
***CONNECTICUT DEPARTMENT
OF TRANSPORTATION***



(“The Charter Oak” Charles D. Brownell, 1857)

***HIGHWAY DESIGN MANUAL
JANUARY 1999***

(Includes March 2000 Revisions & Errata)

PREFACE

The *Connecticut Highway Design Manual* has been developed to provide uniform design practices for preparing roadway plans. The *Manual* presents most of the information normally required in the design of a typical highway project. The highway designer should attempt to meet all criteria presented in the *Manual*; however, the *Manual* should not be considered a standard that must be met regardless of impacts. The highway designer must consider the social, economic or environmental impacts that result from the design values selected. The highway designer should develop solutions that meet the Department's operational and safety requirements while preserving the aesthetic, historic or cultural resources of an area. The Department has designated certain highways or segments of highways that abut significant natural or cultural features as Scenic Highways. The criteria for and listing of Scenic Highways is included in an Appendix to Chapter One. Designers must exercise good judgment on individual projects and, frequently, they must be imaginative, innovative and flexible in their approach to highway design. Designers are reminded that the projects they work on are not just Department projects, but everyone's project.

The Department has developed alternative design standards for bridge rehabilitation projects under the Local Bridge Program. These alternative design standards may be applied to municipally maintained bridges on facilities that are functionally classified as "Rural Local Roads," "Rural Minor Collectors," or "Urban Local Streets."

The Department of Transportation wishes to thank the following organizations for their assistance during the development of this *Manual*:

- < Federal Highway Administration,
- < Council of Small Towns,
- < Rural Development Council,
- < Connecticut Trust for Historic Preservation,
- < Councils of Elected Officials,
- < Regional Councils of Government,
- < Regional Planning Agencies, and
- < Connecticut Council on the Arts.

FOREWORD

Connecticut is blessed with an exceptionally strong sense of time and place, its bustling towns and quiet villages linked by a web of roads, some of which began before the coming of Columbus as trails and paths linking Indian settlements. Whether local resident or visitor to the State, drivers know the experience of the journey can be a lot more than just getting from one point to the next.

The Connecticut landscape is one of great diversity. There are very few places in the country where you can see such varied and distinctive landscapes, all within a two-hour drive. Connecticut has mountainous and rolling uplands dropping down to broad agricultural plateaus, dissected by rocky, fast-moving streams. Connecticut has broad and fertile river valleys framed by distinctive landforms that have supported most of the urban population for its recent history. Connecticut has distinctive coastal plains separated by rocky outcrops and extensive salt marshes.

Beyond exceptional natural land forms, the State is blessed with a similar range of diversity in the ways people have inhabited the land. As was the case along much of the eastern seaboard, people settled Connecticut in a series of episodes that adapted to conditions of the land and changes in technology. For the first 120 or so years, the economy was agrarian, and the landscape was covered with small farms and homesteads. As technology evolved and industrialization began, these forms shifted and urban centers developed.

There are scenic places in both of these landscape types. Within the urban regions, the scenic qualities are a result of tenacious efforts by citizens to preserve what is left of the visible links between the land and people. Here, the scenic qualities are a result of relative scarcity. In the more rural regions, the scenic qualities are a result of tenacious efforts at making a living from the land. Scenic qualities are a result of continuous stewardship and care.

The rich heritage of Connecticut needs to continue. Highway and bridge engineers, amongst many others, are key players in achieving this goal. Engineers have the challenge to not only maintain and upgrade the transportation system to meet the operational and safety needs of the Department, but also to minimize the environmental, historic, cultural, aesthetic, social and economic impacts.

Table of Contents
CONNECTICUT HIGHWAY DESIGN MANUAL

Preface

Foreword

Table of Contents

Date of Revisions

Chapter One *MANUAL USAGE*

Chapter Two *GEOMETRIC DESIGN OF EXISTING HIGHWAYS*
(3R Non-Freeway Projects)

Chapter Three *GEOMETRIC DESIGN OF EXISTING HIGHWAYS*
(4R Freeway Projects)(Spot Improvements)

Chapter Four *RURAL HIGHWAYS AND ROADS*
(New Construction/Major Reconstruction)

Chapter Five *URBAN HIGHWAYS AND STREETS*
(New Construction/Major Reconstruction)

Chapter Six *DESIGN CONTROLS*

Chapter Seven *SIGHT DISTANCE*

Chapter Eight *HORIZONTAL ALIGNMENT*

Chapter Nine *VERTICAL ALIGNMENT*

Chapter Ten *CROSS SECTIONS*

Chapter Eleven *INTERSECTIONS AT-GRADE*

Chapter Twelve *INTERCHANGES*

Chapter Thirteen *ROADSIDE SAFETY*

Chapter Fourteen *MAINTENANCE AND PROTECTION OF TRAFFIC*
THROUGH CONSTRUCTION ZONES

Chapter Fifteen *SPECIAL DESIGN ELEMENTS*

[Glossary](#)

[Index](#)

LIST OF SECTIONS SHOWING LATEST DATE OF REVISIONS

ORIGINAL ISSUE DATE IS JANUARY 1999

<u>Section Number</u>	<u>Date</u>	<u>Section Number</u>	<u>Date</u>
1-1.0		Figure 2-3D	March 2000
1-1.01		Figure 2-3E	March 2000
1-1.02		Figure 2-3F	March 2000
1-1.03		Figure 2-3G	March 2000
1-1.04		Figure 2-3H	March 2000
1-2.0		Figure 2-3I	March 2000
1-2.01		2-4.0	
1-2.02		2-4.01	
1-2.03		2-4.02	
1-2.04		2-4.03	
1-2.05		2-5.0	
1-2.06		2-5.01	
1-2.07		2-5.02	
1-2.08		2-6.0	
1-2.09		2-6.01	
1-2.10		2-6.02	
1-2.11		2-6.03	
1-2.12		2-7.0	
1-2.13		2-7.01	
1-2.14		2-7.02	
1-2.15		2-7.02.01	
2-1.0		2-7.02.02	
2-2.0		2-7.03	
2-2.01		2-7.04	
2-2.01.01		2-8.0	
2-2.01.02		2-9.0	
2-2.01.03		2-9.01	
2-2.02		2-9.01.01	
2-2.03		2-9.01.02	
2-2.04		2-9.02	
2-2.05		2-10.0	
2-3.0		2-10.01	
Figure 2-3A	March 2000	2-10.02	
Figure 2-3B	March 2000	2-10.03	
Figure 2-3C	March 2000	2-10.04	

