example. Using Figure 17.4, the initial impact speed (50 km/h (30 mph)) can be located on the baseline (point 1). A straight vertical line can be drawn from that point until it intersects the horizontal line for three-barrel rows. The deceleration (4.7-g) is read here.

From that point, another line can be drawn parallel to the nearest exit speed line down to the baseline (point 2), which gives an exit speed of 38 km/h (23 mph) from the first row. The procedure is repeated for the second row, giving a deceleration of 2.6-g and an exit speed of 28 km/h (17 mph) at point 3. Repeating this procedure for the third row gives 1.5-g and 21 km/h (12 mph) at exit.

**TABLE 17.3**
**D FACTORS FOR BARRELS**

| ROW | VEHICLE MASS (Vehicle Weight) | | | | | |
|---|---|---|---|---|---|---|
| | 820 kg (1800 lb) | 2040 kg (4500 lb) | 6580 kg (14,500 lb) | 14 970 kg (33,000 lb) | 18 600 kg (41,000 lb) | 36 300 kg (80,000 lb) |
| **ONE BARREL** | 0.16 | 0.33 | 0.60 | 0.78 | 0.82 | 0.90 |
| **TWO BARRELS** | 0.09 | 0.20 | 0.42 | 0.65 | 0.69 | 0.81 |
| **THREE BARRELS** | 0.06 | 0.14 | 0.35 | 0.55 | 0.60 | 0.75 |

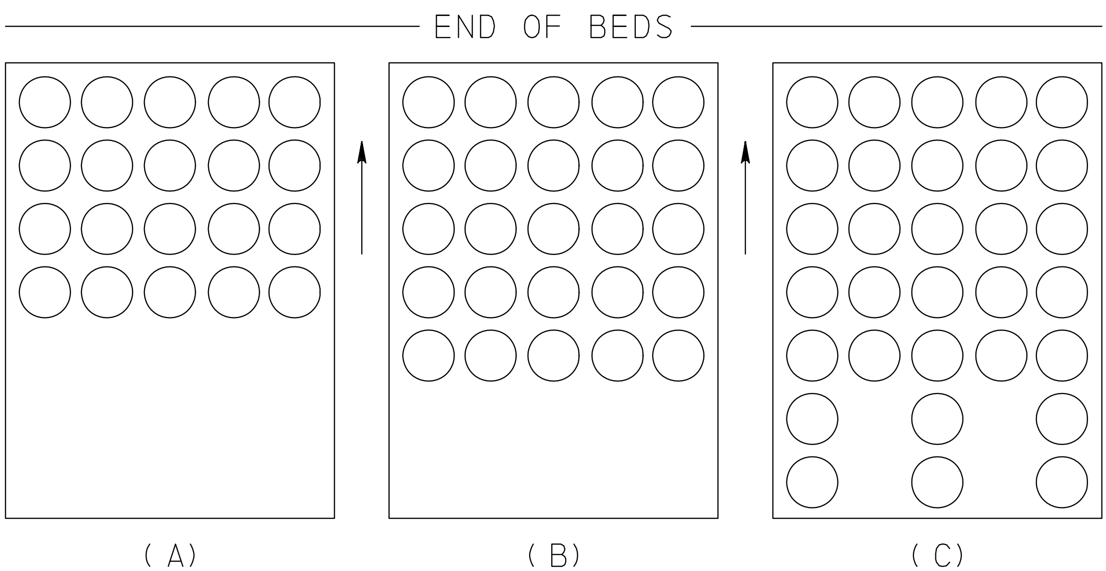


FIGURE 17.2
BARREL DESIGN FOR (A) 30 TO 50 km/h (20 TO 30 mph),
(B) 50 TO 70 km/h (30 TO 45 mph) AND
(C) 70 TO 100 km/h (45 TO 60 mph)

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For this case, the speed is decreased from 50 km/h to 21 km/h (30 to 12 mph) over 3.0 m (10 ft). Also, from Figure 17.1, 3.0 m (10 ft) of a 0% grade bed will remove 21 km/h (12 mph) from the vehicle speed; i.e., the combination of three rows of barrels and 3.0 m (10 ft) of bed will remove a total of 50 km/h (30 mph).

In another example (not marked on the figure) of a single row of two barrels with an impact speed of 60 km/h (40 mph), a 5.3-g deceleration and an exit speed of 49 km/h (33 mph) will be found.

**C. Mounds.** Mounds, which are depicted by Figure 17.5, are treated in a manner similar to that used for the barrels, and the same speed change equation is used; however, a different deceleration equation is needed because, while the average deceleration is calculated in the same manner, the peak is different. Using Equation 17-2, the equations for mounds were developed and are given below:

$$V_f = DV_e \quad \text{(Eq. 17-3)}$$

**METRIC:**

1. **Full Mound:**

$$g_{ave} = 0.001\ 29\ (D^2 - 1)V_e^2$$

$$g_{peak} = 0.002\ 34\ (D^2 - 1)V_e^2$$

$$t = 21.945 / (D + 1)V_e$$

2. **Half Mound:**

$$g_{ave} = 0.002\ 58\ (D^2 - 1)V_e^2$$

$$g_{peak} = 0.004\ 29\ (D^2 - 1)V_e^2$$

$$t = 10.973 / (D + 1)V_e$$

**ENGLISH:**

1. **Full Mound:**

$$g_{ave} = 0.00334\ (D^2 - 1)V_e^2$$

$$g_{peak} = 0.00607\ (D^2 - 1)V_e^2$$

$$t = 13.636 / (D + 1)V_e$$

2. **Half Mound:**

$$g_{ave} = 0.00668\ (D^2 - 1)V_e^2$$

$$g_{peak} = 0.01112\ (D^2 - 1)V_e^2$$

$$t = 6.818 / (D + 1)\ V_e$$

where:

$V_f$ = Exit speed from mound (km/h (mph))
$V_e$ = Entry speed into mound (km/h (mph))
D = Factor given in Table 17.4.
g = Deceleration, g.
t = Time to travel mound(s) (s).

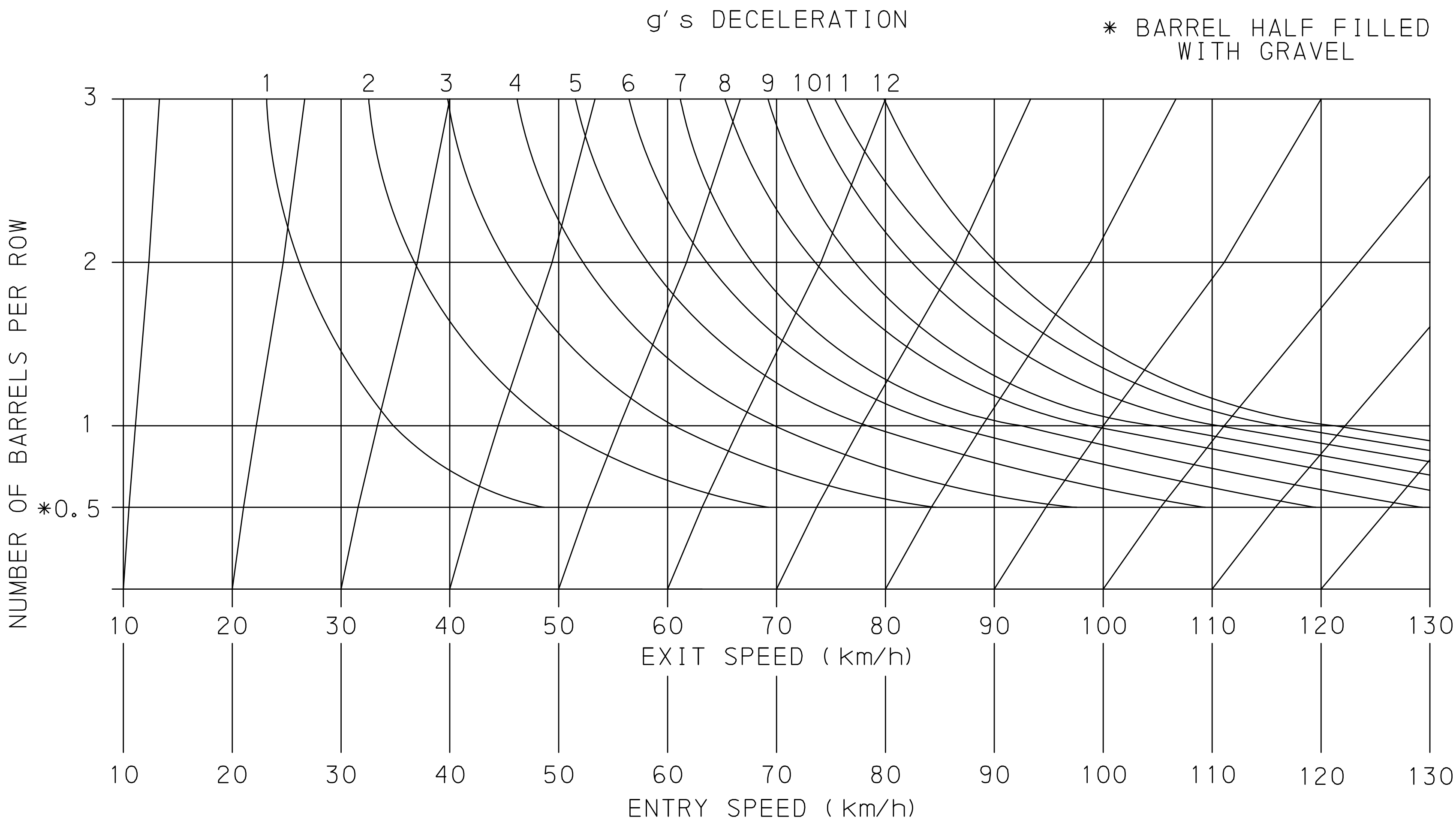


FIGURE 17.3 (METRIC)
DECELERATION CHART FOR A 36 300 kg VEHICLE
USING 0.64 m³ BARRELS FILLED
WITH RIVER GRAVEL (AASHTO NO. 57)

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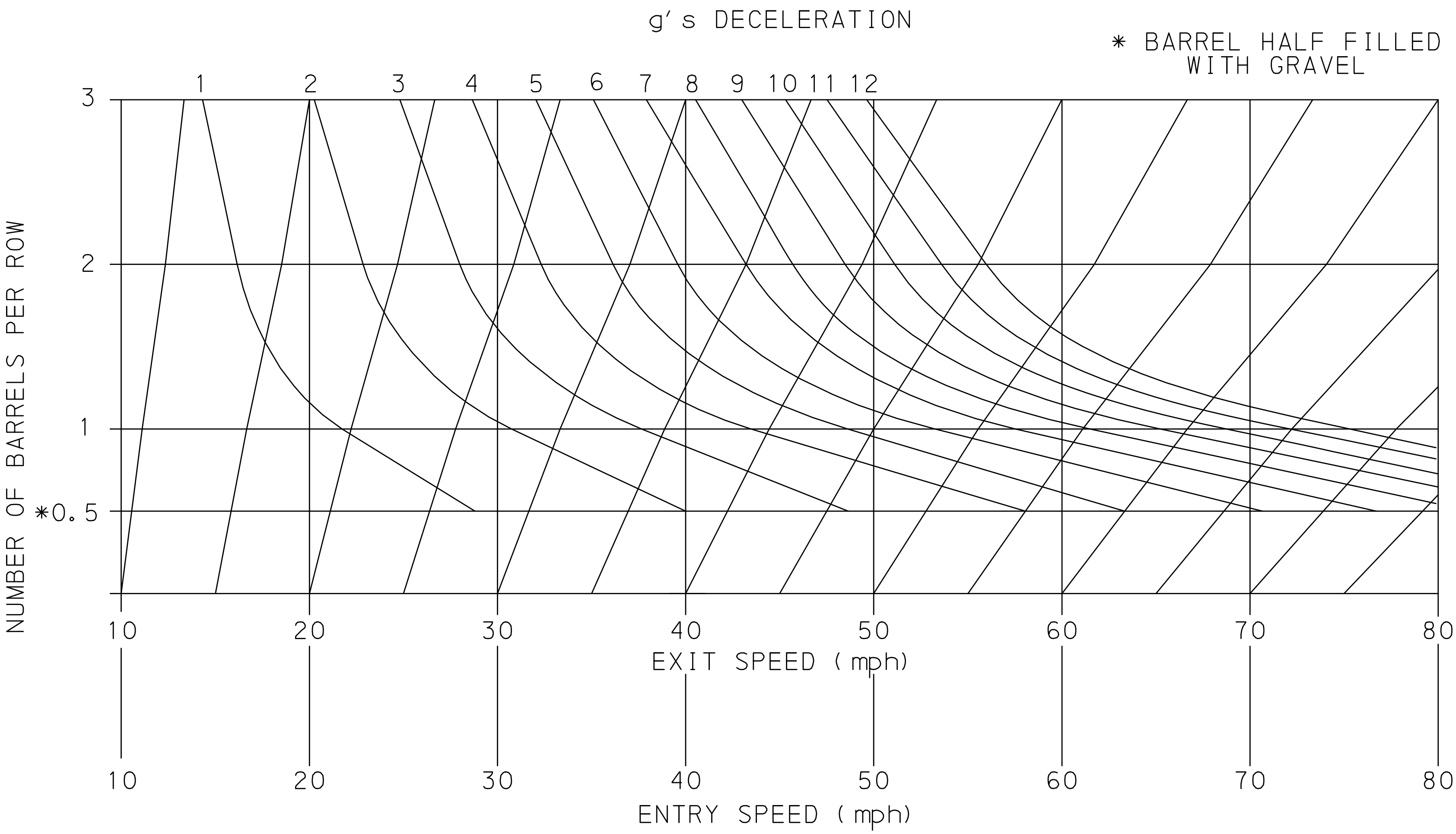


FIGURE 17.3 (ENGLISH)
DECELERATION CHART FOR AN 80,000 lb VEHICLE
USING 22.6 FT³ BARRELS FILLED
WITH RIVER GRAVEL (AASHTO NO. 57).

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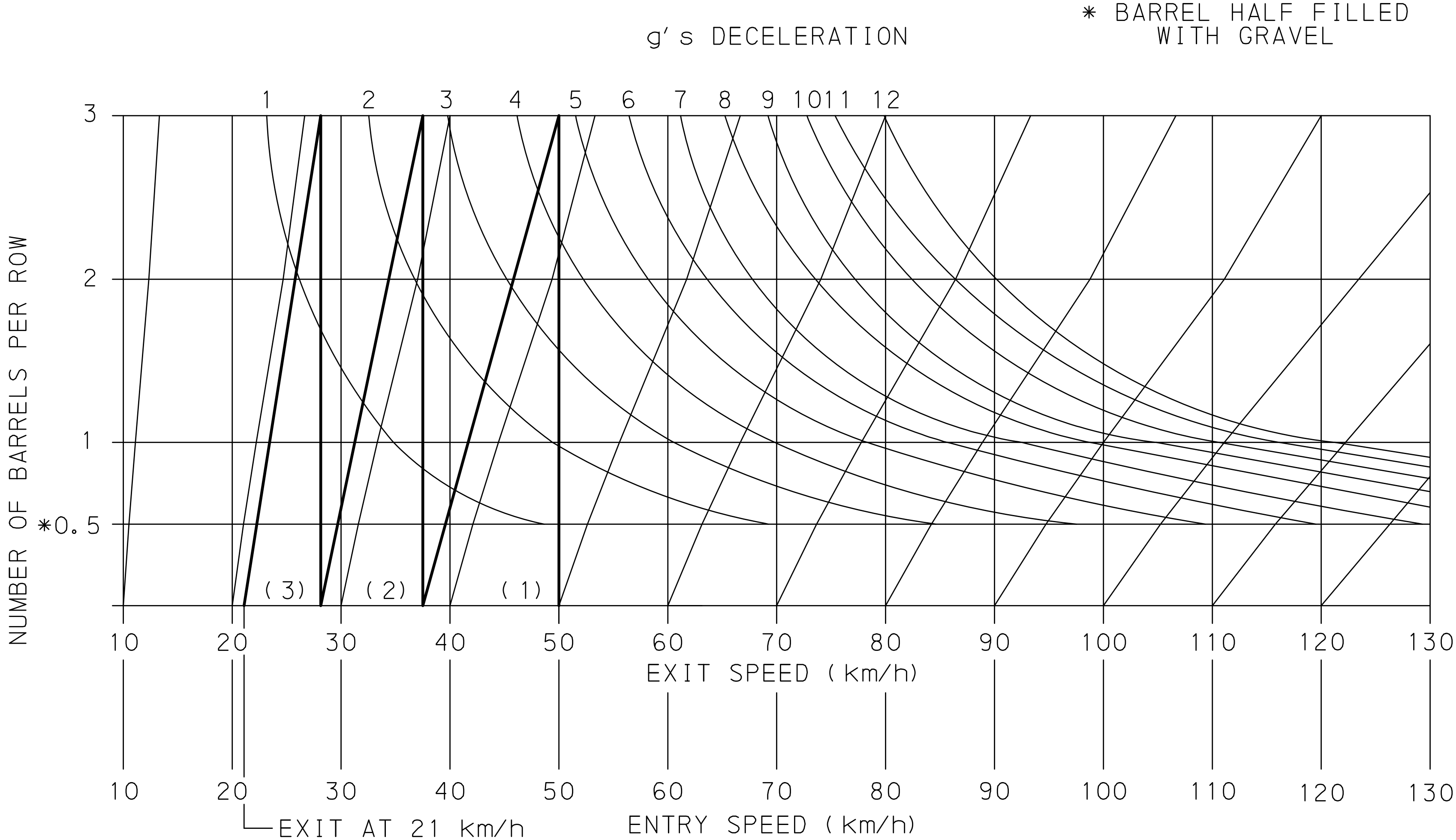


FIGURE 17.4 (METRIC)
EXAMPLE OF A 36 300 kg VEHICLE WITH AN ENTRY SPEED OF 50 km/h INTO 3 ROWS OF 3 BARRELS PER ROW AND AN EXIT SPEED OF 21 km/h

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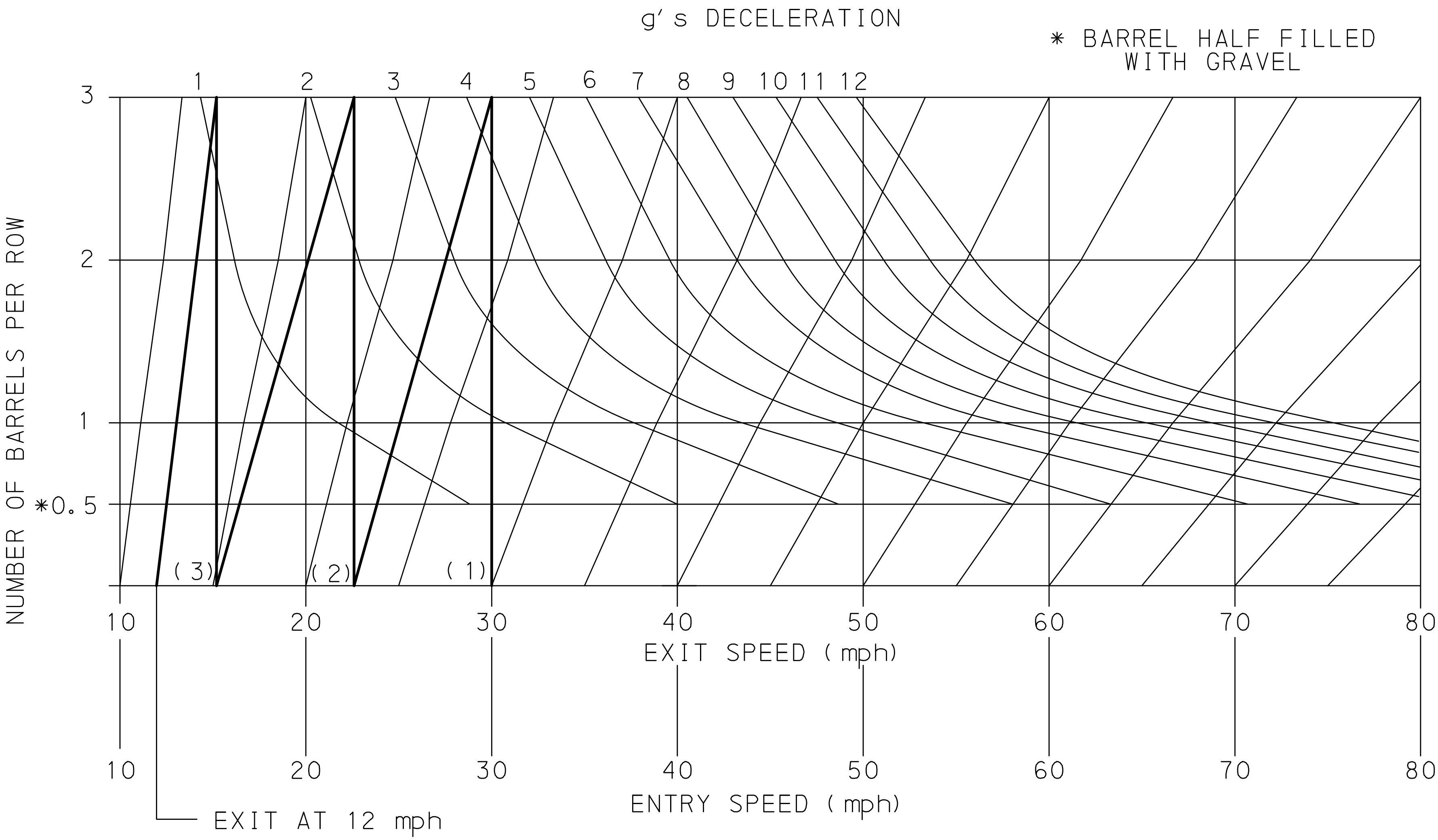


FIGURE 17.4 (ENGLISH)
EXAMPLE OF AN 80,000 lb VEHICLE WITH AN ENTRY SPEED OF 30 mph INTO 3 ROWS OF 3 BARRELS PER ROW AND AN EXIT SPEED OF 12 mph

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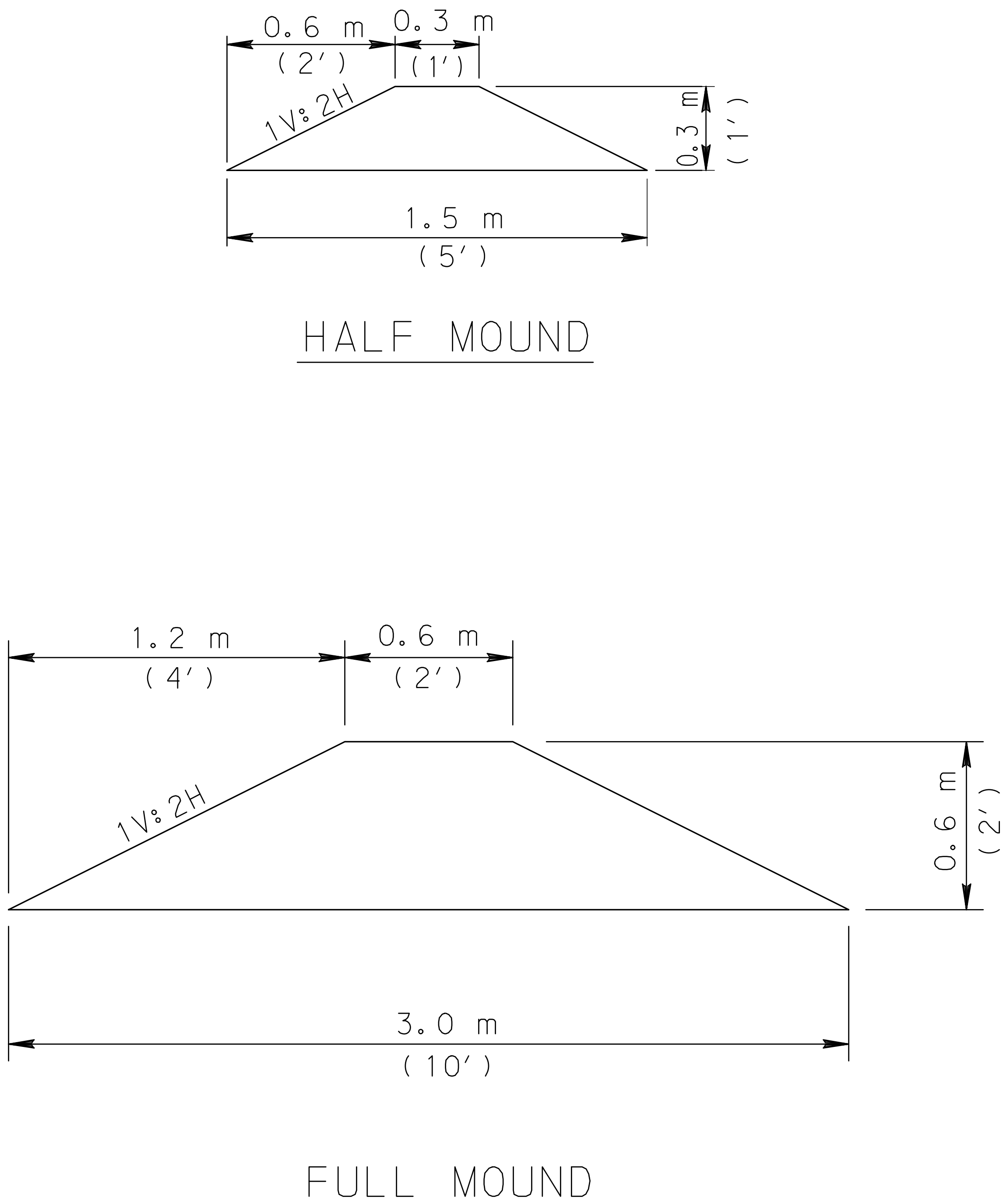


FIGURE 17.5
MOUND SIZES TESTED

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## TABLE 17.4
## D FACTORS FOR MOUNDS

| **MOUND TYPE** | **VEHICLE MASS (VEHICLE WEIGHT)** | | | | | |
|---|---|---|---|---|---|---|
| | 820 kg (1800 lb) | 2040 kg (4500 lb) | 6580 kg (14,500 lb) | 14 970 kg (33,000 lb) | 18 600 kg (41,000 lb) | 36 300 kg (80,000 lb) |
| **FULL** | 0.13 | 0.28 | 0.55 | 0.74 | 0.78 | 0.87 |
| **HALF** | 0.23 | 0.43 | 0.71 | 0.85 | 0.87 | 0.93 |

Tests have shown that mounds should not be placed nearer than 30 m (100 ft) into the bed. When a truck is still riding on top of the bed, it will ride up over the mound, giving high vertical acceleration. In the case of the full-sized mound, the truck can become airborne; however, once the truck sinks into the bed, it generally plows through the mounds.

Mound usage should be avoided, if possible. If they are used, however, they should be placed in the bed such that they will be hit at slow speeds, 40 km/h (25 mph) and less. Although barrels are more expensive than mounds, barrels are recommended.

**3.** Graphs for Designing Mounds. In the same manner used for the barrel designs, given previously, Figure 17.6 is used in the design of mounds. Figure 17.5 shows the cross sections for a full and a half mound. An example is shown in Figure 17.7 for a 36 300 kg (80,000 lb) vehicle traveling 70 km/h (45 mph) into a full mound. It has a peak deceleration of 2.8-g and exits at 61 km/h (38 mph). Although a deceleration force of 2.8-g is acceptable for the driver, the larger forces are on only the first (front) axle, and for a 36 300 kg (80,000 lb) vehicle, this deceleration gives a force of approximately 1020 kN (240,000 lb).

**D. Design with Combination Bed, Mounds and Barrels.** A bed design in combination with mounds or barrels or both requires the use of Figures 17.3, 17.6 and 17.8. Figure 17.8 is a replot of Figure 17.1 with the x and y axes interchanged. This figure can be used to illustrate the design; an example is shown for the 0% grade.

**METRIC EXAMPLE:** Suppose a bed is proposed to stop a 36 300 kg vehicle traveling at 100 km/h on a 0% grade. Consider a mound placed at 30 m and three rows of barrels at the end. For this example, Figures 17.9, 17.10 and 17.11 are used. First, from Figure 17.10, if the speed is reduced to 50 km/h when the barrels are reached, the exit speed due to the barrels alone is 21 km/h. Since the barrels are 2.7 m long, the 0% curve of Figure 17.11 shows that the remaining 21 km/h will be eliminated by the bed while traveling the 2.7 m. Thus, enough length of the bed plus the mound will be needed to get the speed down to 50 km/h.

Using Figure 17.11, a horizontal line should be drawn from the 100 km/h point until the 0% grade line has been intersected. The 0% grade line is then followed for 30 m from 103 m to 73 m, at which point the full mound has been reached. A horizontal line is then drawn to find that the speed is 86 km/h. Using Figure 17.9, an entrance speed of 86 km/h gives an exit speed of 75 km/h. When Figure 17.11 is re-entered at 75 km/h, the 0% curve is followed to 50 km/h, which is the speed reduction previously found for the three rows of barrels. Thus, the first 30 m of the bed (see Figure 17.11) plus 32 m (from 53 m down to 21 m) plus the 2 m at the end adds up to require a bed of 64 m.

**ENGLISH EXAMPLE:** Suppose a bed is proposed to stop a 80,000 lb vehicle traveling at 60 mph on a 0% grade. Consider a mound placed at 100 ft and three rows of barrels at the end. For this example, Figures 17.9, 17.10, and 17.11 are used. First, from Figure 17.10, if the speed is reduced to 30 mph when the barrels are reached, the exit speed due to the barrels alone is 12 mph. Since the barrels are 9 ft long, the 0% curve of Figure 17.11 shows that the remaining 12 mph will be eliminated by the bed while traveling the 9 ft. Thus, enough length of the bed plus the mound will be needed to get the speed down to 30 mph.

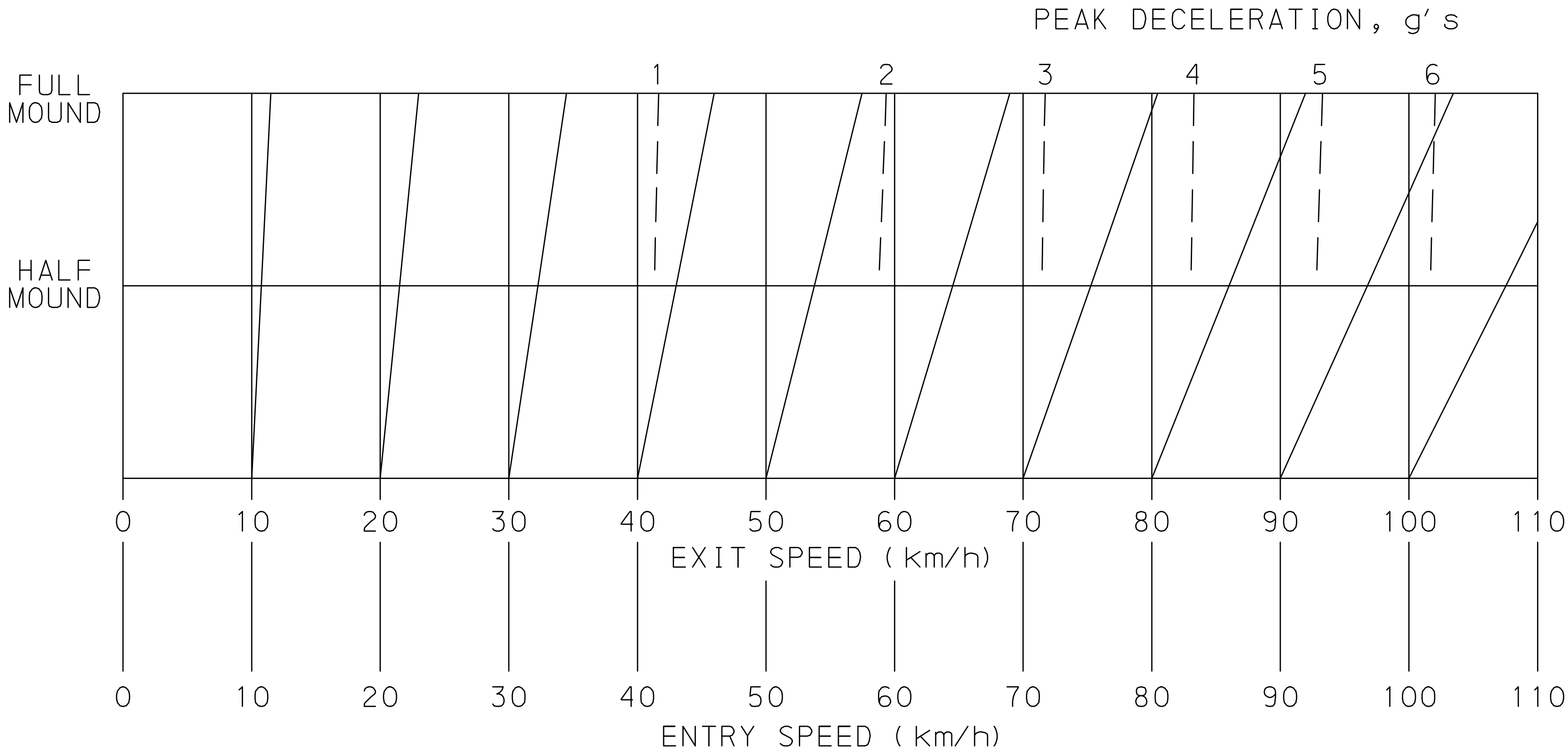


FIGURE 17.6 (METRIC)
DECELERATION CHART FOR A 36 300 kg VEHICLE
INTO A MOUND

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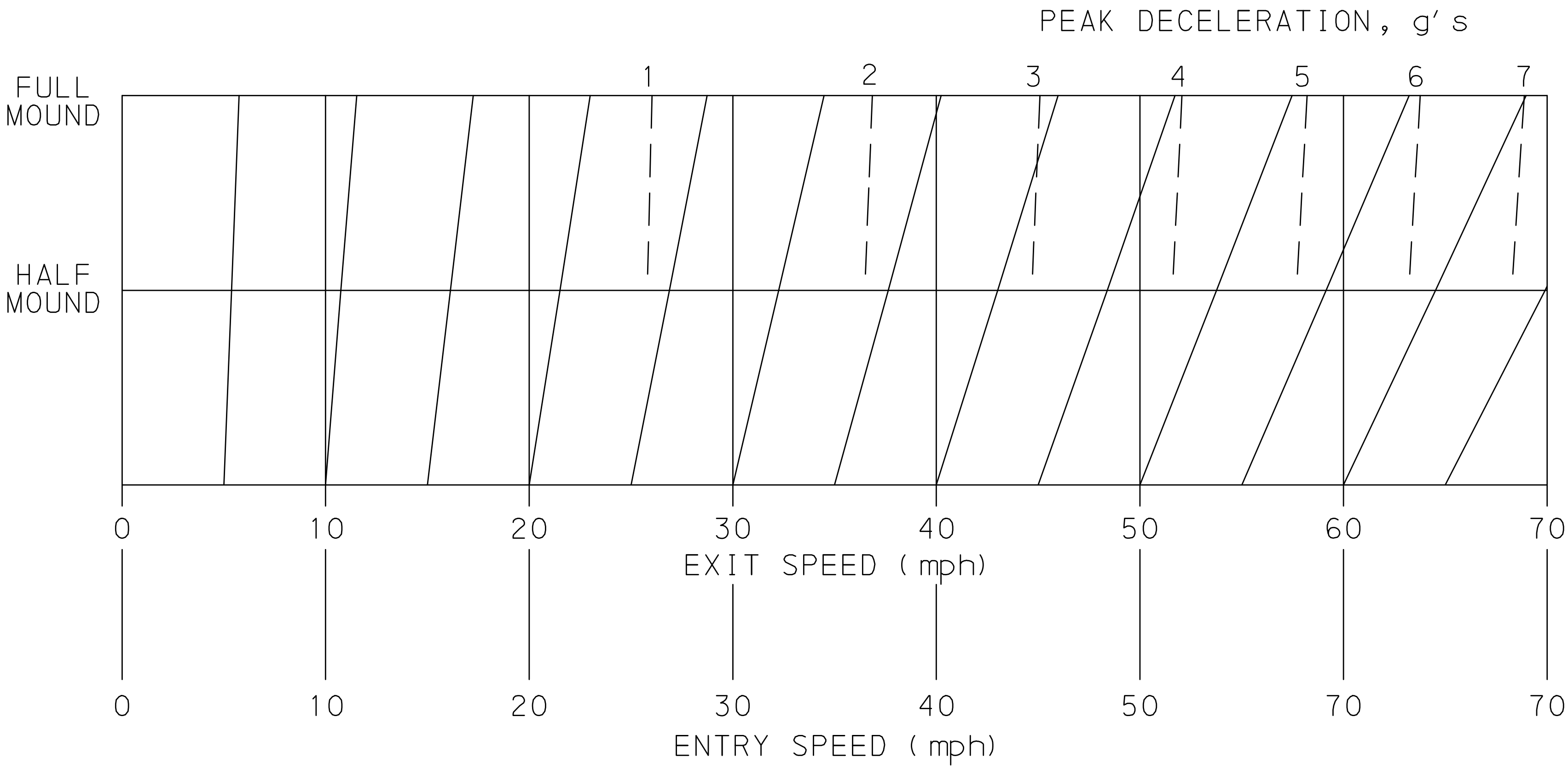