LIST OF SECTIONS SHOWING LATEST DATE OF REVISIONS

ORIGINAL ISSUE DATE IS JANUARY 1999

<u>Section Number</u>	<u>Date</u>	<u>Section Number</u>	<u>Date</u>
3-1.0		Figure 5K	
3-1.01		Figure 5L	
3-1.02		Figure 5M	March 2000
3-1.03		6-1.0	
3-1.04		6-1.01	
3-1.04.01		6-1.01.01	
3-1.04.02		6-1.01.02	
3-1.04.03		6-1.01.03	
3-1.04.04		6-1.02	
3-1.04.05		6-1.02.01	
3-1.04.06		6-1.02.02	
3-2.0		6-1.02.03	
3-2.01		6-1.03	
3-2.02		6-1.03.01	
3-2.03		6-1.03.02	
Figure 4A	March 2000	6-2.0	
Figure 4B	March 2000	6-2.01	
Figure 4C	March 2000	6-2.02	
Figure 4D	March 2000	6-2.03	
Figure 4E	March 2000	6-3.0	
Figure 4F	March 2000	6-3.01	
Figure 4G	March 2000	6-3.02	
Figure 4H	March 2000	6-3.03	
Figure 4I		6-4.0	
Figure 4J		6-5.0	
Figure 5A	March 2000	6-5.01	
Figure 5B	March 2000	6-5.01.01	
Figure 5C	March 2000	6-5.01.02	
Figure 5D	March 2000	6-5.01.03	
Figure 5E	March 2000	6-5.01.04	March 2000
Figure 5F	March 2000	6-5.01.05	
Figure 5G	March 2000	6-5.02	
Figure 5H	March 2000	6-6.0	
Figure 5I	March 2000	6-6.01	
Figure 5J	March 2000	6-6.02	March 2000

LIST OF SECTIONS SHOWING LATEST DATE OF REVISIONS**ORIGINAL ISSUE DATE IS JANUARY 1999**

<u>Section Number</u>	<u>Date</u>	<u>Section Number</u>	<u>Date</u>
6-6.03		8-3.02.01	
6-6.03.01		8-3.02.02	
6-6.03.02		8-3.02.03	
6-6.04		8-3.03	
6-7.0		8-3.04	
7-1.0		9-1.0	
7-2.0		9-1.01	
7-2.01		9-1.02	
7-2.02		9-2.0	
7-3.0		9-2.01	
8-1.0		9-2.02	
8-2.0		9-2.03	
8-2.01		9-2.04	
8-2.02		9-2.04.01	
8-2.02.01		9-2.04.02	
8-2.02.02		9-2.04.03	
8-2.02.03		9-3.0	
8-2.03		9-3.01	
8-2.03.01		9-3.02	
8-2.03.02		9-3.03	
8-2.03.03		9-4.0	
8-2.03.04		9-5.0	
8-2.03.05		10-1.0	
8-2.03.06		10-1.01	
8-2.03.07		10-1.01.01	
8-2.04		10-1.01.02	
8-2.04.01		1-1.02	
8-2.04.02		10-1.02.01	
8-2.04.03		10-1.02.02	
8-2.04.04		10-1.03	
8-2.04.05		10-1.04	
8-2.05		10-1.05	
8-3.0		10-1.05.01	
8-3.01		10-1.05.02	
8-3.02		10-1.05.03	

LIST OF SECTIONS SHOWING LATEST DATE OF REVISIONS

ORIGINAL ISSUE DATE IS JANUARY 1999

<u>Section Number</u>	<u>Date</u>	<u>Section Number</u>	<u>Date</u>
10-1.05.04		11-2.01.02	
10-2.0		11-2.01.03	March 2000
10-2.01		11-2.01.04	
10-2.01.01		11-2.02	March 2000
10-2.01.02		11-2.03	
10-2.02		11-3.0	
10-2.03		11-3.01	
10-3.0		11-3.02	
10-3.0		11-3.03	
10-3.01		11-3.03.01	
10-3.02		11-3.03.02	
10-3.02.01		11-3.03.03	
10-3.02.02		11-3.03.04	
10-3.02.03		11-3.03.05	
10-4.0		11-4.0	
10-4.01		11-4.01	
10-4.01.01		11-4.02	
10-4.01.02		11-4.02.01	
10-4.02		11-4.02.02	
10-5.0		11-4.02.03	
10-6.0		11-4.02.04	
10-7.0		11-4.02.05	
11-1.0		11-5.0	
11-1.01		11-5.01	
11-1.01.01		11-5.02	
11-1.01.02		11-5.03	
11-1.02		11-5.04	
11-1.03		11-5.05	March 2000
11-1.04		11-5.06	
11-1.04.01		11-6.0	
11-1.04.02		11-6.01	
11-1.05		11-6.02	
11-2.0		11-6.03	
11-2.01		11-7.0	
11-2.01.01	March 2000	11-7.01	