FIGURE 17.6 (ENGLISH)
DECELERATION CHART FOR AN 80,000 lb VEHICLE
INTO A MOUND

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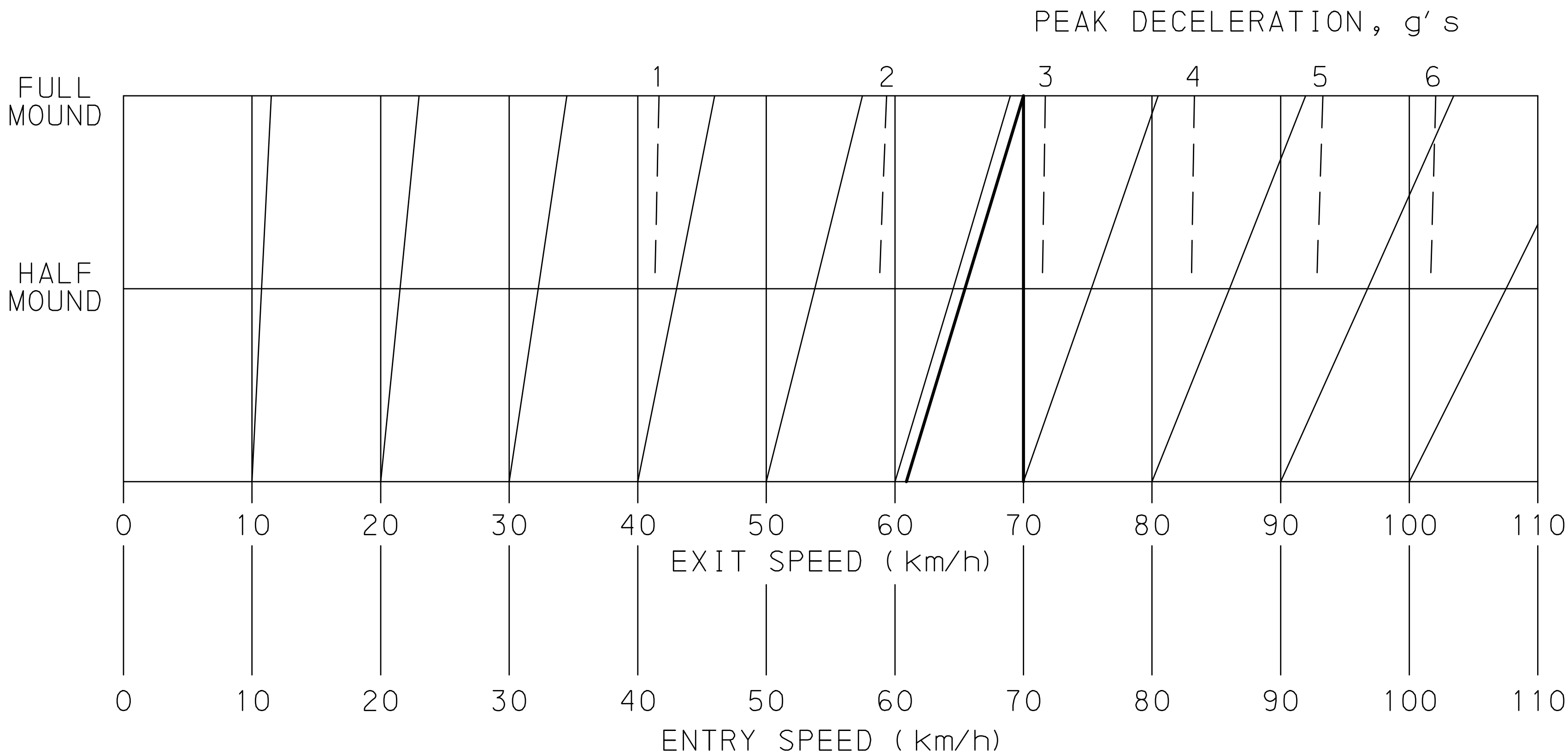


FIGURE 17.7 (METRIC)
EXAMPLE USING DECELERATION CHART FOR A 36 300 kg VEHICLE WITH AN ENTRY SPEED OF 70 km/h INTO A FULL MOUND

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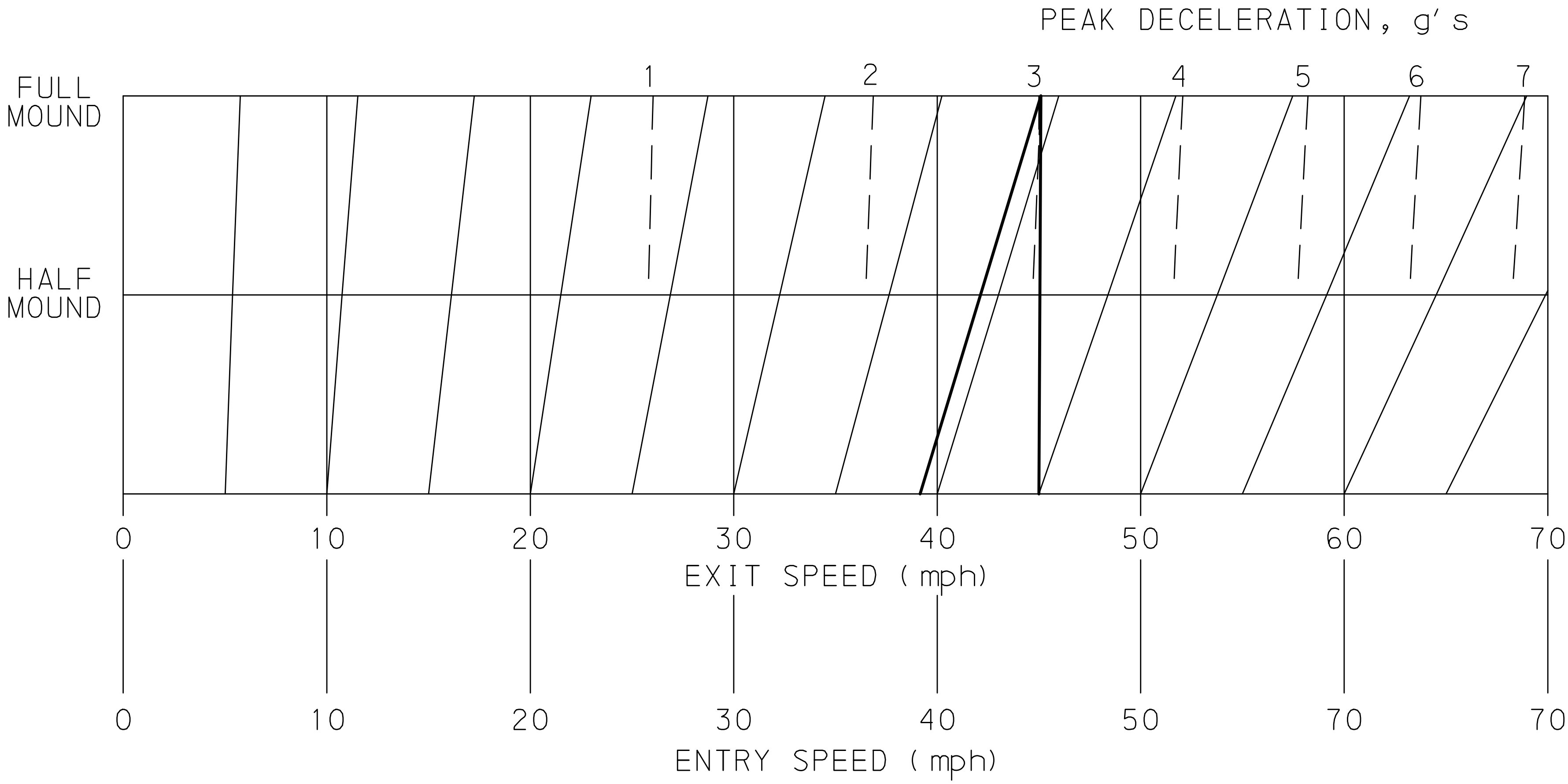


FIGURE 17.7 (ENGLISH)
EXAMPLE USING DECELERATION CHART FOR AN 80,000 lb
VEHICLE WITH AN ENTRY SPEED OF
45 mph INTO A FULL MOUND

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Using Figure 17.11, a horizontal line should be drawn from the 60 mph point until the 0% grade line has been intersected. The 0% grade line is then followed for 100 ft from 311 ft to 211 ft, at which point the full mound has been reached. A horizontal line is then drawn to find that the speed is 51 mph. Using Figure 17.9, an entrance speed of 51 mph gives an exit speed of 45 mph. When Figure 17.11 is re-entered at 45 mph, the 0% curve is followed to 30 mph, which is the speed reduction previously found for the three rows of barrels. Thus, the first 100 ft of the bed (see Figure 17.11) plus 105 ft (from 158 ft down to 65 ft) plus the 5 ft at the end adds up to require a bed of 198 ft.

When space permits, the bed length should be designed as required for the entry speed without regard to reduction in distance due to barrels or mounds. The barrels in this case would be provided as an added safety benefit at the end of the ramp.

**E. Bed Design.** The method for designing the length of an arrester bed was addressed in the previous section, along with the need to consider the grade of the bed and the use of barrels and of gravel mounds in the overall bed design. Other characteristics of the bed which must be considered for an effective design are the depth and width of the bed and drainage features. Also essential to the overall arrester bed operation is the installation of a concrete anchor block 15 to 30 m (50 to 100 ft) in front of the bed to act as a dead man for the tow vehicle used for truck extraction.

**1.** Bed Depth. A minimum of 1070 mm (42 in) is the recommended depth for beds of river gravel. Testing has shown that a bed with 915 mm (36 in) of river gravel gives the same results as a bed as deep as 2440 mm (8 ft). The minimum recommended depth includes 150 mm (6 in) to allow for compaction when the gravel contains many fines, especially if the bed is located where the potential for heavy use is great. Frequent use results in the significant increase in fines content, which decreases the effectiveness of the bed.

Smooth, rounded, uncrushed gravel of approximately a single size is the most effective arrester bed material. The best size is approximately 13 mm (0.5 in) in diameter.

The river gravel graded to AASHTO No. 57 was found to be the best of those materials tested if it had been washed so that fines were removed. A greater percentage of larger or smaller stones decreased the effectiveness and increased planning. Crushed stone should not be used because it provides a drag factor of about half that of rounded gravel and compacts more quickly. To be effective, crushed aggregate would require longer beds and fluffing almost weekly.

Rounded river gravel produces higher decelerations than the more angular crushed aggregate because the truck sinks into the river gravel more, transferring more energy to the stones over a shorter distance.

**2.** Bed Width. In general, a width of 6.6 to 7.5 m (22 to 25 ft) is recommended on the basis of an entry design which has a horizontal straightaway of at least one truck length, directing the vehicle in a straight line through the center of the bed. If the top of the bed is at ground level, a minimum width of 6.6 m (22 ft) would be sufficient. Conversely, if either side of the bed is a drop-off of any height, the bed should be wider. The vehicle's direction of momentum as it enters the bed is the direction it will travel through the bed; this direction should be the bed center line.

**3.** Bed Drainage. Proper drainage so that water does not stand in the bed is important. A 305 mm (12 in) base layer of large (at least 75 mm (3 in) in diameter) crushed limestone aggregate (AASHTO No. 1) will effectively drain the arrester bed. The stones should be confined to the layer by covering them with geotextile material (Type 3) to separate the larger stones from the river gravel. The cross slope of the base should be toward one side, with either subgrade drains or a crown for removing any water from the arrester layer. The river gravel covering this sloping base layer should have no cross slope at the top surface; i.e., the bed should be filled such that the top surface has no cross slope.

**F. Incidental Items.**

**1.** Service Road. A service road located adjacent to the arrester bed is recommended so the tow and maintenance vehicles can use it without becoming trapped in the bedding material. The typical width of this road is 3.0 m (10 ft).

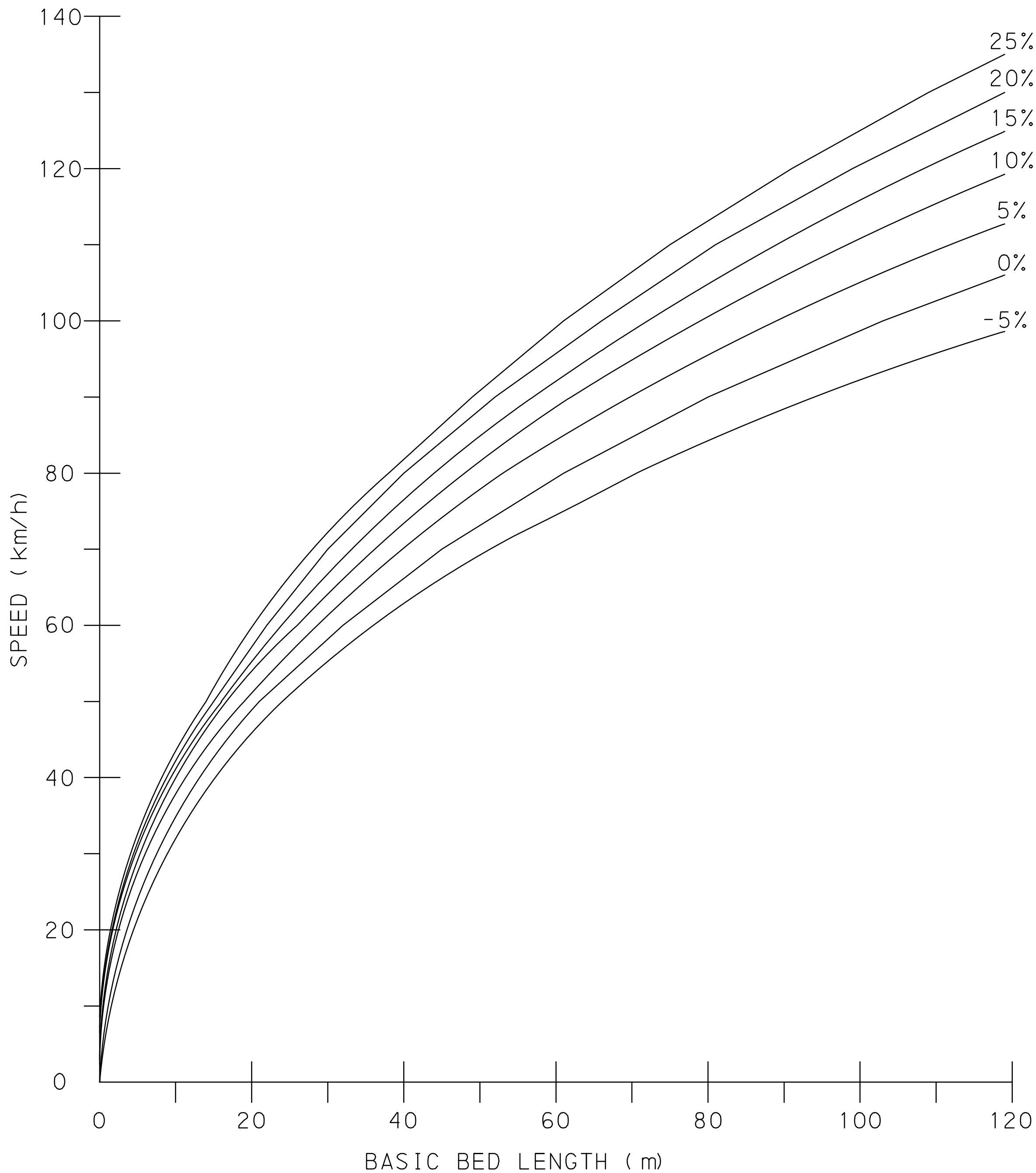


FIGURE 17.8 (METRIC)
EFFECT OF GRADE ON RIVER GRAVEL BED

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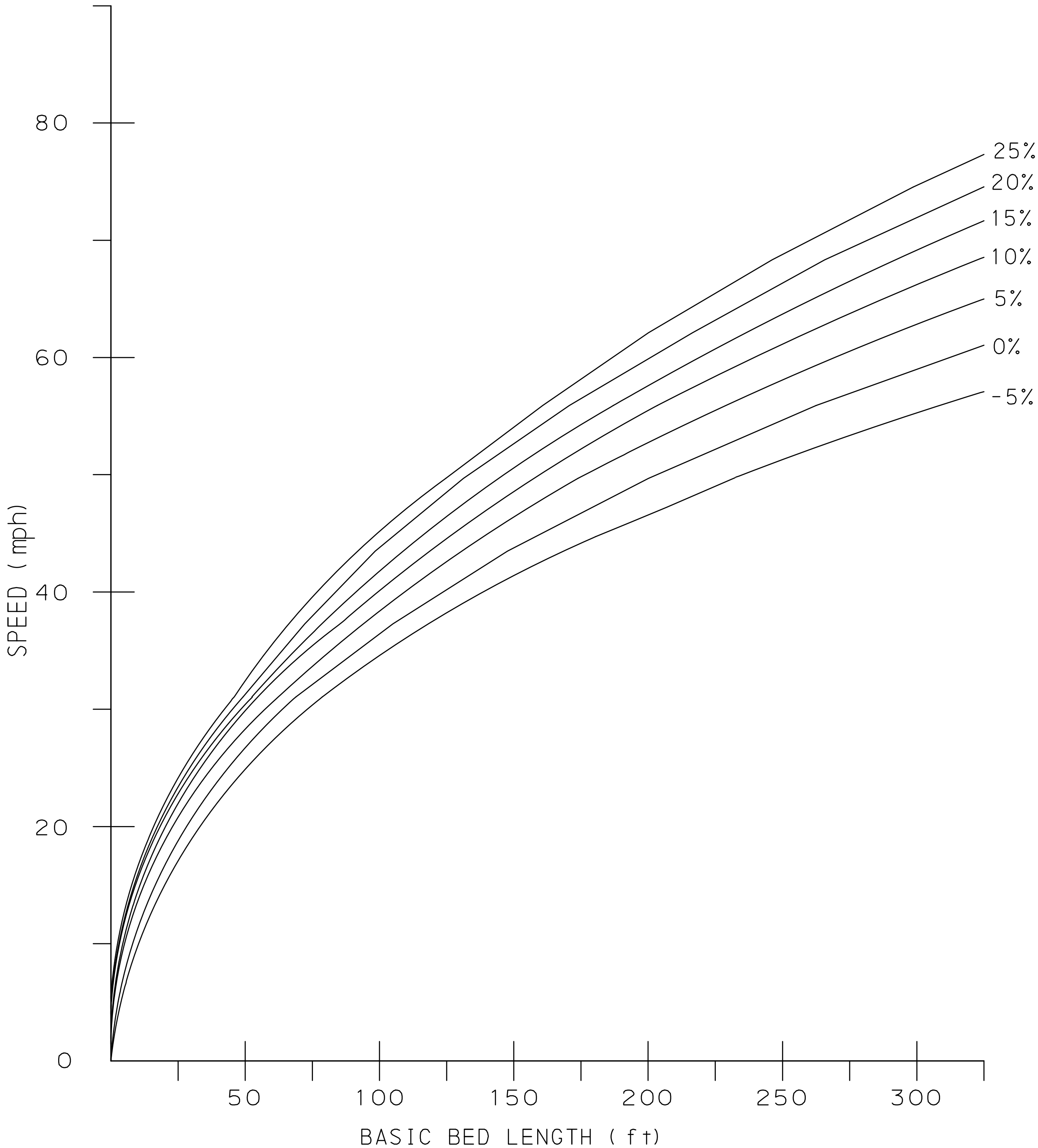