LIST OF SECTIONS SHOWING LATEST DATE OF REVISIONS

ORIGINAL ISSUE DATE IS JANUARY 1999

<u>Section Number</u>	<u>Date</u>	<u>Section Number</u>	<u>Date</u>
11-7.02		12-4.02	March 2000
11-8.0		12-4.03	March 2000
11-8.01		12-4.04	March 2000
11-8.01.01		12-5.0	
11-8.01.02		12-5.01	
11-8.02		12-5.02	
11-8.03		12-5.03	
11-9.0		12-6.0	
12-1.0		13-1.01	
12-1.01		13-2.0	
12-1.01.01		13-2.01	
12-1.01.02		13-2.02	
12-1.02		13-2.03	
12-1.02.01		13-2.04	
12-1.02.02		13-3.0	
12-2.0		13-3.01	
12-2.01		13-3.02	
12-2.02		13-3.03	
12-2.03		13-3.04	
12-2.04		13-3.05	
12-2.05		13-3.06	
12-2.06		13-3.07	
12-3.0		13-3.08	June 1999
12-3.01		13-4.0	
12-3.01.01		13-4.01	
12-3.01.02	March 2000	13-4.01.01	
12-3.01.03		13-4.01.02	
12-3.01.04		13-4.01.03	
12-3.01.05		13-4.01.04	
12-3.02		13-4.01.05	
12-3.02.01	March 2000	13-4.01.06	
12-3.02.02		13-4.01.07	
12-3.02.03		13-4.01.08	
12-4.0		13-4.02	
12-4.01		13-4.03	

LIST OF SECTIONS SHOWING LATEST DATE OF REVISIONS

ORIGINAL ISSUE DATE IS JANUARY 1999

<u>Section Number</u>	<u>Date</u>	<u>Section Number</u>	<u>Date</u>
13-4.03.01		13-7.01.04	
13-4.03.02		13-7.02	
13-5.0		13-7.02.01	March 2000
13-5.01		13-7.02.02	
13-5.02		13-7.02.03	
13-5.02.01		13-7.02.04	March 2000
13-5.02.02		13-7.02.05	March 2000
13-5.02.03		13-8.0	
13-5.02.04		Appendix	March 2000
13-5.02.05		14-1.0	
13-5.03		14-1.01	
13-5.03.01		14-1.02	
13-5.04		14-2.0	
13-5.05		14-2.01	
13-5.05.01		14-2.02	
13-5.05.02		14-3.0	
13-6.0		14-3.01	
13-6.01		14-3.02	
13-6.02		14-3.03	
13-6.03		14-3.04	
13-6.04		14-3.05	
13-6.05		14-4.0	
13-6.06		14-4.01	
13-6.07		14-4.02	
13-6.08		14-4.03	
13-6.09		14-4.04	
13-6.09.01		14-4.05	
13-6.09.02		14-5.0	
13-6.10		15-1.0	
13-6.11		15-1.01	
13-7.0		15-1.02	
13-7.01		15-1.03	
13-7.01.01		15-1.03.01	
13-7.01.02		15-1.03.02	
13-7.01.03		15-1.04	

LIST OF SECTIONS SHOWING LATEST DATE OF REVISIONS

ORIGINAL ISSUE DATE IS JANUARY 1999

<u>Section Number</u>	<u>Date</u>	<u>Section Number</u>	<u>Date</u>
15-1.05		15-5.02.01	
15-1.05.01		15-5.02.02	
15-1.05.02		15-5.02.03	
15-1.06		15-6.0	
15-1.07		15-6.01	
15-1.08		15-6.02	
15-1.08.01		15-6.03	
15-1.08.02		15-6.04	
15-1.08.03		15-6.04.01	
15-1.08.04		15-6.04.02	
15-1.09		15-6.04.03	March 2000
15-2.0		15-6.04.04	
15-2.01		15-6.04.05	
15-2.02		15-6.04.06	
15-2.02.01		15-6.04.07	
15-2.02.02		15-6.04.08	
15-2.02.03		15-6.05	
15-2.02.04		15-7.0	
15-2.03		15-7.01	
15-3.0		15-7.02	
15-3.01		15-7.03	
15-3.01.01		15-7.04	
15-3.01.02		15-7.05	
15-3.02		15-8.0	
15-3.02.01			
15-3.02.02			
15-3.02.03			
15-3.02.04			
15-4.0			
15-4.01			
15-4.02			
15-4.03			
15-5.0			
15-5.01			
15-5.02			

Chapter One

MANUAL USAGE

Table of Contents

	<u>Page</u>
1-1.0 OVERVIEW	1-1(1)
1-1.01 <u>Objective</u>	1-1(1)
1-1.02 <u>Scope</u>	1-1(1)
1-1.03 <u>Basis for Design</u>	1-1(3)
1-2.0 MANUAL SUMMARY	1-2(1)
1-2.01 <u>Introduction</u>	1-2(1)
1-2.02 <u>Chapter Two “Geometric Design of Existing Highways (3R Non-Freeway Projects)”</u>	1-2(1)
1-2.03 <u>Chapter Three “Geometric Design of Existing Highways (4R Non-Freeway Projects) (Spot Improvements)”</u>	1-2(1)
1-2.04 <u>Chapter Four “Rural Highways and Roads (New Construction/Major Reconstruction)”</u>	1-2(2)
1-2.05 <u>Chapter Five “Urban Highways and Streets (New Construction/Major Reconstruction)”</u>	1-2(2)
1-2.06 <u>Chapter Six “Design Controls”</u>	1-2(2)
1-2.07 <u>Chapter Seven “Sight Distance”</u>	1-2(3)
1-2.08 <u>Chapter Eight “Horizontal Alignment”</u>	1-2(3)
1-2.09 <u>Chapter Nine “Vertical Alignment”</u>	1-2(3)
1-2.10 <u>Chapter Ten “Cross Sections”</u>	1-2(4)
1-2.11 <u>Chapter Eleven “Intersections At-Grade”</u>	1-2(4)
1-2.12 <u>Chapter Twelve “Interchanges”</u>	1-2(4)
1-2.13 <u>Chapter Thirteen “Roadside Safety”</u>	1-2(5)
1-2.14 <u>Chapter Fourteen “Maintenance and Protection of Traffic Through Construction Zones”</u>	1-2(5)
1-2.15 <u>Chapter Fifteen “Special Design Elements”</u>	1-2(6)