FIGURE 17.8 (ENGLISH)
EFFECT OF GRADE ON RIVER GRAVEL BED

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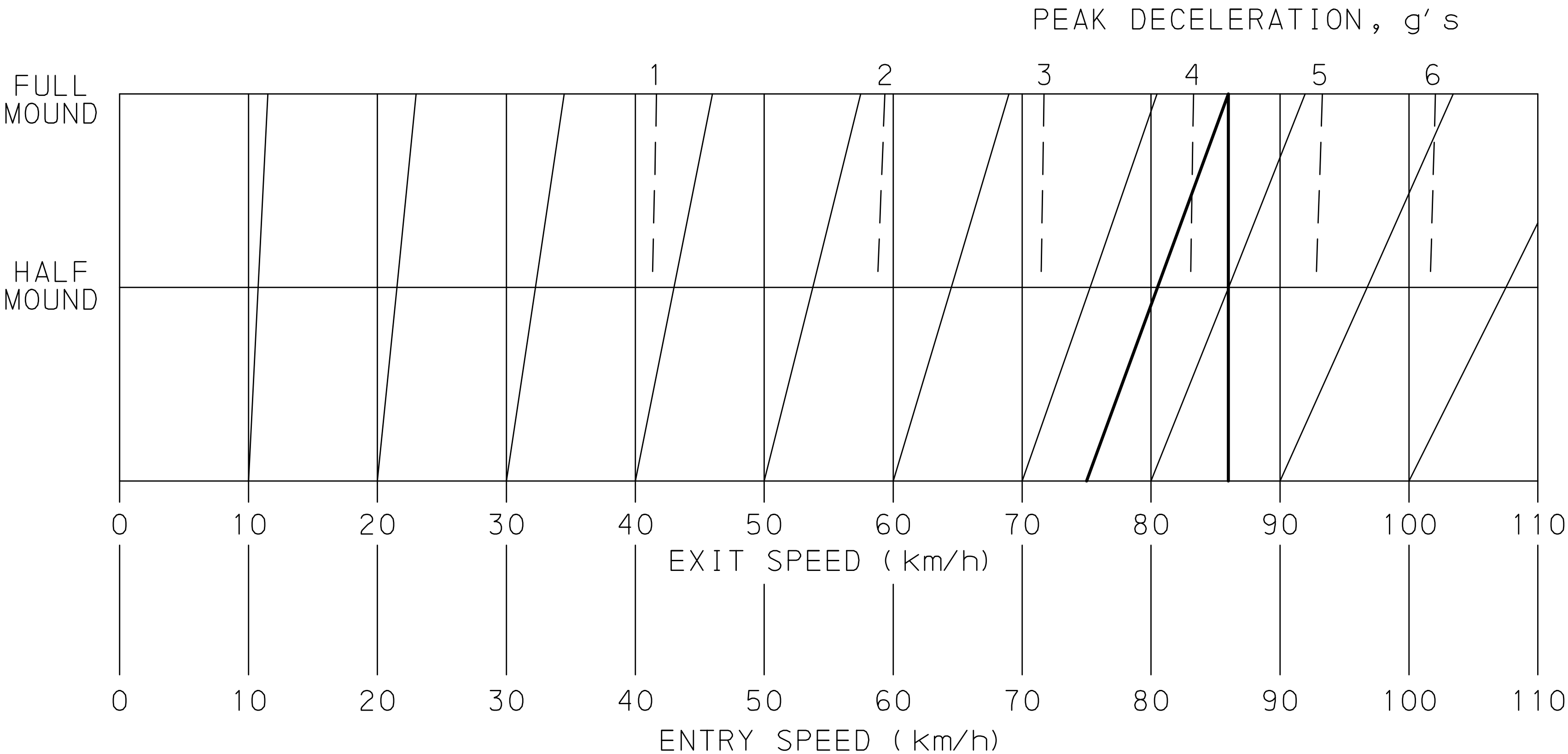


FIGURE 17.9 (METRIC)
EXAMPLE USING DECELERATION CHART FOR A 36 300 kg VEHICLE
INTO A FULL MOUND

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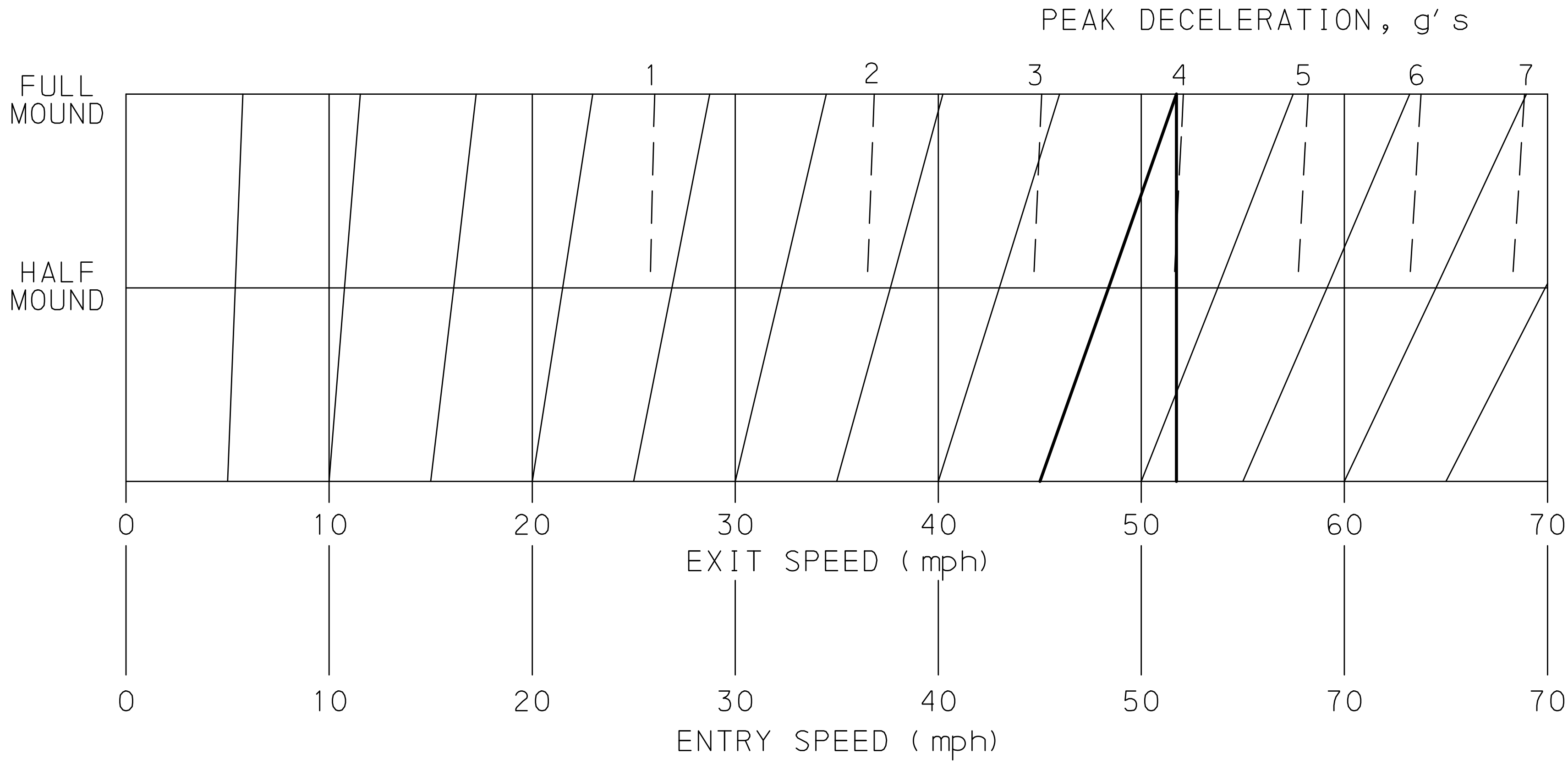


FIGURE 17.9 (ENGLISH)
EXAMPLE USING DECELERATION CHART FOR AN 80,000 lb VEHICLE
INTO A FULL MOUND

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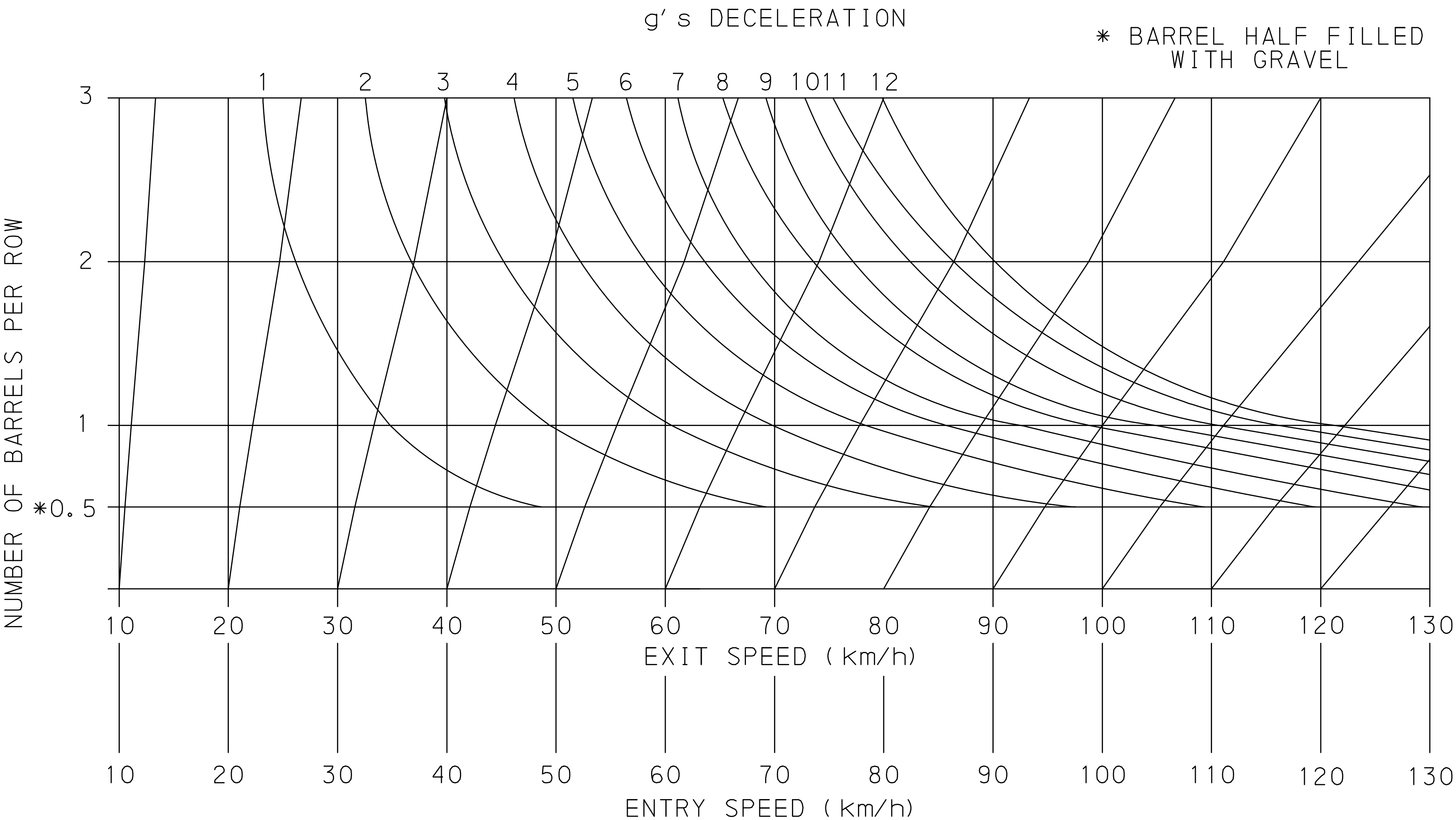


FIGURE 17.10 (METRIC)
EXAMPLE USING DECELERATION CHART FOR A 36 300 kg VEHICLE
USING 0.64 m³ BARRELS FILLED
WITH RIVER GRAVEL (AASHTO NO.57)

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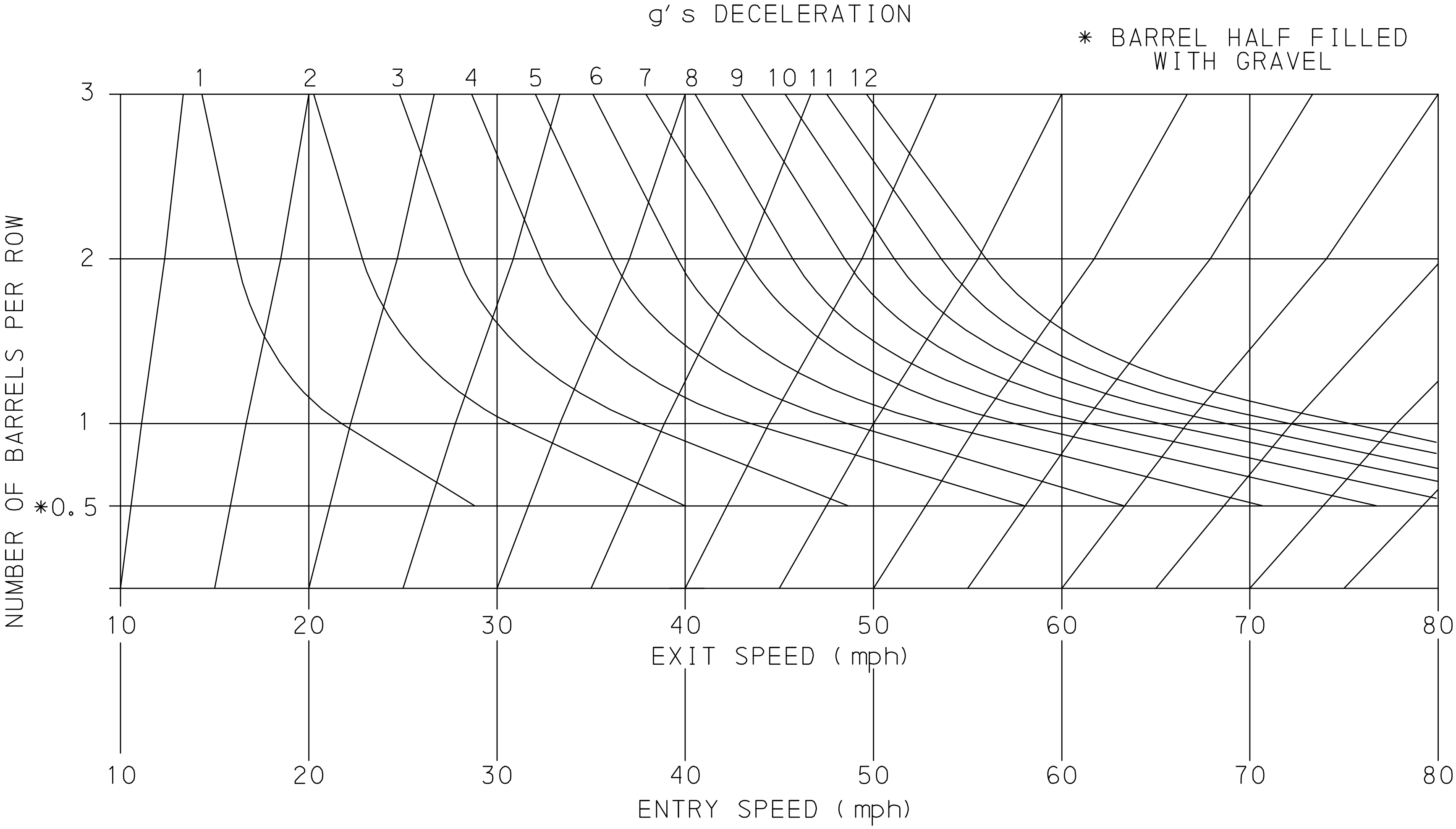


FIGURE 17.10 (ENGLISH)
EXAMPLE USING DECELERATION CHART FOR AN 80,000 lb VEHICLE AND 22.6 $ft^3$ BARRELS FILLED WITH RIVER GRAVEL (AASHTO NO. 57)

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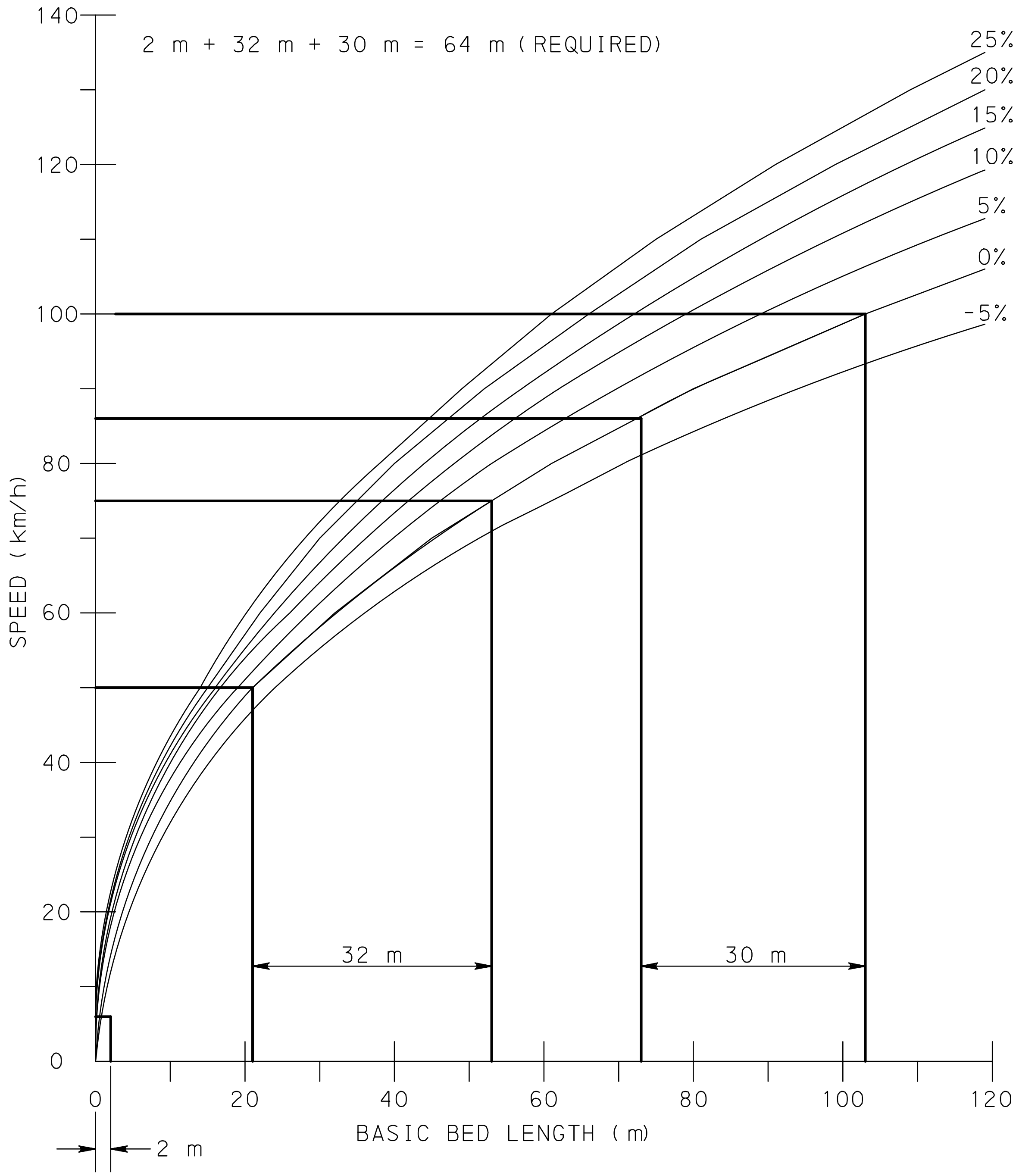