Chapter One

MANUAL USAGE

1-1.0 OVERVIEW

1-1.01 Objective

The *Connecticut Highway Design Manual* has been prepared to provide guidance on the geometric design of bridge and highway projects. If used conscientiously and diligently, the *Manual* should be a significant benefit to designers in selecting cost-effective designs that will meet the objectives of the local community and those of the Department. Each project should be designed as part of the total environment, specifically designed to fit into the context of the area where it will be constructed. The design produced, especially those within rural areas, should reflect the natural, scenic and cultural landscape of the area. Where practical, designers should take advantage of the physical and topographical characteristics of an area to maximize aesthetics. For a highway project to ultimately be successful, public involvement must be established early in the design process so that a common goal may be achieved. Included as an Appendix to Chapter One is the executive summary from the Department's *A Guide for Public Outreach*, which has been prepared by the Office of Communications.

Throughout the design process, a designer may need to use the flexibility provided by this *Manual* to produce a design solution that satisfies diverse and occasionally conflicting interests. To aid in building an understanding of sensitivity and flexibility in design, the Federal Highway Administration has produced a guide, *Flexibility in Highway Design*. Designers should refer to this guide for examples of projects that have successfully integrated aesthetic, historic and scenic values along with safety and mobility. Also, the Department has produced a number of corridor studies for State-designated "Scenic Roads," which are referenced at the end of Chapter Two. These studies include recommendations that will allow for roadway improvements while protecting the scenic character of these roadways. Designers should be familiar with these studies and should consider applying some of the design tools included in these studies to other projects within sensitive areas.

1-1.02 Scope

The *Connecticut Highway Design Manual* provides design criteria for the following highway elements:

1. geometrics;
2. roadside safety;
3. maintenance and protection of traffic through construction zones; and
4. special design elements:
 - a. accessibility for disabled individuals,
 - b. bikeways,
 - c. landscaping,
 - d. commuter lots, and
 - e. fencing.

The designer should be aware of the projects' surrounding environment and carefully integrate the design within its context. Through site visits, the designer may develop an appreciation of the physical characteristics of an area and an understanding of community values. The designer must be aware of the impacts that result from rigidly applying the criteria contained within this *Manual*. The designer should carefully evaluate each criterion so that the final design provides for safety and operational improvement but in harmony with the aesthetic, historic and cultural resources of the community. The *Manual* provides flexibility to a designer through the use of a range of design values where appropriate. Where the application of the minimum design criteria results in unreasonably high construction costs or extreme impacts to the surrounding environment, the design exception process can address the use of lower than minimum design values on a case-by-case basis. See Section 6-6.0.

The proper design of a highway project requires input from various disciplines. Early coordination is required so that their input may be effectively incorporated into the final design of a project. Their input may impact the original scope or change the character of the project. The design of a highway project will likely include the evaluation and design of the following elements:

1. pavement design and rehabilitation;
2. hydraulic design of drainage appurtenances;
3. traffic engineering elements (e.g., traffic signals, lighting, signs, pavement markings);
4. geotechnical elements (e.g., slope stability, soil bearing strength);
5. structural design elements (e.g., bridges, culverts, retaining walls);
6. environmental considerations including:
 - a. noise,
 - b. water quality,
 - c. biological resources, and
 - d. historical resources;

7. right-of-way impacts (e.g., property owners, utilities, railroads); and
8. highway capacity.

1-1.03 Basis for Design

The *Connecticut Highway Design Manual* has been structured to select the applicable set of design criteria based on the following factors:

1. urban/rural location;
2. design classification, based primarily on the extent of roadside development;
3. the functional class of the facility:
 - a. freeway,
 - b. arterial,
 - c. collector, or
 - d. local; and
4. the project scope of work:
 - a. new construction,
 - b. 4R freeways,
 - c. major reconstruction (non-freeways),
 - d. 3R (non-freeways), or
 - e. spot improvements.

1-2.0 MANUAL SUMMARY

1-2.01 Introduction

The following summarizes the content of each chapter within the *Connecticut Highway Design Manual*.

1-2.02 Chapter Two “Geometric Design of Existing Highways (3R Non-Freeway Projects)”

ConnDOT often programs highway improvements on existing non-freeways for reasons other than geometric or safety deficiencies (e.g., pavement deterioration). These projects typically must be designed within restrictive right-of-way, financial and environmental constraints. Therefore, the design criteria for new construction are often not attainable without major and, frequently, unacceptable adverse impacts. At the same time, however, the Department must take the opportunity to make cost-effective, practical improvements to the geometric design of existing highways and streets.

For these reasons, the Department has adopted in Chapter Two revised limits for geometric design criteria for projects on existing non-freeways which are, in many cases, lower than the values for new construction. These criteria are based on a sound, engineering assessment of the underlying principles behind geometric design and on how the criteria for new construction can be legitimately modified to apply to existing highways without sacrificing highway safety.

Chapter Two presents the Department's criteria for 3R non-freeway projects. These criteria are intended to find the balance among many competing and conflicting objectives. These include the objective of improving Connecticut's existing highways; the objective of minimizing the adverse impacts of highway construction on existing highways; and the objective of improving the greatest number of kilometers within the available funds.

1-2.03 Chapter Three “Geometric Design of Existing Highways (4R Freeway Projects) (Spot Improvements)”

Based on the same approach to 3R non-freeway projects in Chapter Two, Chapter Three presents modified geometric design criteria for:

1. 4R freeway projects, and
2. spot improvement projects.

The design criteria for these two project scopes of work reflect the practical constraints of designing highway improvements on existing facilities.

1-2.04 Chapter Four “Rural Highways and Roads (New Construction/Major Reconstruction)”

Chapter Four presents a set of summary tables of geometric design criteria for new construction/ major reconstruction projects in rural areas based on:

1. functional classification;
2. design classification on non-freeways (based on the average number of access points per kilometer per side); and
3. for arterials, two-lane versus multi-lane.

These tables provide the *Manual* user with a convenient summary of the geometric design criteria which apply to a specific facility. The tables also identify the controlling design criteria which require a written design exception if not met.

1-2.05 Chapter Five “Urban Highways and Streets (New Construction/Major Reconstruction)”

Chapter Five presents a set of summary tables of geometric design criteria for new construction/ major reconstruction projects in urban areas based on:

1. functional classification;
2. design classification on non-freeways (based on the type of area); and
3. for arterials, two-lane versus multi-lane.

These tables provide the *Manual* user with a convenient summary of the geometric design criteria which apply to a specific facility. The tables also identify the controlling design criteria which require a written design exception if not met.

1-2.06 Chapter Six “Design Controls”

Proper highway design must reflect the consideration of many basic design controls which provide the overall framework for highway design. Chapter Six discusses the Department’s application of these controls, including:

1. highway systems (e.g., functional classification, Federal-aid);
2. the various speed measurements (e.g., design speed);
3. highway capacity analyses;
4. access control; and
5. project scope of work.

Chapter Six also discusses the Department's process for requesting a design exception for those geometric design values which do not meet the Department's criteria.

1-2.07 Chapter Seven "Sight Distance"

Sufficient sight distance is critical to safe highway operations. Chapter Seven presents ConnDOT criteria for various sight distance elements, including stopping sight distance and decision sight distance. The Chapter also discusses the application of the two sight distance parameters. Intersection sight distance is addressed in Chapter Eleven "Intersections At-Grade."

1-2.08 Chapter Eight "Horizontal Alignment"

Highway horizontal alignment has a significant impact on highway safety and construction costs. Chapter Eight presents ConnDOT criteria which will establish the alignment of a highway facility. This includes:

1. types of horizontal curves;
2. minimum radii;
3. superelevation development (e.g., transition lengths, axis of rotation); and
4. sight distance around horizontal curves.

Because of their different operating conditions, Chapter Eight presents separate criteria for all rural highways/high-speed urban highways ($V \geq 80$ km/h) and for low-speed urban streets ($V \leq 70$ km/h).

1-2.09 Chapter Nine "Vertical Alignment"

Highway vertical alignment, perhaps more so than any other highway element, has a significant impact on construction costs and highway operations, especially where there is an appreciable volume of trucks. Chapter Nine presents ConnDOT criteria on vertical alignment, including:

1. maximum and minimum grades,
2. critical lengths of grade,

3. warrants and design for climbing lanes,
4. the design of crest and sag vertical curves, and
5. vertical clearances.

1-2.10 Chapter Ten “Cross Sections”

The highway cross section has a significant impact on the driver's perception of the serviceability and safety of the highway facility. Chapter Ten presents ConnDOT criteria on cross section elements to supplement the design values in Chapters Two, Four and Five. Chapter Ten discusses:

1. the roadway section (e.g., travel lanes, shoulders, cross slopes, parking lanes, curbs);
2. roadside elements (e.g., sidewalks, fill slopes, cut sections);
3. medians;
4. cross sections for bridges and underpasses; and
5. right-of-way.

1-2.11 Chapter Eleven “Intersections At-Grade”

Intersections at-grade represent major points of conflict between crossing flows of traffic. Driver delay is inevitable because of the need to assign right-of-way, and accidents often cluster about intersections. Therefore, they merit considerable attention in highway design. Chapter Eleven presents ConnDOT criteria for the design of intersections at-grade, including:

1. general design controls (e.g., capacity, selection of design vehicle, alignment, profile);
2. intersection sight distance;
3. design for right turns;
4. turning roadways;
5. auxiliary turning lanes (e.g., warrants, length, dual turn lanes);
6. median openings;
7. channelization; and
8. driveways.

1-2.12 Chapter Twelve “Interchanges”

Interchanges offer the safest and most effective method to accommodate traffic operations between two intersecting highways. However, their high cost and significant impacts limit their application to freeways and other selected major facilities. Chapter Twelve presents ConnDOT criteria for the selection and design of interchanges, including:

1. warrants;
2. types;
3. traffic operations (e.g., lane balance, lane reduction, capacity);
4. freeway/ramp junctions (e.g., exit and entrance ramps);
5. geometric design of ramps; and
6. design of the ramp/crossing road intersection.

1-2.13 Chapter Thirteen “Roadside Safety”

Regardless of the highway engineering design, a certain number of vehicles will run off the road. The roadside design should provide these drivers with a reasonable opportunity to recover and safely return to the highway. This is accomplished through the availability of a clear roadside and/or the installation, where warranted, of protective barriers. Chapter Thirteen presents ConnDOT criteria for roadside safety, including:

1. clear zone criteria;
2. guide rail warrants;
3. guide rail types and selection;
4. median barriers (e.g., warrants, types, design);
5. guide rail layout and design (e.g., length of need, flare rates, placement behind curbs); and
6. crash cushions/end treatments.

1-2.14 Chapter Fourteen “Maintenance and Protection of Traffic Through Construction Zones”

A significant portion of the Department’s future highway program will be to upgrade existing facilities. Because this will inevitably disrupt existing traffic operations, Chapter Fourteen presents ConnDOT criteria on traffic control through construction zones to minimize operational and safety problems. The Chapter discusses:

1. the ConnDOT responsibilities for maintenance and protection of traffic,
2. traffic control management,
3. geometric design through the construction zone, and
4. roadside safety through the construction zone.

1-2.15 Chapter Fifteen “Special Design Elements”

In addition to the traditional highway design elements, the Department is responsible for ensuring that the highway design properly incorporates a wide variety of special design elements. Chapter Fifteen presents ConnDOT criteria for these elements, including:

1. accessibility for disabled individuals,
2. layout and design of commuter lots,
3. location and design of bus stops,
4. warrants and design of bikeways,
5. landscaping,
6. warrants and location for fencing, and
7. design implications for noise barriers.