FIGURE 17.11 (METRIC)
EXAMPLE USING DESIGN CURVE
FOR O-PERCENT GRADE

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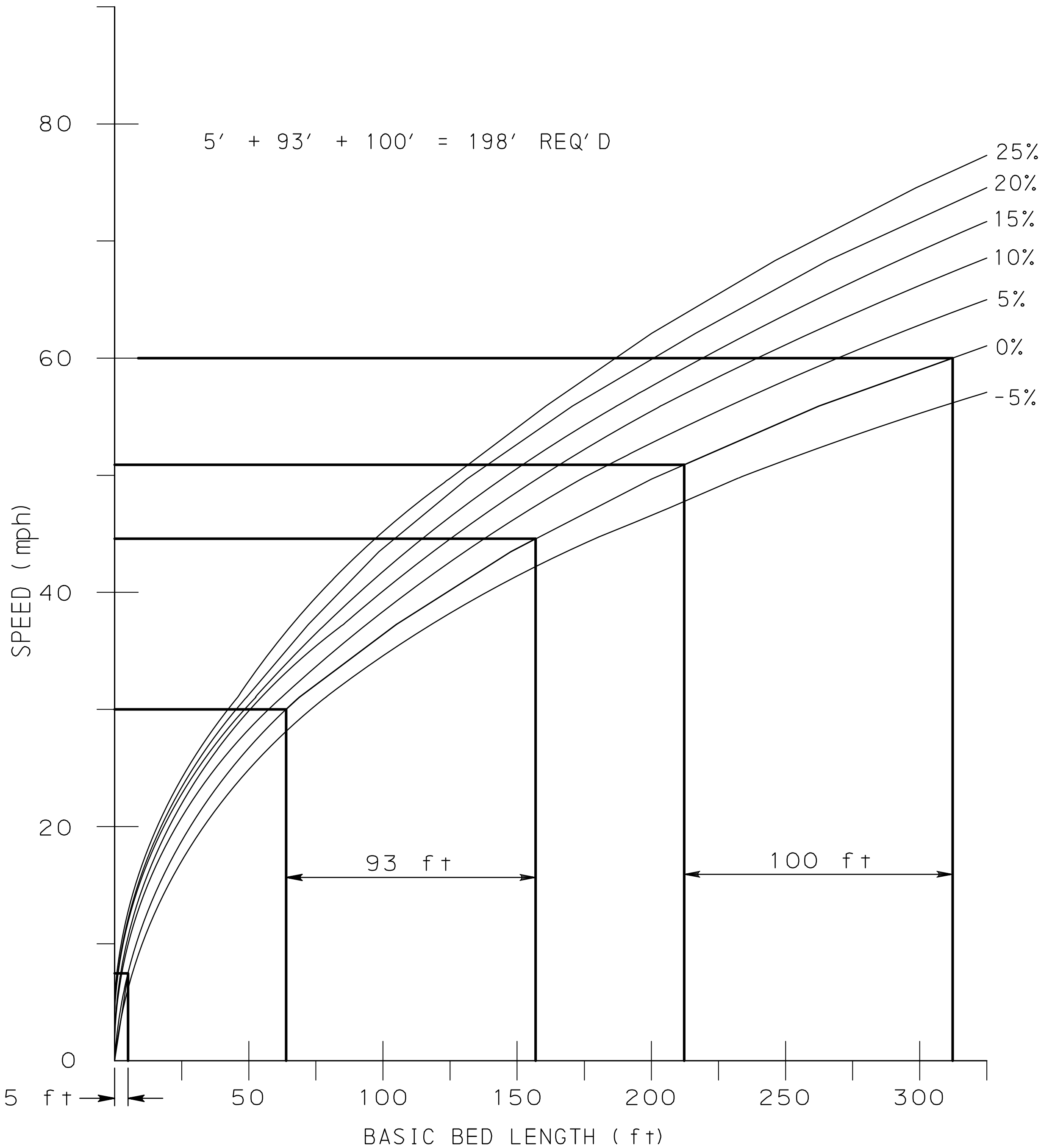


FIGURE 17.11 (ENGLISH)
EXAMPLE USING DESIGN CURVE
FOR 0-PERCENT GRADE

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**2.** Concrete Anchor Block. Every escape ramp must include a concrete anchor block to which a tow vehicle can attach when it pulls an arrested vehicle from the gravel bed. The anchor provides a necessary dead man which can withstand the retraction loads required to pull an arrested vehicle from the ramp bed. Retraction loads range from 25-100% of the gross vehicle mass (weight) and are generally about 50%. Thus, for example, a load of more than 18 140 kg (40,000 lb) may be required to extract a loaded tractor trailer. During some tests, towing service personnel who did not believe the anchor would be necessary found that the tow truck, rather than the captured vehicle, was moved during extraction attempts. In one such case, the paved approach was damaged. Thus, it is recommended that every escape ramp include an anchor block such as that shown in Figure 17.12, and should be located at the center and flush with the road surface 15 to 30 m (50 to 100 ft) from the start of the bed. Additional blocks may be needed, depending on the length of the escape ramp. Towing services should be required to use the anchor block.

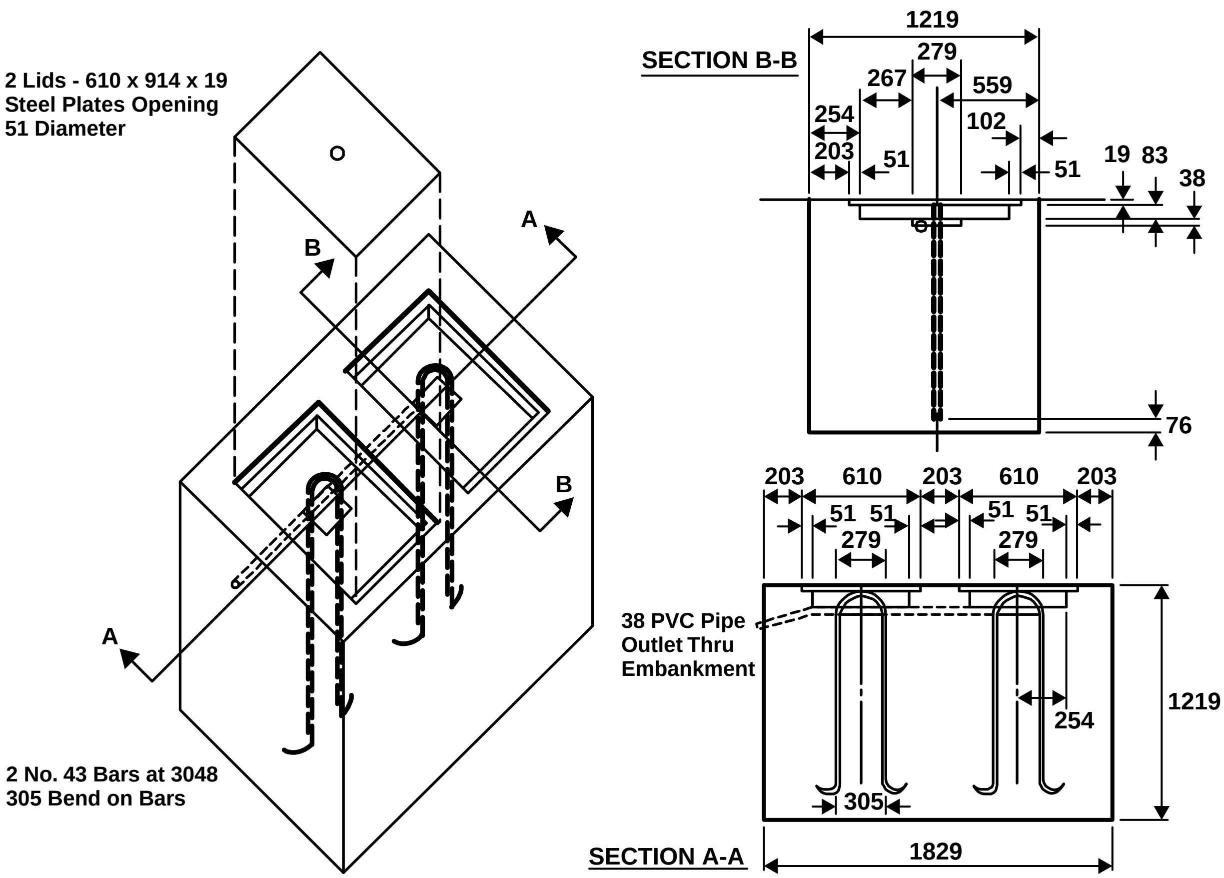
**3.** Gravel Fluffer. To preserve its original density, the gravel bed should be fluffed by a device capable of breaking up the compacted areas. A typical mechanical device is shown on Figure 17.13. This device, designed by PTI, consists of a sled with prongs that extend down into the gravel bed. As the sled is pulled through the bed, its prongs break up the compacted areas. One important element of a fluffer is adequate mass (weight) to break up the compacted area at the required depth.

**4.** Extraction. Extraction should be performed with a wrecker and a winch. The front of the wrecker must be chained to a dead man anchor block, and the winch must be used with a block and tackle that has at least a two to one mechanical advantage.

After the vehicle being extracted from the bed begins to move, it can be raised onto 50 mm × 150 mm (2 in × 6 in) boards to greatly reduce the drawbar pull required to remove the vehicle from the bed and, correspondingly, the pull loads on the vehicle and its axles. At least two boards per wheel set should be used so that, as a wheel rolls off one board, it will roll onto the next board. As the wheel then rolls clear of the first board, that board can be placed in front of the second board, which can then be moved in front of the first board, and so on, in a leapfrog fashion.

When the captured vehicle has wheel flaps, an important note of caution must be heeded. Flaps must be removed or tied such that they will not wrap around the wheel between the stones and the tire. Only a turning wheel will ride up onto the aggregate rather than dig into them, and a barrier between the stones and tire will prevent the wheel from turning. Consequently, when the wheel flaps provide such a barrier, the wheel generally digs deeper into the stones, thus creating a need for greater force to pull the vehicle.

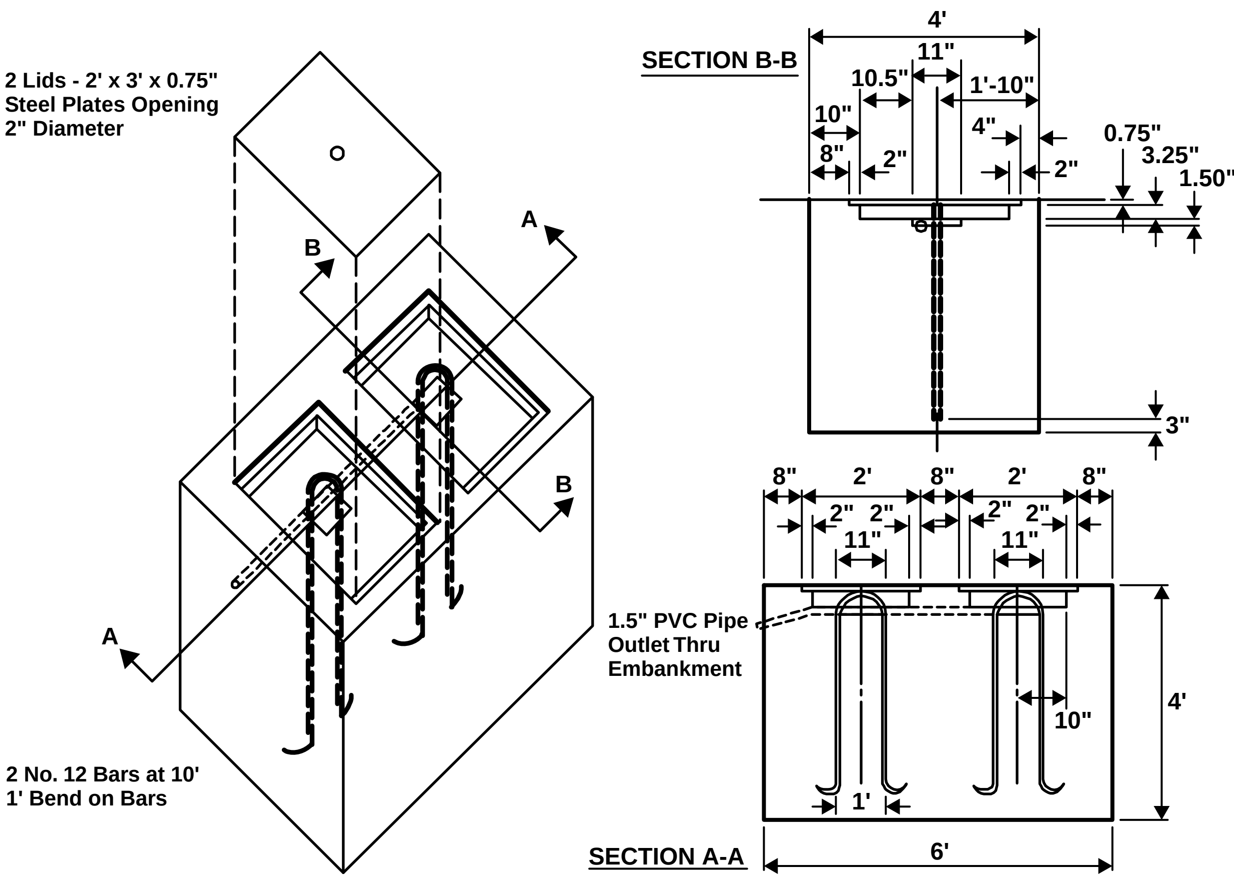
**G. Maintenance.** All of the beds were found to compact with time depending on the durability of the stone. During the design phase, consideration should be given to access by maintenance vehicles to fluff and maintain escape ramps in good operating condition. For maintenance details and requirements, refer to the Maintenance Manual.




Note: All Dimensions are in Millimeters (mm) Except as Noted.

**FIGURE 17.12 (METRIC)**

**Design of a Concrete Anchor Block Dead Man**




## FIGURE 17.12 (ENGLISH)
# Design of a Concrete Anchor Block Dead Man

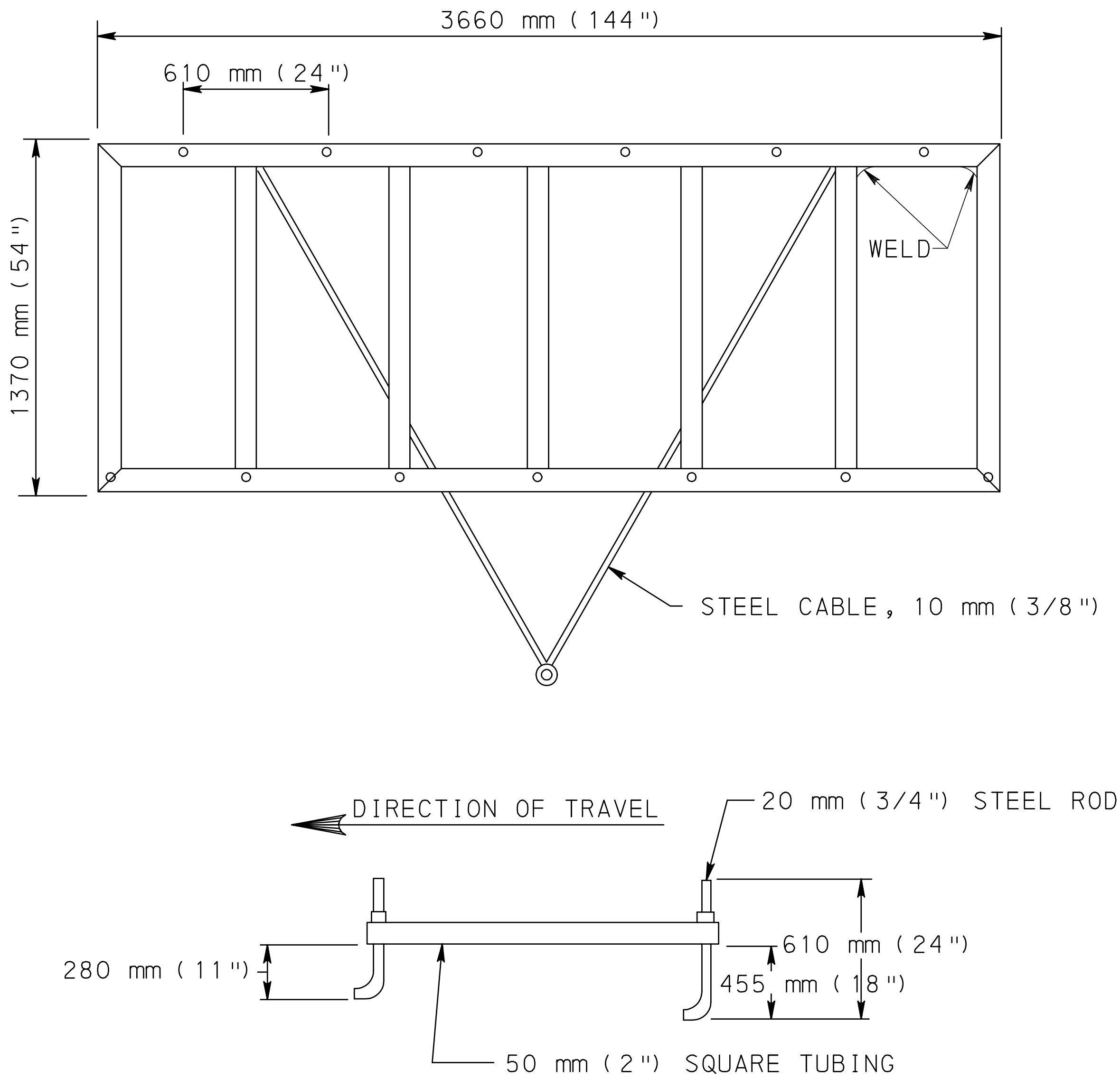



FIGURE 17.13
LAYOUT OF THE GRAVEL FLUFFER DESIGN

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# CHAPTER 18

## TEMPORARY ROADS AND BRIDGES

### 18.0 INTRODUCTION

These guidelines are to be used to design temporary roads and bridges where traffic will be maintained at the construction site of a bridge replacement or rehabilitation project on a two-lane highway. These guidelines are not recommended for four-lane highways or situations which require high speed transitions.

Temporary roads and bridges do not have to be designed as a permanent facility since they will only be in use for a short time (often only a few months or one construction season).

Each temporary road and bridge is to be designed to be compatible with the existing site conditions, the volume and composition of the traffic being maintained and an acceptable operating speed for the temporary condition.

Designs must consider the location of existing utility facilities and their proposed relocations to avoid or reduce interference with these utility facilities.

Any temporary right-of-way or easements required for temporary roads and bridges are to be determined and included in the project Right-of-Way Plan so it can be acquired as part of the overall right-of-way.

Public Utility Commission approval will be required for construction of temporary roads or bridges across railroads.

Engineering judgement is to be used with these guidelines. If the existing site readily lends itself to a temporary road design with design features higher that the minimums of these guidelines, do not force the design down to these minimums.

Thorough consideration of the composition of the maintained traffic is important. Logging trucks, large coal trucks or large recreational vehicles, for example, can impose requirements that will dictate the design.

Dimensions given in these guidelines are to be considered minimums, which may have to be increased to provide a design compatible with specific project conditions.

The decision to maintain traffic at the site of a bridge project or to provide a detour or other option is to be made in accordance with Publication 10C, Design Manual, Part 1C, *Transportation Engineering Procedures,* Chapter 3.

Environmental evaluation of temporary roads and bridges is to be performed as part of the evaluation of the permanent bridge construction project. Current Department policy regarding environmental evaluations of temporary roads and bridges is to be followed (see Publication 10C, Design Manual, Part 1C, *Transportation Engineering Procedures*, Chapter 3.)

Each project that requires a temporary road or bridge will include temporary road and bridge special provisions in the proposal, specifically prepared for that project.

### 18.1 DEFINITIONS

For the purpose of these guidelines, the following definitions apply:

**1.** Temporary Stream Crossing. A temporary crossing of a stream with multiple pipes, pipe arches or similar conduits covered with fill material.

**2.** Temporary Bridge. A temporary crossing of a stream or other topographic feature consisting of a bridge superstructure with an appropriate substructure.

**3.** Temporary Road. A temporary roadway forming the approaches to a temporary stream crossing or temporary bridge.

## 18.2 TRAFFIC CONTROL

Adequate advance warning signs and informational and regulatory signing on the temporary road itself is very important. If warranted, rumble strips, additional signing, regulatory speed control, painted pavement edge lines, warning lights, temporary lighting (dusk to dawn or generator-driven construction lights) or similar devices should be specified. Appropriate narrow bridge or bridge posting signs must be incorporated, as required.

The transition from the existing highway to the temporary road is highly critical. Drivers should not be surprised by an unexpected situation where there is insufficient time to make a proper decision or maneuver.

A Traffic Control Plan shall be prepared as required by Publication 212, *Official Traffic Control Devices*, and Publication 213, *Temporary Traffic Control Guidelines,* and made a part of the Plans, Specifications, and Estimate (PS&E) for the project. Coordination with the District Traffic Unit during design is important to insure that proper traffic control devices are incorporated.

## 18.3 TEMPORARY ROAD

Temporary roads can be single-lane or two-lane. Single-lane temporary roads can be used if they provide adequate capacity to handle the traffic.