Appendix

This Appendix to Chapter One presents the following:

1. *Criteria for Designation of Scenic Highways.*
2. *A Guide for Public Outreach, Executive Summary.*

CRITERIA FOR DESIGNATION OF SCENIC HIGHWAYS

A potential state scenic highway must abut significant natural or cultural features such as agricultural land or historic buildings and structures which are listed on the National or State Register of Historic Places, or afford vistas of marshes, shoreline, forests with mature trees, or other notable natural or geologic feature which singularly or in combination set the highway apart from other state highways as being distinct. The Highway shall have a minimum length of one (1) mile and shall abut development which is compatible with its surroundings. Such development must not detract from the scenic or natural character or visual qualities of the highway area.

Guidelines for Requesting Designation

1. Requests for state scenic highway designation from any agency, municipality, group or individual should be directed to:

***Commissioner
Department of Transportation
2800 Berlin Turnpike
P.O. Box 317546
Newington, CT 06131-7546***

2. The applicant must prepare a report for submission to the Commissioner which shall include the following:
 - a. A statement of the highway segments or areas to be included.
 - b. A description of natural and cultural resources and features of scenic interest.
 - c. A description of existing land use.
 - d. Photographs of outstanding and representative scenery.
 - e. A list of properties on the National or State Register of Historic Places. The applicant may contact the Connecticut Historical Commission [(860) 566-3005] for assistance in identifying properties which have been historically designated along a proposed scenic highway.
3. The Scenic Roads Advisory Committee shall make a systematic evaluation of the extent and quality of historic, scenic, natural and cultural resources for the proposed scenic highway.
4. The Scenic Roads Advisory Committee may review any reports, letter, articles, or other documents which is deemed necessary to assist in its recommendation. It may also request additional information from the applicant to clarify any information provided in the report. Its recommendation shall be forwarded to the Commissioner for action.

SCENIC ROADS

As of June 1, 1999

ROUTE	TOWN	DATE DESIGNATED	MILES	LOCATION
4	Harwinton	7/29/96	1.60	From Cooks Dam, west to Route 118.
118		7/29/96	0.10	From Route 4, west to Cemetery Road.
4	Sharon	7/26/90	3.10	From Route 7 west, to Dunbar Road.
4	Sharon	10/22/92	0.80	From Dunbar Road, west to Old Sharon Road.
7	Sharon	7/26/90	4.29	From the Cornwall Bridge crossing of the Housatonic River, north to Route 128, at the covered bridge.
7	Kent	10/17/91	10.50	From the New Milford Town line, north to the Cornwall Town line.
10	Farmington	4/13/99	1.0	From Route 4, south to Tunxis Street.
14	Windham/ Scotland	1/13/99	4.4	From the Windam Center School to 0.3 mi. East of Scotland Center
14A	Sterling	2/2/95	0.70	From Route 49, east to Porter Pond Road.
15	Greenwich to Stratford	1/28/93	37.50	The Merritt Parkway from the New York State Line to the Housatonic River Bridge.
33	Wilton	11/3/97	4.90	From the Wilton/Ridgefield Town line, south to the intersection with Old Ridgefield Road #1.
41	Salisbury	12/20/93	8.01	From the Sharon/Salisbury Town line, north to the Massachusetts State line.
41	Sharon	7/26/90	4.00	From Boland Road, north to Cole Road.
41	Sharon	10/22/92	2.20	From Cole Road, north to the Sharon/Salisbury Town line.
41	Sharon	10/22/92	2.20	From Boland Road, south to the New York State line.
		DATE		

ROUTE	TOWN	DESIGNATED	MILES	LOCATION
44	Salisbury	12/20/93	8.83	From the New York State line, east to the Salisbury/North Canaan Town line.
45 SR 478	Washington Warren	12/26/96	6.9	From the Washington/Kent Town line on SR 478, east to Route 45, north on Route 45 to the northern junction of SR 478, and west on SR 478 to the Warren/Kent Town line.
49	North Stonington	2/2/95	10.90	From Route 184, north to 0.10 miles before Route 165.
49	Voluntown	2/2/95	7.90	From the Boat Launch area, north to Route 14A.
53	Redding	12/18/92	2.03	From the Redding/Weston Town line, north to the southern junction of Route 107.
58	Easton	5/6/94	3.14	From the Fairfield/Easton Town line, north to Freeborn Road.
67	Roxbury	11/14/90	0.87	From Ranny Hill Road, south to 0.30 miles south of Route 317.
67	Roxbury	8/23/96	2.90	From the Roxbury/Bridgewater Town line, east to Ranny Hill Road.
77	Guilford	5/3/91	11.56	From Route 146, north to the Durham/Guilford Town line.
146	Branford Guilford	5/29/90	12.20	From Eades Street, Branford to US Route 1, Guilford.
154	Haddam	1/13/94	9.16	From the Chester/Haddam Town line, north to the Haddam/Middletown Town line.
160	Glastonbury	1/18/91	1.06	From the Roaring Brook Bridge, west to the Connecticut River.
164	Preston	2/1/94	2.58	From Old Shetucket Turnpike, north to the Preston/Griswold Town line.
169	Lisbon Woodstock	4/15/91	32.10	From Rocky Hollow Road in Lisbon, north to the Massachusetts State line.
ROUTE	TOWN	DATE DESIGNATED	MILES	LOCATION

179	Canton	2/25/91	0.30	From the Burlington/Canton Town line to the junction with SR 565.
181	Barkhamsted	1/10/95	1.10	From Route 44, north to Route 318.
183	Colebrook	5/20/94	3.10	From Route 182, north to Church Hill Road.
202	New Hartford	8/12/91	5.10	From the Canton/New Hartford Town line, west to the Bakersville Methodist Church.
203	Windham	1/13/99	1.7	From Route 32 northerly to Route 14, Windham Center Green.
219	Barkhamstead	1/10/95	2.60	From Route 318, south to the end of Lake McDonnough Dam.
219	New Hartford	9/24/98	0.70	From the Lake McDonnough Dam, southerly to the south side of the "Green Bridge" (Br. No. 1561).
234	Stonington	2/20/90	3.16	From North Main Street, west to Route 27.
272	Norfolk	5/13/96	11.00	From the Norfolk/Goshen Town line, north to the Massachusetts State line.
317	Roxbury	11/14/90	0.40	From Painter Hill Road, west to Route 67.
318	Barkhamsted	1/10/95	2.60	From Route 181 to Route 219.
565	Canton	2/25/91	0.70	From Route 179, northeast to Allen Place.