**A. Single-Lane Temporary Road.** Single-lane temporary roads can be considered when a study/capacity analysis indicates that any resultant traffic backup (queue) will be acceptable.

Traffic on single-lane temporary roads can be controlled by stop signs or traffic signals.

Obtain peak hour traffic counts to use with the Highway Capacity Manual to perform capacity analyses, when necessary.

**1.** Stop Sign Control. Consider controlling traffic with stop signs, placed at both ends of the single lane, when the Average Daily Traffic (ADT) is approximately 1500 vehicles per day or less and the length of temporary road is approximately 45 m (150 ft) or less.

Use stop signs only if sight distance is available so that vehicles stopped at each end of the temporary road can clearly see each other.

In fog-prone areas, do not use stop sign control, use traffic signal control.

For ADTs slightly under or above 1500 vehicles per day and/or temporary road lengths greater than 45 m (150 ft), perform a study/capacity analysis to determine if traffic queues will be acceptable.

**2.** Traffic Signal Control. Consider using traffic signals for traffic control of single lanes, where stop sign control is not acceptable.

Perform a study/capacity analysis, using hourly volumes, to determine if traffic queues will be acceptable.

If traffic signal control can not be used, a two-lane temporary road should be provided.

**3.** Geometry. Abrupt, sharp curvature in the transition area from the existing highway to the temporary road is to be avoided.

Clear sight distance to the stop sign or traffic signal, on the approach to these traffic control devices, is essential. Sight distance and adequate length of roadway to bring a vehicle to a complete stop from its operating speed must be provided. Consider the placement of any guide rail, barrier or temporary signing when checking for clear sight distance.

Any vertical curves must provide headlight stopping sight distance to satisfy this requirement.

The entire length of the temporary road, between the stop signs, should be visible to a driver stopped at the stop sign.

Where traffic signals are used, a study should be performed by the designer (in coordination with the District Traffic Unit) to determine the acceptable operating speed through the temporary road area. It is recommended that a minimum operating speed of 25 km/h (15 mph) be provided.

**4.** Pavement and Shoulder Width. The minimum pavement width recommended for single-lane roadways is:

ADT of 500 or less = 3.0 m (10 ft)
ADT greater than 500 = 3.6 m (12 ft)

Minimum shoulder widths of 0.6 m (2 ft) are recommended.

When selected material surfacing is specified for pavement material, paving should be provided for the entire pavement and shoulder width. Minimums would be:

ADT of 500 or less = 4.2 m (14 ft)
ADT greater than 500 = 4.8 m (16 ft)

When higher-type pavement material is specified, consider paving the entire pavement and shoulder width, if this is more economical than constructing separate shoulders of different material.

Pavement widths may have to be widened, through horizontal curves, to provide adequate turning radii for trucks.

**B. Two-Lane Temporary Road.** When a single-lane temporary road cannot adequately handle the traffic, two-lane temporary roads will be used.

**1.** Geometry. In the transition area from the existing highway to the temporary road, the horizontal curvature should be designed so that the operating speed of a vehicle will be reduced by no more than 25 km/h (15 mph).

Clear sight distance that permits the driver to see the transition and appropriate advance signing is important.

Provide appropriate superelevation for the operating speed within the transition curvature.

**2.** Pavement and Shoulder Width. The minimum pavement width recommended for two-lane roadways is:

ADT of 8,000 or less = 6.0 m (20 ft)
ADT greater than 8,000 = 6.6 m (22 ft)

Minimum shoulder widths of 0.6 m (2 ft) are recommended.

When selected material surfacing is specified for pavement material, paving should be provided for the entire pavement and shoulder width (a minimum of 7.2 m (24 ft)).

When a higher-type pavement material is specified, consider paving the entire pavement and shoulder width if this is more economical than constructing separate shoulders of different material.

Pavement widths may have to be widened, through horizontal curves, to provide adequate turning radii for trucks.

**C. Guide Rail.** Guide rail is to be provided on temporary roads when required for embankment protection, protection at roadside obstacles (especially where the obstacles are potentially hazardous because of roadway geometry) and non-traversable hazards (such as permanent bodies of water). Refer to Chapter 12.

Guide rail connection to bridge railing of temporary bridges and appropriate runout of the guide rail is to be provided.

Concrete median barrier may be used for guide rail, especially if temporary stream crossings have a minimum fill (cover) over the pipes which would cause interference with driving guide rail posts. If concrete barrier is used, the effect on sight distance must be checked carefully to ensure that it is acceptable.

If there is a concern that concrete median barrier would act as a dam if high water overtopped a temporary stream crossing, an alternative is to use guide rail attached to a concrete slab as per Publication 72M, *Roadway Construction Standards*, for use over buried or underground structures.

**D. Side Slopes.** Generally, side slopes, in cut or fill sections on temporary roads, are to be as steep as feasible, based on the stability of the soil and rock involved. Slopes of 1V:1H are considered maximum, with flatter slopes to be used if necessary.

Gabions may be specified to retain slopes, but not as a bridge abutment.

**E. Pavement Type and Shoulder Type.** Pavement and shoulders of temporary roads are to be maintained in a smooth condition during use. Special provisions for adequate maintenance and dust control must be included in the PS&E.

**1.** Selected material surfacing is recommended as the pavement material for temporary roads with low ADTs and/or low speeds.

**2.** Consideration can be given to using adequately compacted milled bituminous material as the pavement material to control potholes and dust and for medium ADTs.

**3.** For higher ADTs, consideration should be given to using bituminous material as the pavement material. Bituminous concrete base course, without a top material, will normally be adequate for the short period of time the temporary road will be in use.

**4.** Selected material shoulders are recommended as a minimum. Compacted milled bituminous material and higher type shoulders should be considered if a high-type pavement is used.

**5.** Pavement and shoulder thicknesses should be determined based on ADT, percent of trucks, expected life of the temporary road and stability of the subgrade, in consultation with the District Materials/Geotechnical Engineer and Pavement Engineer.

## 18.4 TEMPORARY BRIDGE

Temporary bridges will be designed using current Department bridge design methodology found in Publication 15M, Design Manual, Part 4, *Structures*, Volume 1, Part A, Chapter 5, including consideration of geometric constraints (truck turning patterns, etc.) as per this Manual.

**18.5 WATERWAY OPENING - PA DEP PERMIT**

The application for the Pennsylvania Department of Environmental Protection's (PA DEP) Waterway Obstruction Permit must include the proposed waterway opening for the temporary bridge or crossing. This required waterway opening is to be designed so that the temporary condition will not cause any significant damage by flooding adjacent property.

**A. Temporary Stream Crossing (Pipes).** The minimum flood that can be used is for the 2.33-year design storm ($Q_{2.33}$). A greater recurrence interval (such as the 10-year design storm ($Q_{10}$)) shall be used if warranted by site conditions and engineering analysis.

**B. Temporary Bridge.** Refer to Publication 15M, Design Manual, Part 4, *Structures*, Volume 1, Part A, Chapter 5 for guidelines to size the waterway opening.

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# CHAPTER 19

## CONSIDERATIONS FOR ALTERNATIVE TRANSPORTATION MODES

### 19.0 INTRODUCTION

Many of the Commonwealth's transportation corridors must not only consider vehicular movements, but also the movement of people, distribution of goods, and provision of essential services. The needs of bicyclists, pedestrians, and transit users must be considered in designing all roadway projects. Sidewalk networks should be well connected with opportunities for regular, safe street crossings. On collector and arterial roadways, bike lanes or wide curb lanes can encourage people to bike rather than drive for short and moderate distance trips. If a roadway is designed to discourage vehicular speeding, it can be comfortably used by pedestrians and bicyclists alike. Transit-friendly design should support a high level of transit activity. By encouraging alternative transportation, communities can reduce vehicular trips and minimize congestion.

It should be acknowledged that there are potential trade-offs between vehicular mobility and bicycle, pedestrian, and transit mobility. A balance should be sought in attaining these goals on all projects.

The following sections discuss considerations for providing pedestrian facilities, bicycle facilities, and public transportation. Specific guidance on selecting design values is provided for bicycle facilities in Chapter 16 and for pedestrian facilities in Chapter 6.

### 19.1 BICYCLE FACILITIES

Reconstruction or restriping projects for arterial and collector roadways should consider the best means of accommodating bicyclists. Guidance on selecting a bicycle facility should be provided by a bike network plan that identifies the most important bicycle generators in the community, and provides recommendations on how to best accommodate bicyclists between those destinations. Bicycle generators include schools, parks, major shopping areas, employment centers, transit stations, and large residential developments.

A bike network plan should identify roadways for bike lanes, compatible shoulders or shared lanes, and shared use paths. In many cases, the selected roadways will be arterial and collector roadways. Bicyclists prefer to travel these roadways for the same reason that motorists do: they provide the most direct route to key destinations.

The Bicycle and Pedestrian Checklist, which is found in Publication 10X, Design Manual, Part 1X, *Appendices to Design Manuals 1, 1A, 1B, and 1C*, Appendix S, provides an evaluation tool to complete in the planning and design processes.

### 19.2 PEDESTRIAN FACILITIES

**A. Sidewalks.** Sidewalks are desirable to support both mobility and safety. A basic strategy for improving pedestrian conditions is to provide sidewalks along all roadways with developed land uses. In 2000, FHWA announced that bicycling and walking facilities will be incorporated into all transportation projects unless "exceptional circumstances" exist. However, the provision of sidewalks has usually been a local responsibility, falling under the municipality's authority to approve new land uses and supporting infrastructure. No state law applies to the installation of sidewalks in commercial or residential areas in Pennsylvania. Therefore, the most fundamental action that can be taken by any municipality to improve pedestrian facilities is to amend its land development ordinance to require the installation of sidewalks for new land uses.

**B. Sidewalk and Buffer Widths.** Chapter 1, Tables 1.3 through 1.7 (Matrices of Design Values) present roadside widths for sidewalks and buffers with different land use contexts. Dimensions are provided for "clear sidewalk widths," or the section of sidewalk unencumbered by street furniture and not immediately next to buildings. The presence of "buffers", comprised of landscaping in suburban areas, and street furniture in urban areas, is important to the comfort level and perceived safety of pedestrians.

**C. Medians.** On multi-lane roadways, medians can be among the most desirable features for pedestrians. At signalized intersections in which the pedestrian crossing phase is the minimum required by the MUTCD, and pedestrians are unable to complete the crossing of the entire intersection, a median will permit them to safely wait until the next pedestrian crossing phase.

Along suburban corridors at unsignalized locations, medians play an even more vital role. Because of the distance typically separating signalized intersections in most suburban areas, pedestrians are frequently reluctant to cross roadways only at these locations. Although an important goal of urban design in any community should be to maximize the numbers of pedestrians crossing at signalized intersections, many pedestrians will continue to conduct mid-block crossings. The hazard of these crossings can be mitigated, to some extent, by the installation of physical medians.

**D. Crosswalks.** AASHTO's *Guide for the Planning, Design and Operation of Pedestrian Facilities* recommends midblock crosswalks under the following circumstances:

- Already substantial number of midblock crossings.
- Due to existing and planned pedestrian generators, pedestrians are highly unlikely to cross the street at the next intersection.
- Spacing between adjacent intersections exceeds 200 m (660 ft).
- Adequate sight distance is available.

Midblock crosswalks should typically not be installed within 90 m (300 ft) of signalized intersections. On low-speed, two-lane roadways in urban contexts, particularly with very high levels of pedestrian activity, mid-block crosswalks may be considered within 60 m (200 ft) of signalized intersections.

Examples of treatments to accompany mid-block crosswalks include:

- Raised medians.
- Advanced yield markings and signs.
- Overhead or post mount flashing sign.
- In-pavement light.
- In-street "yield to pedestrian" signs.
- Half signals.

Found below are possible options for the installation of midblock crosswalks, or crosswalks at unsignalized intersections, on different roadway types:

**1.** Regional Arterial. Installation of midblock crosswalks on regional arterials should involve the most intensive treatments. These should only be used on roadways of 60 km/h (40 mph) or less. A raised median is preferable to accompany mid-block crossings on multi-lane roadways. Advanced yield markings, warning lights, and high-visibility markings may also be considered.

**2.** Community Arterial. On multi-lane roadways, a raised median and advanced yield markings are preferred. Accompanying lights are recommended for two-lane roadways of 60 km/h (35 mph) or above, as well as multi-lane roadways. All crosswalks installed should be high visibility. Curb extensions or "bulbouts" may be considered on any street with off-street parking.

**3.** Main Street. "Yield to Pedestrian" signs mounted on the roadway centerline are preferred for this roadway sub-type, along with high-visibility markings. Curb extensions or "bulbouts" are less critical, but may be considered for streets with on-street parking. They will provide better visibility of and by pedestrians, and should not reduce the number of on-street parking spaces, since parking within 7.6 m (25 ft) of the crosswalk would be prohibited in any case.

**4.** Community Collector. On multi-lane roadways, a raised median and advanced yield markings are preferred. Accompanying lights may be considered for two-lane roadways of 60 km/h (35 mph) or above, as well as multi-lane roadways. All crosswalks installed should be high visibility. Curb extensions or "bulbouts" are preferred on any street with on-street parking.

**5.** Neighborhood Collector. Crosswalks should be accompanied by pedestrian warning signs or "Yield to Pedestrian" signs mounted on the roadway centerline. Crosswalks may be high visibility depending on traffic volumes and speeds. Curb extensions or "bulbouts" to accompany on-street parking may also be considered.

**6.** Local Road. Crosswalks should be accompanied by pedestrian warning signs.

## 19.3 PUBLIC TRANSPORTATION

**A. Vehicle Types.** The bus types seen most often in urban areas are intercity buses (motor coaches), city transit buses, and articulated buses. For these bus types, the 2004 AASHTO Green Book, Chapter 2 lists the typical dimensions (Exhibit 2-1) and minimum turning radii (Exhibit 2-2).

Vehicle width does not include both the right and left side mirrors, each of which can add another 300 mm (12 in) to the vehicle width.

**B. Bus Stops.** The primary considerations regarding bus stops are their identification, placement and physical features, which are discussed below. If transit agencies have guidelines on bus stops, they should be incorporated in the design.

**1.** Identification. A sign at each bus stop should indicate the agency's name and logo; bus route and destination; schedule; and the agency's telephone number and website. Parking prohibitions should be identified by pavement markings or by another sign (e.g., No Parking Bus Stop Sign, R7-107A, as found in Publication 236M, *Handbook of Approved Signs*).

**2.** Placement. Bus stops are placed at the nearside or farside of an intersection, or at midblock locations. Below are basic factors that should be considered in bus stop placement:

- At intersections, a consistent pattern of stops (e.g., all nearside or all farside) enables transit patrons to readily comprehend where they need to board a bus.
- At intersections where more than one bus route operates, and in particular where buses operate on cross streets, consideration should be given to the ability to conveniently transfer to other bus routes.
- Stops should be located close to major passenger generators.
- Curb space should be provided to accommodate the desired number of buses and passenger waiting areas.

Bus stops at intersections are preferred because they provide the best pedestrian accessibility from both sides of the street as well as the cross streets. They also provide for the most convenient transfers to intersecting bus routes.

In limited instances, a midblock bus stop will be suggested by the presence of major generators. Compared to conditions at adjacent intersections, midblock bus stops lessen sight distance problems for pedestrians and motorists, produce fewer pedestrian conflicts, and reduce pedestrian congestion at passenger waiting areas.

A major concern with midblock bus stops is that they increase the walking distance for pedestrians who must cross at intersections, and, in so doing, can encourage people to cross the street midblock (i.e., "jaywalk"). This is problematic on high-speed roadways.

At intersections, farside bus stops are typically preferred to nearside stops, especially in urban centers or other areas with high pedestrian volumes. One study found that about 2% of pedestrian crashes in urban areas, and 3% of crashes in rural areas, are related to bus stops. A common pattern is when the pedestrian steps into the street from in front of a stopped bus. This pattern is associated with nearside stops more than farside stops.

Other considerations related to bus stops at intersections include:

- Where it is not desirable to stop the bus in a travel lane and a turn-out is warranted, a farside stop (or even a midblock stop) is preferred.
- If a route requires a left turn, the bus stop should be placed on the farside after the left turn is completed. If this is not possible, a midblock bus stop is preferred, but must be located far enough from the intersection so that the bus can still maneuver into the proper left turn lane.
- If a route requires a right turn, or if there is a high volume of right turns at an intersection, the bus stop should be located at the farside location.
- If too many buses would utilize a farside stop and there is not enough room to extend the bus stop, a nearside location should be used instead.
- When an intersection is complex and has several dedicated turn lanes, farside bus stops are preferred because they are removed from the location where complex traffic movements are performed.
- At simple signalized intersections, nearside stops permit riders to discharge when they are stopped at red lights.

**3.** Geometrics. The bus stop area in which parking is prohibited must be long enough to permit buses to maneuver to and from the curb, and to accommodate the safe movement of pedestrians from the curb to the bus. The amount of distance required for a bus stop depends on four factors: (1) the type of bus stop; (2) the length of buses using the stop; (3) the number of buses using the stop; and (4) the posted speed limit of the roadway.

Curb space may be limited in some urban business districts, due to high demand for on-street parking. However, the municipality should not designate bus stops of inadequate length, since the bus will be unable to "dock" at the curb. In this situation, the driver will either "nose in" the vehicle or stop in the street, forcing passengers to step into the street, and not permitting the deployment of the wheelchair lift/ramp for disabled riders.

If space is highly constrained, the municipality may wish to forego mid-block bus stops, since they require the greatest length. The municipality may also consider the use of "bus bulbs." A bus bulb is a section of the sidewalk that extends from the curb of a parking lane to the edge of the through lane. Buses stop in the traffic lane instead of weaving into and out of the bus stop that is located in the parking lane. The bus bulb need only extend the length of the bus, and thereby saves parking spaces. However, because traffic behind is held up during passenger loading, the bus bulb is not preferred for heavily congested roadways.

**C. Turn-outs.** A turn-out is desirable for roadways where the posted speed limit is higher than 60 km/h (40 mph), at stops with a high number of passenger boardings and dwell times. These features allow buses to pull out of the flow of traffic to board and discharge passengers, thus not impeding the free flow of vehicular traffic.

When nearside bus stops have a turn-out, the "exit taper" length can be removed since it is assumed that the bus will utilize the intersection area to merge with traffic. Similarly, if farside bus stops have a turn-out, then the "entrance taper" length can be removed. If multiple buses will use the bus stop, then the "Total Bus Stop Length" can be increased by the length of the additional buses with an allowance of 3.0 m (10 ft) for separation between buses.

**D. Bus Stop Characteristics.** Other desirable characteristics of a bus stop include:

- Front and rear door clearances should be 1525 mm (5 ft) wide and 2440 mm to 3050 mm (96 in to 120 in) deep.
- All-weather, slip resistant surface in bus stop area.
- Slopes not to exceed 2% in boarding area.
- Vertical clearances of 2135 mm (84 in).
- No obstructions in boarding/discharging areas, and room for pedestrians to wait without entering the roadway and without impeding other pedestrian movements.
- Compliance with ADA standards, including ability to accommodate bus wheelchair lifts and/or ramps.
- Bus riders must be readily visible to satisfy traffic safety and security issues, with adequate lighting from adjacent parcels and street lights.

Bus stop spacing represents a trade-off between providing a high number of stops (thus increasing service coverage and maximizing ridership) while still allowing the transit service to operate at reasonable speeds and trip times. Table 19.1 summarizes typical bus stop spacing for the illustrated roadway typologies identified in Figure 1.2.

**TABLE 19.1**
**BUS STOP SPACING**

| CONTEXT | STOPS | TYPICAL SPACING |
|---|---|---|
| Urban Core, Town Center | 6 to 8 per kilometer (10 to 12 per mile) | 135 m (450 ft) |
| Town/Village Neighborhood, Suburban Center | 3 to 6 per kilometer (5 to 10 per mile) | 225 m (750 ft) |
| Suburban Corridor, Suburban Neighborhood | 3 to 4 per kilometer (4 to 6 per mile) | 300 m (1,000 ft) |
| Rural | As needed | As needed |

**E. Bus Stop Amenities.**

**1.** Passenger Waiting Shelters. Following are minimum design specifications for shelters:

- Three walls (a rear and two sides) with a minimum covered area of 4.5 $m^2$ (48 $ft^2$). For areas with space limitations, other types of shelters (e.g., umbrella or half-wall or canopies) may be used.
- Interior seating.
- A minimum front clearance of 1220 mm (48 in) (1525 mm (60 in) desirable) from the shelter to the edge of the curb.
- Minimum sidewalk around shelter (i.e., sides and rear) of 915 mm (36 in) (1525 mm (60 in) desirable).
- Display panel for route and schedule information, if not provided on information kiosk.

**2.** Seating. Bus stop seating increases patron comfort and reduces perceived waiting time. A bench should be at least 1830 mm (72 in) wide and placed 1220 mm (48 in) from the curb.

**3.** Information Kiosks/Boxes. These display schedules, maps and other information.

**4.** Other Customer Features. Consider providing trash receptacles, bicycle storage racks, public telephones, lighting, and landscaping.

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# CHAPTER 20

## WILDLIFE CROSSINGS

### 20.0 INTRODUCTION

The linear nature of surface transportation systems creates a suite of concerns for transportation and natural resource management agencies as they seek to provide safe and efficient transportation infrastructure and to reduce the impacts of their projects on environmental resources. Techniques have been developed to avoid, minimize, and mitigate these impacts. However, the avoidance, minimization, and mitigation efforts used may not always provide the greatest environmental benefit, or may do very little to promote ecosystem sustainability. This concern, along with a 1995 Memorandum of Understanding, between 14 Federal Departments and Agencies, to foster an ecosystem approach mobilized an interagency Steering Team to collaborate over a three-year period to write *Eco-Logical: An Ecosystem Approach to Developing Infrastructure Projects*.

*Eco-Logical* presents a framework for achieving greater interagency cooperative conservation. *Eco-Logical* provides a nonprescriptive approach that enables Federal, State, tribal and local partners involved in infrastructure planning, design, review and construction to work together to make infrastructure more sensitive to wildlife and their ecosystems. Following this approach, this chapter provides guidance to the Pennsylvania Department of Transportation's (PennDOT's) District Offices in determining the appropriateness of a Wildlife Crossing or an exclusionary device associated with transportation improvements in the Commonwealth. This section provides guidance should an Engineering District elect to study and construct a crossing or exclusionary device. There is no intent to direct or mandate the use of such devices by the Engineering Districts. PennDOT reserves the discretion to deviate from this guidance if the circumstances are warranted. The construction of such devices is at the sole discretion of the Department. This guidance is for information purposes only; it is not regulatory.

This guidance is to ensure that the Department is aware that there are strategies available to avoid vehicular and wildlife conflicts. Most of the information in this guidance was derived from The Federal Highway Administration's (FHWA) *Eco-Logical: An Ecosystem Approach to Developing Infrastructure Projects* and *Wildlife Crossing Structure Handbook Design and Evaluation in North America*.

### 20.1 DEFINITIONS

**A. Fragmentation.** Splitting up or separation of a habitat, landscape or ecosystem into smaller parcels.

**B. Habitat Connectivity.** The state of structural landscape features being connected, enabling access between places via a continuous route.

**C. Target Species.** A species that has been identified as the subject of conservation or monitoring actions.

**D. Travel Corridors.** Features that connect two or more otherwise isolated patches of habitat that allow animals to travel safely from one area to another, but may also provide food or other necessities as well.

**E. Ungulates.** A large group of mammals all of which have hooves (e.g., Deer and Elk).

**F. Wildlife Crossing.** Structures that allow animals to cross human-made barriers safely.

**G. Wildlife Fencing.** Fence designed and built to keep animals from accessing right-of-way habitat and road surface, or to funnel animal movement to safe crossing locations (e.g., wildlife crossing structures).

## 20.2 BACKGROUND

Wildlife crossings are structures that allow animals to cross human-made barriers safely. Wildlife crossings may include underpass tunnels, viaducts, and overpasses (mainly for large or herd-type animals); amphibian tunnels; culverts (for small mammals such as otters, mink, and porcupine). Wildlife crossings are a practice allowing connections or reconnections between habitats and assist in avoiding collisions between vehicles and animal.

Each year in the United States, an estimated 200 human deaths and 29,000 injuries result from crashes involving animals (i.e., deaths from a direct motor vehicle (MV) animal collision or from a crash in which a driver tried to avoid an animal and ran off the roadway) (National Highway Traffic Safety Administration, 2002). Accidents from drivers trying to avoid animals are especially true for the low mobility mammals, amphibians and reptiles (groundhog, river otter, salamander and turtles). Additionally, 1.5 million traffic accidents involving deer in the United States cause an estimated $1.1 billion in vehicle damage each year (Donaldson, 2005). Pennsylvania ranks third in the nation, behind only Texas and Wisconsin in fatalities resulting from deer accidents. From 2006 to 2010 Pennsylvania has seen an average of over 4,200 deer collisions and 12 fatalities a year and this number is expected to keep rising. In 2010 alone, there were 4,668 collisions and 10 fatalities. The costs of these incidents to Pennsylvania are rising as well. Repairs due to deer collisions cost the state $14,484,804. When you factor in the fatalities that number soars to $58,168,480.

Studies have also shown that mortality from vehicles is a threat to wildlife populations when population numbers are already low or when vital habitats occur near roadways due to fragmentation. PennDOT recognizes the importance of reducing impacts to wildlife and improving, or at the very least, maintaining habitat connectivity. However, the emphasis on public safety is paramount and cannot be overstated. As a transportation agency, the function of PennDOT is first and foremost to provide a safe and efficient transportation infrastructure for the traveling public.

## 20.3 WILDLIFE CROSSING TYPES (for descriptive purposes only.)

Follow PennDOT design guidelines when choosing the appropriate type.

**A. Overpass Design.** See Figure 20.1 for an example of an overpass design.

**1.** Landscape Bridge. Designed exclusively for wildlife use. Due to their large size they are used by the greatest diversity of wildlife and can be adapted for amphibian and reptile passage.

**2.** Wildlife Overpass. Smaller than landscape bridges, these overpass structures are designed exclusively to meet needs of a wide range of wildlife from small to large.

**3.** Multi-use Overpass. Generally the smallest of the wildlife overpasses. Designed for mixed wildlife-human use. This wildlife crossing type is best adapted in human disturbed environments and will benefit generalist type species adapted to regular amounts of human activity and disturbance.

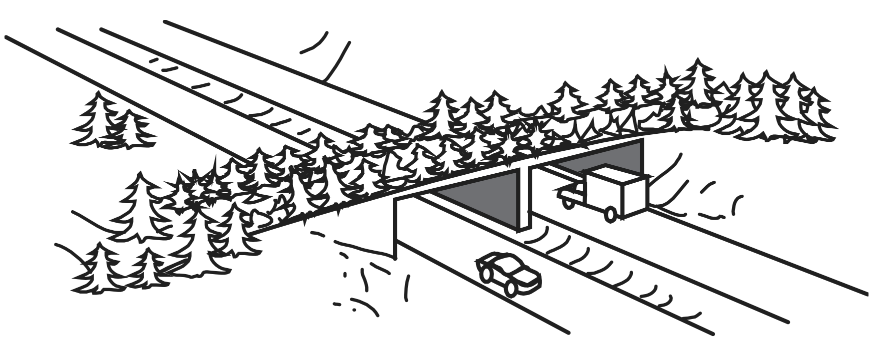

**Figure 20.1**
**Example of Overpass Design**

**B. Underpass Design.**

**1.** Viaduct or Flyover. This underpass design is the largest of underpass structures. The large span and vertical clearance of viaducts allow for use by a wide range of wildlife. Structures can be adapted for amphibian and reptiles, semi-aquatic and semi-arboreal species. These work well because of the large open natural areas. This design should not be constructed exclusively for wildlife movement. The Viaduct or Flyover will be included in the design of a transportation project if warranted to meet the project needs based on the topography of the area. Figure 20.2 provides an example of an underpass, viaduct design.

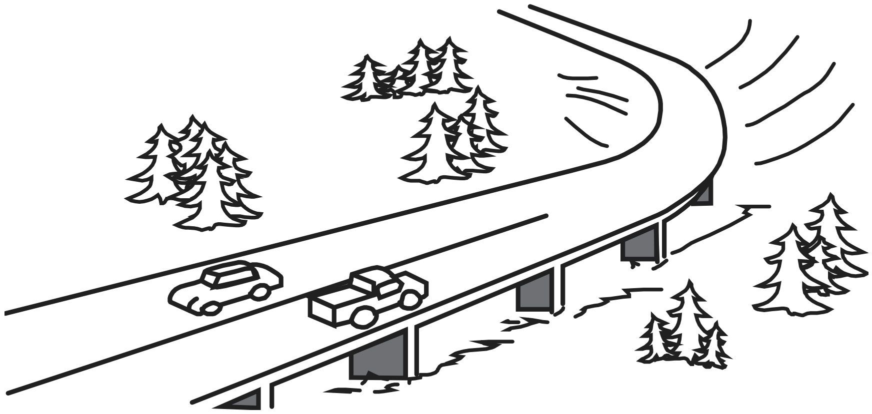

**Figure 20.2**
**Example of Underpass, Viaduct Design**

**2.** Large Mammal Underpass. Not as large as most viaducts, but the largest of underpass structures designed specifically for wildlife use. Designed for large mammals but small- and medium-sized mammals use readily as well. The large mammal underpass should be included in the design of a transportation project if warranted to meet the project needs based on the topography of the area. Figure 20.3 provides an example of an underpass, viaduct design.

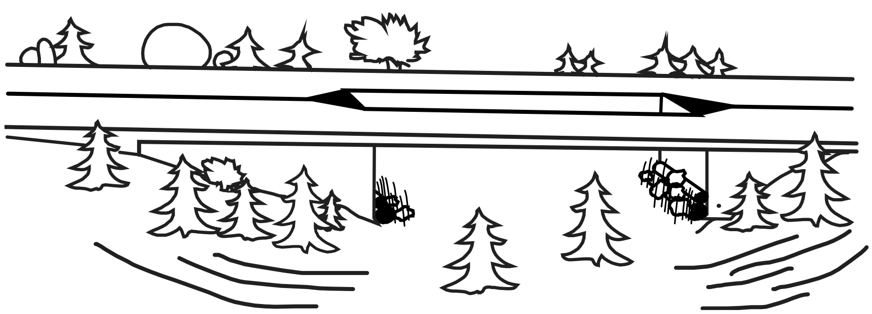

**Figure 20.3**
**Example of Large Mammal Underpass**

**3.** Multi-Use Underpass. Design similar to large mammal underpass; however, management objective is co-use between wildlife and humans. Design is generally smaller than a large mammal underpass because of type of wildlife using the structures along with human use. These structures may not be adequate for all wildlife but usually results in use by generalist species common in human-dominated environments (e.g., urban or peri-urban habitats). Large structures may be constructed to accommodate the need for more physical space for humans and habitat generalist species.

**4.** Underpass with Water Flow. An underpass structure designed to accommodate the needs of moving water and wildlife. These underpass structures are frequently used by some large mammal species, but their use depends largely on how it is adapted for their specific crossing needs. Small- and medium-sized mammals generally utilize these structures, particularly if riparian habitat or cover is retained within the underpass. Figure 20.4 provides an example of an underpass with water flow design.

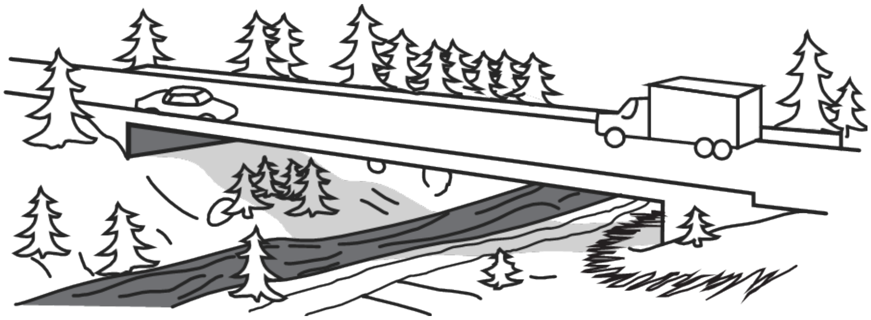

**Figure 20.4**
**Example of Underpass with Water Flow**

**5.** Small- to Medium-Sized Mammal Underpass. One of the smaller wildlife crossing structures. Primarily designed for small- and medium-sized mammals, but species use will depend largely on how it may be adapted for their specific crossing needs. Figure 20.5 provides an example of a small- to medium-sized mammal underpass.

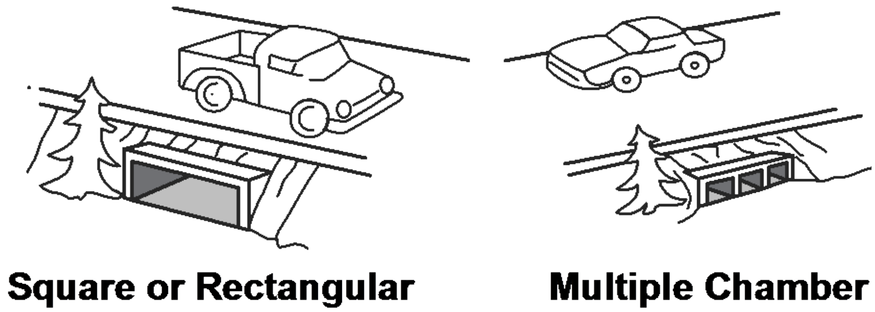


**Figure 20.5**
**Example of Small- to Medium-Sized Mammal Underpass**

**6.** Amphibian and Reptile Tunnels. Crossing designed specifically for passage by amphibians and reptiles, although other small- and medium-sized vertebrates may use as well. Many different amphibian and reptile designs have been used to meet the specific requirements of each species or taxonomic group. Figure 20.6 provides an example of amphibian and reptile tunnels designs.

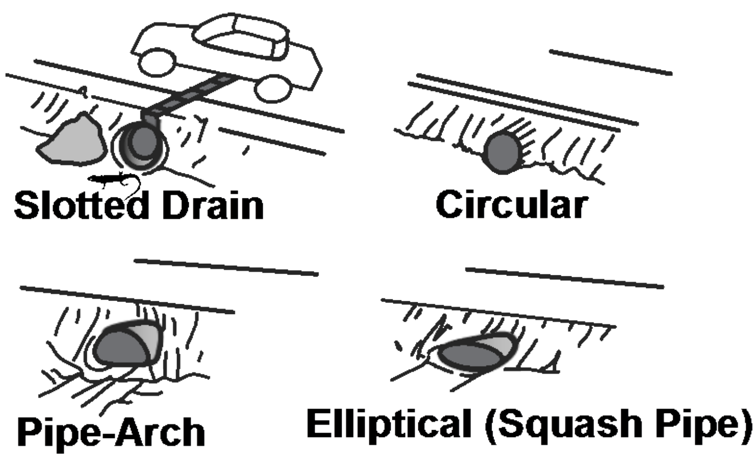


**Figure 20.6**
**Example of Amphibian and Reptile Tunnels**

## 20.4 WILDLIFE DESIGN GROUPS

Planning and designing wildlife crossings will often be focused on a certain species of conservation interest (e.g., threatened or endangered species), a specific species group (e.g., amphibians) or abundant species that pose a threat to motorist safety (e.g., Deer, Elk).

This guidance looks at wildlife and species groups when discussing the appropriate wildlife crossing designs. The eight groups mentioned below are general in composition. However, recommendations will be provided, if it is available, for species-specific design requirements (See Tables 20.1, 20.2 and 20.3). Their ecological requirements and how roads affect them are described along with some sample wildlife species for each group.

**A. Large Mammals (Ungulates [Deer and Elk], Carnivores [Bears, Bobcat]).** Species with large area requirements and potential migratory behavior; large enough to be a motorist safety concern; traffic related mortality may cause substantial impacts to local populations; susceptible to habitat fragmentation by roads.

**B. High Mobility Medium-Sized Mammals (Fisher, Coyote, Fox).** Species that range widely; fragmentation effects of roads may impact local populations.

**C. Low Mobility Medium-Sized Mammals (Raccoon, Skunk, Hare, Groundhog).** Species with smaller area requirements; common road related mortality; relatively abundant populations.

**D. Semi-arboreal Mammals (Marten, Red Squirrel, Flying Squirrel).** Species that are dependent on forested habitats for movement and meeting life requisites; common road-related mortality.

**E. Semi-aquatic Mammals (River Otter, Mink, Muskrat).** Species that are associated with riparian habitats for movement and life requisites; common road-related mortality.

**F. Small Mammals (Ground Squirrels, Voles, Mice).** Species that are common road-related mortality; relatively abundant populations.

**G. Amphibians (Frogs, Toads, Salamanders).** Species with special habitat requirement; relatively abundant populations at the local scale; populations are highly susceptible to road mortality.

**H. Reptiles (Snakes, Lizards, Turtles).** Species with special habitat requirement; road environment tends to attract individuals; relatively abundant populations.

### Table 20.1
### General guidelines for minimum and recommended dimensions of wildlife overpass designs.

| Type | Usage | Species and Group | Dimensions Minimum | Dimensions Recommended[1] |
|---|---|---|---|---|
| Landscape Bridge | Wildlife Only | All wildlife species<br>Amphibians (if adapted) | **W: 230 ft**<br>(70 m) | **W: >330 ft**<br>(>100 m) |
| Wildlife Overpass | Wildlife Only | Large mammals<br>High-mobility medium-sized mammals<br>Low mobility medium-sized mammals<br>Small mammals<br>Reptiles<br>Amphibians (if adapted) | **W: 130-165 ft**<br>(40-50 m) | **W: 165-230 ft**<br>(50-70 m) |

| Type | Usage | Species and Group | Dimensions Minimum | Dimensions Recommended[1] |
|---|---|---|---|---|
| Multi-use Overpass | Mixed Use: Wildlife & Human activities | Large mammals<br>High-mobility medium-sized mammals<br>Low mobility medium-sized mammals<br>Small mammals<br>Amphibians (if adapted)<br>Reptiles | **W: 32 ft**<br>(10 m) | **W: 50-130 ft**<br>(15-40 m) |

[1] These dimensions are recommendations and may vary depending on site conditions and species needs.