TOTAL 229.89

DEPARTMENT OF TRANSPORTATION

Designation of Scenic Roads

Section 1: Regulations of Connecticut State Agencies are amended by adding new sections 13b-31c-1 to 13b-31c-5 inclusive, as follows:

Sec. 13b-31c-1. Definitions

(a) "Advisory Committee" means the Scenic Road Advisory Committee established pursuant to these regulations.

(b) "Commissioner" means the Commissioner of the Department of Transportation (DOT).

(c) "Department" means the Department of Transportation (DOT).

(d) "Improvement" means actions or activities initiated by the Department of Transportation which alter or improve a designated scenic road in one or more of the following ways: (1) widening of the right-of-way or traveled portion of the highway, (2) installation or replacement of guide railing, (3) paving, (4) changes of grade, and (5) straightening and removal of stone walls or mature trees.

(e) "Scenic Road" means any state highway or portion thereof that (1) passes through agricultural land or abuts land on which is located an historic building or structure listed on the National Register of Historic Places or the state register of historic places, compiled pursuant to section 10-321 of the general statutes, or (2) affords vistas of marshes, shoreline, forests with mature trees or notable geologic or other natural features.

(f) "State Highway" means a highway, bridge or appurtenance to a highway or bridge designated as part of the state highway system within the provisions of chapter 237 of the Connecticut General Statutes, or a highway, bridge or appurtenance to a highway or bridge specifically included in the state highway system by statute.

Sec. 13b-31c-2. Administration, advisory committee, composition and duties

(a) The Commissioner shall establish a Scenic Road Advisory Committee. This Committee will include representation from the Departments of Transportation, Environmental Protection and Economic Development.

(b) The Advisory Committee shall meet quarterly, unless there is no business, or as necessary to:

(1) Develop a method to systematically evaluate request for scenic road designation.

(2) Review and evaluate the requests submitted to the Commissioner to designate a State highway, or portion thereof, as a scenic road.

(3) Prepare recommendations to the Commissioner as to those highways, or portion thereof, appropriate for designation as a scenic road.

(4) Review Department proposals to evaluate whether the proposed improvement will have an effect upon or alter the characteristics that qualified the highway as scenic.

(5) Recommend alternate courses of action which could avoid, mitigate or minimize adverse effects of the improvement on the scenic road, without compromising the safety of the traveling public.

(6) When conditions of development, zone change or other local action occur they may review the designated scenic road and recommend to the Commissioner any changes in designation.

Section 13b-31c-3. Request to designate a highway as scenic

(a) Requests to designate a state highway as a scenic road may be made to the Commissioner by any agency, municipality, group or individual.

(1) Requests for consideration must include a report providing pertinent information on the proposed designated highway. This report shall be prepared by the requesting agency, municipality, group or individual and submitted to the Commissioner. The report shall include the following:

(A) Highway segments or areas to be included.

(B) Description of natural and cultural resources and features of scenic interest.

(C) Existing land use.

(D) Photographs of outstanding and representative scenery.

(E) Properties listed on the National Register of Historic Places and/or state register of historic places.

(b) The Advisory Committee shall make a systematic evaluation of the extent and quality of historic or scenic, natural and cultural resources for the proposed designated scenic road.

(c) The Advisory Committee may review any reports, letters, articles, etc. or any other document which it deems necessary to assist in its recommendation. It may also request additional information from the applicant to clarify any information provided in the report.

(d) Within 90 days of its meeting, the Advisory Committee shall, based on the review of the submitted information report and systematic evaluation of the resources, forward recommendations to the Commissioner for approval or denial of designation. This recommendation will include the identification of the specific features or characteristics which would qualify it as scenic or the reasons why a scenic designation is not considered appropriate.

(e) Within 45 days after reviewing the Advisory Committee's recommendation, the Commissioner will approve or deny the request for scenic road designation.

(f) Within 15 days of the Commissioner's determination, the requesting agency, municipality, group or individual shall be informed in writing of the decision and the basis for it.

Sec. 13b-31c-4. Reconsideration of requests to designate a highway

(a) State highways which do not receive a recommendation for designation or are recommended for deletion will receive no further consideration until additional information is presented to the Commissioner. This additional data is limited to the specific item or items which resulted in the denial or deletion of scenic designation. Within 60 days of its meeting to reconsider, the Advisory Committee shall forward its recommendation to the Commissioner for a final decision.

(b) Within 45 days after receiving the Advisory Committee's recommendation, the Commissioner shall render a final decision on the requested designation.

(c) Within 15 days of the Commissioner's final determination, the requesting agency, municipality, group or individual shall be informed in writing of the final decision and the basis for it.

Sec. 13b-31c-5. Qualifications for a scenic road

(a) In order to qualify for scenic road designation, the state highway under consideration must have significant natural or cultural features along its borders such as agricultural land, an historic building or structure which is listed on the National Register of Historic Places or the state register of historic places or affords vistas of marches, shoreline, forests with mature trees or notable geologic or other natural features which singly or in combination set this highway apart from other highways as being distinct.

(b) The proposed scenic road shall have a minimum length of 1 mile.