## Table 20.2
## General guidelines for minimum and recommended dimensions of wildlife underpass designs.

| Type | Usage | Species and Group | Dimensions Minimum | Dimensions Recommended[2] |
|---|---|---|---|---|
| Viaduct or Flyover | Multi-purpose | All wildlife species | *There are no minimum dimensions. Structures are generally larger than the largest wildlife underpass structures.* | *There are no minimum dimensions. Structures are generally larger than the largest wildlife underpass structures.* |
| Large Mammal Underpass | Wildlife only | Large mammals<br>High-mobility medium-sized mammals<br>Low mobility medium-sized mammals<br>Semi-arboreal & semi-aquatic Mammals (adapted)<br>Small mammals<br>Amphibians (adapted)<br>Reptiles | **W: 23 ft**<br>(7 m)<br>**Ht: 13 ft**<br>(4 m) | **W: >32 ft**<br>(>10 m)<br>**Ht: >13 ft**<br>(>4 m) |
| Multi-Use Underpass | Mixed use: Wildlife & Human activities | Large mammals<br>High-mobility medium-sized mammals<br>Low mobility medium-sized mammals<br>Semi-arboreal & semi-aquatic Mammals (adapted)<br>Small mammals<br>Amphibians (adapted)<br>Reptiles | **W: 16.5 ft**<br>(5 m)<br>**Ht: 8.2 ft**<br>(2.5 m) | **W: >23 ft**<br>(>7 m)<br>**Ht: >11.5 ft**<br>(>3.5 m) |

| Type | Usage | Species and Group | Dimensions Minimum | Dimensions Recommended[2] |
|---|---|---|---|---|
| Underpass With Water Flow | Wildlife and drainage | Large mammals<br>High-mobility medium-sized mammals<br>Low mobility medium-sized mammals<br>Semi-arboreal mammals (adapted)<br>Semi-aquatic mammals<br>Small mammals & amphibians<br>Semi-arboreal mammals & reptiles (adapted) | **W*: 6.5 ft dry pathway** (2 m)<br>**Ht: 10 ft** (3 m)<br><br>**Width will be dependent on width of hydrologic channel in crossing.* | **W*: >10 ft dry pathway** (>3 m)<br>**Ht: >13 ft** (>4 m)<br><br>**Width will be dependent on width of hydrologic channel in crossing.* |
| Small to Medium-Sized Mammal Underpass | Wildlife and seasonal drainage | High-mobility medium-sized mammals (adapted)<br>Low mobility medium-sized mammals<br>Semi-aquatic mammals (adapted)<br>Small mammals<br>Amphibians (adapted)<br>Reptiles | **Same as recommended dimensions.**<br><br>*Size selection is based on the target species needs or connectivity objective at the site.* | **W: 1-4 ft** (0.3-1.2 m)<br>**Ht: 1-4 ft** (0.3-1.2 m)<br>OR<br>**1-4 ft dia.** (0.3-1.2 m) |
| Amphibian and Reptile Tunnel | Wildlife only | Amphibians<br>Low mobility medium-sized mammals (adapted)<br>Semi-aquatic (adapted)<br>Small mammals & reptiles (adapted) | *Dimensions vary depending on target species or taxa or local conditions.*<br><br>*Tunnels range from 1–3 ft (0.35–1 m) in diameter.* | *Dimensions vary depending on target species or taxa or local conditions.*<br><br>*Tunnels range from 1–3 ft (0.35–1 m) in diameter* |

[2] These dimensions are recommendations and may vary depending on site conditions and species needs.

## 20.5 POLICY/GUIDANCE

The decision to incorporate wildlife crossings, exclusionary fencing, etc. into the highway design is not a straight forward and simple formula but a combination of these three factors: Public Safety, Cost Factors (e.g., design, construction and maintenance) and Environmental Benefits. These three areas are interrelated when it comes to wildlife crossings and the weight assigned to each is a moving target. Factors such as public opinion, ADT, crash data, future land use and species concerns can shift the values one way or the other. The value of each factor varies from project to project and must be looked at according to the circumstances present. Data collected or provided to address the above guidelines should serve as the basis of decision for determining whether or not a wildlife crossing and/or exclusionary devices are appropriate. The criteria below take this into account and Figure 20.7 can assist in making that determination. The specific design (type, size and location) of the crossing should be determined by the District with coordination from the Pennsylvania Game Commission (PGC), Pennsylvania Fish and Boat Commission (PF&BC) and/or U.S. Fish and Wildlife Service (USFWS).

The following criteria should be used in determining whether a wildlife crossing may be included in a transportation project:

**1.** Wildlife crossings and exclusionary devices should be considered when the project is a new roadway or bridge or a new alignment where the centerline deviates from the existing one enough that vertical and horizontal design controls for new construction are used to at least some degree, and meets all of the following conditions:

- Traffic volumes are ≥ 4,000 ADT and the target species is subject to high mortality when crossing the road (if applicable).
- The project crosses areas where drainage ways are present.
- The project crosses areas that present minimal grade separations requiring little cut or fill to install the crossing.
- Target species have been documented to utilize habitat impacted by the project to fulfill life requisite values.
- The project is within the primary or secondary range of a listed species.
- The project has the potential to inhibit movement of target species between critical life requisite habitats or prohibits movement of target species along documented travel corridors.
- Habitat exists on both sides of the roadway.
- Public lands or lands under conservation easement are present in sufficient amounts, on both sides of the road, where the crossing will be located in order to ensure future land use is compatible with the target species' needs.
- On projects where multiple locations meet these requirements the number and spacing of wildlife crossings will be determined by PennDOT after consultation with the natural resource agencies.

**2.** Wildlife crossings and exclusionary devices may, at PennDOT's discretion, be considered when the project is a bridge replacement, drainage improvement, or reconstruction project if the following conditions are met:

- The project meets the above requirements.
- The project is within a known area of wildlife/vehicle strikes (motorist safety).
- There are documented recent road kills of targeted species within the project area.
- The requesting organization/agency is prepared to participate as a funding partner and adequate funding is available (when applicable).

**3.** PennDOT will consider the need for a wildlife crossing or exclusionary devise when the PGC, PF&BC or USFWS have expressed a science-based need for a wildlife crossing, in conjunction with the Department, for a target species. A target species being a species that has been identified as the subject of a conservation or monitoring action.

- All requests for wildlife crossings and/or exclusionary devices will be made in accordance with the Pennsylvania Department of Transportation Natural Resources Assessment and Mitigation Agency Partnering Policy (Publication 546, *Threatened and Endangered Species Desk Reference*, Appendix KK). This policy requires the requesting entity to provide documentation or studies to substantiate their requests and it requires an analysis to determine whether the resource is a Natural Resource Meriting Compensation and further whether the compensation is a reasonable expenditure of public funds. In cases where supporting data does not exist, PennDOT will not conduct studies nor will it generate data for such purposes.

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## Table 20.3
## Suitability of wildlife crossing design types for distinct wildlife species and taxa.

| | Landscape bridge | Wildlife overpass | Multi-use overpass | Viaduct or flyover | Large mammal underpass | Multi-use underpass | Underpass with water flow | Small- to medium-sized mammal underpass | Amphibian and reptile tunnel |
|---|---|---|---|---|---|---|---|---|---|
| **Ungulates** | | | | | | | | | |
| Elk | ● | ● | ● | ● | ● | ● | ● | ⊗ | – |
| White-Tailed Deer | ● | ● | ● | ● | ● | ● | ● | ⊗ | – |
| **Carnivores** | | | | | | | | | |
| Black Bear | ● | ● | ⊗ | ● | ● | ⊗ | ● | ⊗ | – |
| Coyote | ● | ● | ● | ● | ● | ● | ● | ● | – |
| Fox | ● | ● | ● | ● | ● | ● | ● | ● | – |
| Bobcat | ● | ● | ● | ● | ● | ● | ● | ⊗ | – |
| Fisher | ● | ● | ● | ● | ○ | ● | ○ | ● | – |
| Marten | ● | ● | ● | ● | ○ | ● | ○ | ● | – |
| Weasel | ● | ● | ● | ● | ○ | ● | ○ | ● | – |
| River Otter | ○ | ○ | ○ | ● | ○ | ○ | ● | ○ | ⊗ |
| **Low mobility medium-sized mammals** | ● | ● | ● | ● | ● | ● | ● | ● | ○ |
| **Semi-arboreal mammals** | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ⊗ | ⊗ |
| **Semi-aquatic mammals** | ○ | ○ | ○ | ○ | ○ | ○ | ● | ○ | ○ |
| **Small mammals** | ● | ● | ● | ● | ● | ● | ● | ● | ○ |
| **Amphibians** | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ● |
| **Reptiles** | ● | ● | ● | ● | ● | ● | ○ | ● | ○ |

● Recommended/Optimum solution; ○ Possible if adapted to local conditions; ⊗ Not recommended; – Not applicable

A current list of wild mammals in Pennsylvania can be found at: www.portal.state.pa.us/portal/server.pt/document/1039450/current_list_of_wild_mammals_2011_pdf.

A current list of wild amphibians and reptiles in Pennsylvania can be found at: fishandboat.com/water/amprep/native.htm.

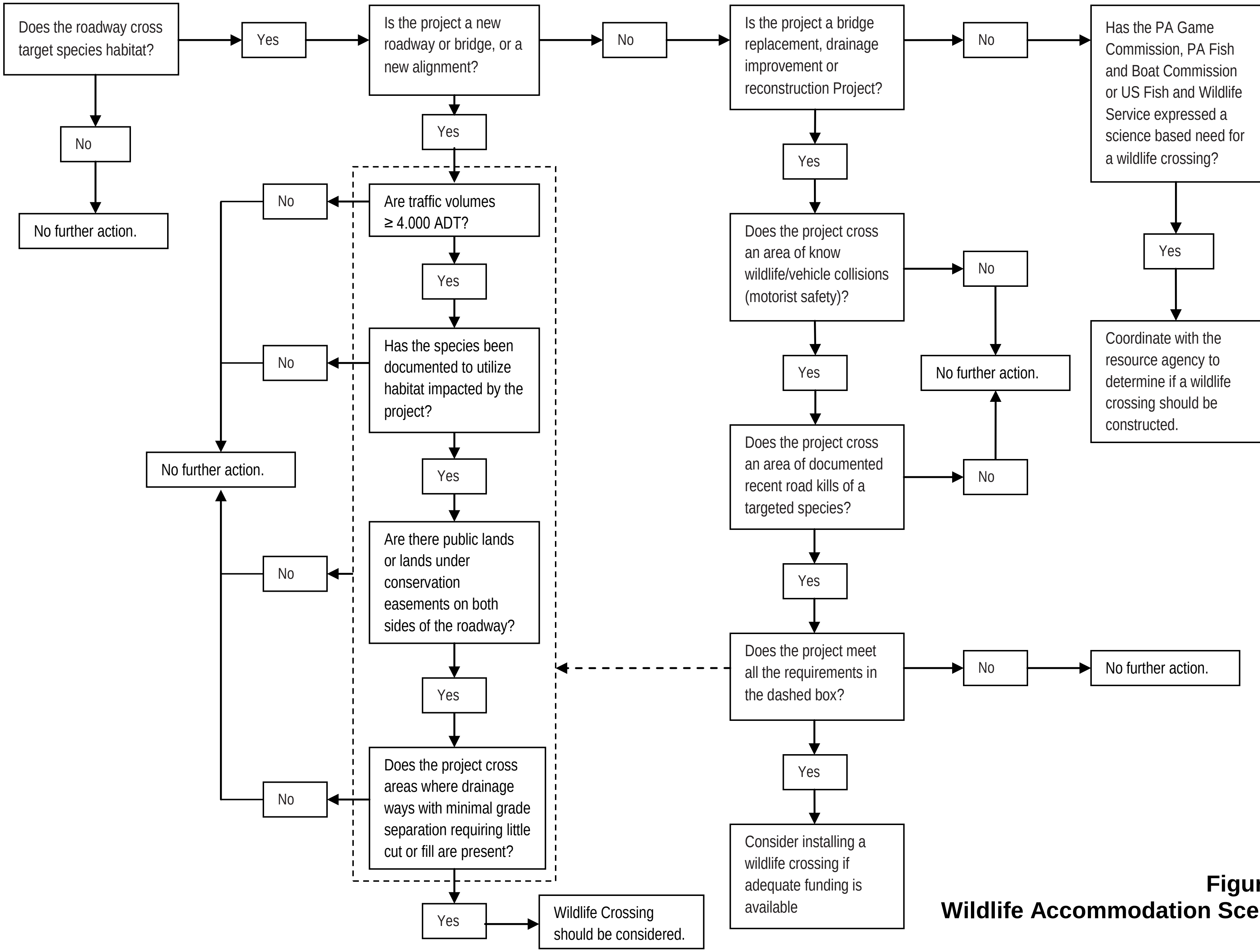


**Figure 20.7**
**Wildlife Accommodation Scenarios**

## 20.6 DESIGN

Each project site has different conditions that require consideration in the design of a crossing system or exclusionary device. During the project development process, direct coordination is recommended between the Department and PGC, PF&BC and/or USFWS, to establish the design considerations for each specific crossing and site. This coordination should occur as early as practical during the design phase to ensure that all project objectives are met.

Criteria which should be utilized in the determination of a crossing design should include but are not limited to:

- The crossing cannot compromise safety or state or federal design criteria.
- The crossing cannot restrict access by adjacent property owners.
- The crossing cannot negatively impact adjacent properties (e.g., provide direct access for wildlife to private properties where none presently exist).
- The crossing cannot have the potential to negatively impact existing drainage patterns or flood off-site properties.
- The crossing utilizes the most cost-feasible design for the target species.
- Significant additional habitat impacts cannot result from the construction of the crossing.
- The addition of the crossing cannot result in significant modifications to the proposed project (e.g., excessive increases in roadway grades, increases in required right-of-way).

## 20.7 WILDLIFE FENCING

The use of fencing in conjunction wildlife crossings is critical. Most wildlife is extremely wary and will avoid confinement or unnatural situations. Given the choice between going through unfamiliar wildlife crossing structures and crossing highway pavement, many will choose the latter. Fencing forces the wildlife to use the crossing and over time will become comfortable. Without fence most wildlife would not use the structure.

When designing a wildlife passage the fencing should be designed to minimize the corral or chute effect. This is done by constructing fencing to the top of the wildlife crossings, rather than the bottom, making approach to the wildlife crossing as wide as possible.

For large mammals, a 1.8 m to 2.4 m (6 ft to 8 ft) woven-wire fence presents a formidable barrier when properly constructed and maintained (Figure 20.8). The 20-year life span of a well-built fence can justify its cost. Major materials include sturdy, rot-resistant wooden corner posts set in concrete (optional), wooden or studded steel T line posts, woven-wire fencing, and gates. If needed, extensions can be attached to the top of the fence to prevent deer or elk from jumping over. Bears, coyotes and other carnivores may try to dig under or climb over. Burying fencing underground reduces the possibility of wildlife digging under the fence and also increases the lifetime of the fencing reducing maintenance costs. Fencing is also important for medium to small mammals, reptiles and amphibians as well. For many of these species, Type 2 right-of-way highway fencing (1.2 m (4 ft) wire mesh) should be adequate. Variable mesh fencing that has small-sized mesh openings at the bottom and the standard mesh size at the top should be used where small mammals, reptile and amphibians are anticipated.

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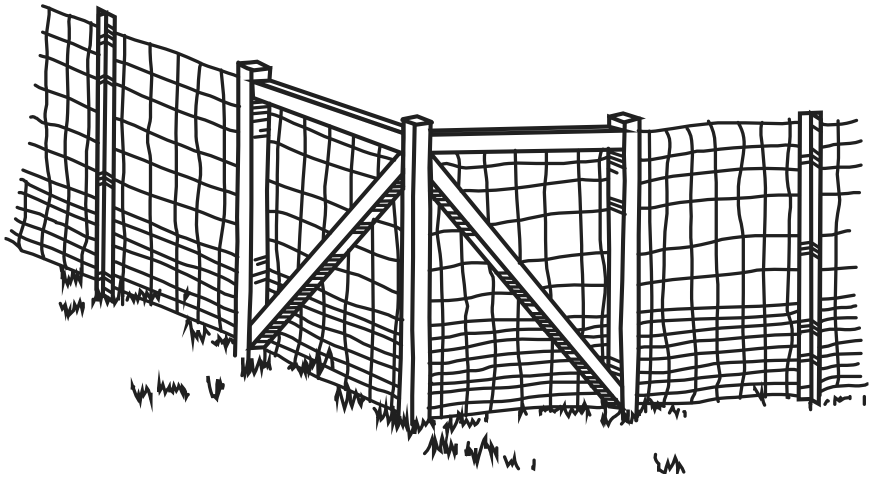

**Figure 20.8**
**Wildlife Exclusion Fence**

If wildlife becomes trapped inside the fenced area, they need to be able to safely exit the highway area. The most effective means of escape are through earthen ramps (or "jump-out" structures) as shown in Figure 20.9. Earthen ramps or jump-outs allow wildlife (large and small) to safely exit right-of-ways by jumping down to the opposite side of the fence. Earthen escape ramps are mounds of dirt placed against a smooth backing material and constructed on the right-of-way side of the fence. The landing spot around the outside wall must consist of loose soil, sand or other soft material to prevent injury to animals.

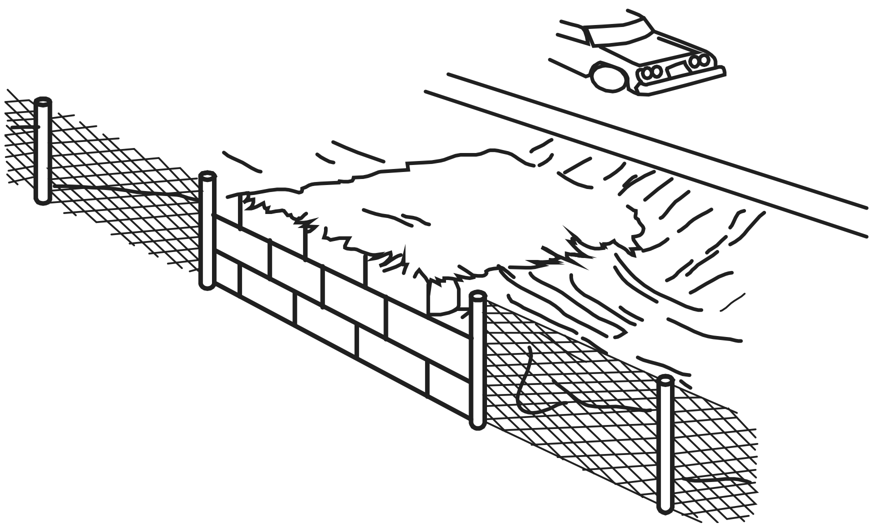

**Figure 20.9**
**Earthen Ramp or "Jump-Out" Structure**

**20.8 DETERMINING EFFECTIVENESS**

Monitoring of wildlife crossings may be conducted by PennDOT, the agency with jurisdiction of the species, and/or any partnering organization to determine the success of the accommodation and to help in the improved design and placement of future crossings. Measures of effectiveness should be developed during the design phase and monitored post-construction. "Effectiveness" may be defined as:

- Reduced animal-vehicle collisions (AVCs)
- Number of crossings by target species
- Adequate number of crossings (how many?)

- Connectivity maintained to sustain populations, communities, ecosystem functions
- Population increases of the species

## 20.9 MAINTENANCE

Existing and newly-installed wildlife crossing structures must be periodically maintained to continue to provide safe passage as, in the absence of routine maintenance, these structures may be avoided or become unusable by the species that they were intended to benefit. Maintenance staff should be involved in the wildlife crossings planning to provide input on design considerations and their impacts on maintenance needs as well as in post-project assessments to consult on any maintenance concerns that may have arisen. It cannot be assumed that crossing structures, once in place, will remain effective without periodic maintenance, and maintenance crews must be informed of the procedures necessary to keep crossing structures accessible and to function as intended.

Maintenance activities may include but are not limited to:

- Clearing of vegetation and maintenance of aprons of culverts. If scouring following storms prevents access, the scoured rocks or soil should be replaced with like materials to eliminate "hanging culverts" and not replaced with boulders, rip-rap or other substrates unsuited to the animal species the culvert was intended to benefit.
- Maintaining cover material for smaller species (including but not limited to: pipes, rocks, and root balls).
- Fences should be cleared of accumulated debris and repaired if they are torn or displaced from their original positions.

Vegetation over and under-crossings should be kept free of weeds that inhibit passage of all but the largest animals while native plants are encouraged to provide cover or forage.

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