(c) The proposed scenic road shall have development which is compatible with its surroundings and must not detract from the scenic, natural character and visual quality of the highway area.

Section 2: The Regulations of Connecticut State Agencies are amended by adding new sections 13b-31e-1 to 13b-31e-4 inclusive, as follows:

Section 13b-31e-1. Determination of effect upon designated scenic roads

(a) **Determination of effect:** Improvements proposed to scenic roads shall be reviewed by the Advisory Committee to evaluate whether the improvements will have a significant effect upon or alter the specific features or characteristics that qualified it to be designated as scenic.

(1) No adverse effect: If the Advisory Committee finds that the proposed improvement will not significantly affect these features or characteristics, the undertaking may proceed as proposed.

(2) Adverse effect: If the Advisory Committee finds that the proposed improvement will have a significant adverse impact on the features or characteristics of the scenic road, it shall:

(A) Notify the Commissioner of their finding.

(B) Return the project to the designer with recommended alternate courses of action that could avoid, mitigate or minimize adverse effects of undertaking on the scenic road. These recommendations could include, but are not limited to, consideration of a waiver of Department or Federal standards, the use of tinted pavements, stone wall replacements and tree or shrub replacements.

(C) If alternatives or waivers are not considered to be feasible by the designer, the Advisory Committee shall make recommendations to the Commissioner as to whether the project should be constructed as proposed.

(D) In all cases, the Commissioner shall make the final determination as to whether to approve or deny the proposed improvements or alternations.

Sec. 13b-31e-2. Public notification of proposed improvements or alterations to a designated scenic road

(a) For those highway construction or maintenance activities that a majority of the Advisory Committee determines to constitute an "improvement" to a designated scenic road within the meaning of Section 1(d) of this regulation, the Department shall publish, in a newspaper of general circulation in the area of the proposed improvements, a notice describing the alteration or improvement. There shall be a thirty (30) day comment period following this notice during which interested persons may submit written comments.

(b) The Advisory Committee shall review and evaluate all written comments. A report of findings will be prepared outlining the resolution of the various comments and forward to the Commissioner.

(c) In all cases, the Commissioner shall make the final determination as to whether to approve or deny the proposed improvements or alterations.

Sec. 13b-31e-3. Special improvement and maintenance standards for scenic roads

(a) At the time a highway is officially designated as scenic, the characteristics responsible for this designation shall be clearly identified and recorded. Any alteration to a scenic road shall maintain these characteristics, if practical.

(b) Improvements to scenic roads shall be developed in conformity with current Department design and/or maintenance standards for the type road unless it is determined that using such standards will have a significant adverse impact upon the roadway's scenic characteristics. In which case, exemption from Department or Federal standards may be considered to preserve the roadway's scenic qualities.

(c) In designing improvements to and/or preparing for maintenance on a designated scenic road, special consideration should be given to the following:

(1) **Widening of the Right of Way:** The Department may not purchase additional property along a designated scenic road unless the Commissioner has first determined that property acquisition is necessary. The area purchased should be kept to a minimum with the need and use outlined in a detailed report to the Commissioner.

(2) **Widening of the Traveled Portion:** Wherever possible and as safety allows, roadway widening should be kept to a minimum width and accomplished within the existing highway right-of-way. The Department may not widen or issue a permit to allow others to widen any portion of a designated scenic road unless the Commissioner has first determined, after review and approval of a traffic engineering report, that such an improvement is necessary to improve an existing or potential traffic problem.

(3) **Guide Rails (Guardrails):** Guide rails should be replaced in-kind in accordance with current Department standards unless the Commissioner determines after review and approval of a traffic engineering report, that a safety problem exists and another type of guard rail system is necessary for more positive protection.

(4) **Paving:** Paving is to be accomplished in accordance with current Department standards. The pavement type, drainage appurtenances and curbing installation will be accomplished as required with

consideration given to the characteristics of the scenic road. The width of paving should not extend more than 12 inches beyond the existing shoulder.

(5) **Changes of Grade:** Wherever possible, proposed changes in grade should be designed to a minimum to restrict the impact on the scenic features. Changes of grade must be approved by the Commissioner after review and approval of a traffic engineering report where it has been determined that such an improvement is necessary to improve an existing or potential traffic problem.

(6) **Straightening or Removal of Stone Walls:** The Commissioner may approve the straightening or removal of a stone wall after review and approval of a traffic engineering report that has determined that such action is necessary to improve an existing or potential safety hazard, improve a sight line restriction, for installation of drainage appurtenances or for other sound reason. The Department will attempt, if practical, to relocate the stone wall within the highway right-of-way or on private property of the abutting property owner. The stone wall should be reconstructed in a manner consistent with its former appearance.

(7) **Removal of Mature Trees:** Wherever possible and as safety allows, mature trees within the highway right-of-way should not be removed. If roadway widening is approved, the alignment should be such as to restrict its impact on mature trees. The Commissioner may approve the removal of mature trees after review of an engineering report which outlines the need.

(8) **General Maintenance:** All scenic roads shall receive the level of maintenance necessary for safe public travel.

(9) **Road Bed Maintenance:** Necessary improvements, as determined by the Director of Maintenance, may be made to improve safety, drainage or reduce a maintenance problem, but shall not disturb the scenic characteristics for which the roadway was designated.

(10) **Cross Drainage Maintenance:** Cross drainage shall be maintained where necessary to prevent damage to the highway, possible washouts and other problems which may be detrimental to the safety of the traveling public.

(11) **Vegetation Maintenance:** Where necessary for the safety and protection of the traveling public, tree branches and shrubs may be trimmed. Mowing shall be performed as necessary in accordance with Department standards for health and safety requirements.

(12) **Sign Maintenance:** All information, regulatory, warning and identification signs shall be erected and maintained as necessary or provided for by the State Traffic Commission.

(13) **Winter Maintenance:** Winter maintenance procedures shall be conducted in accordance with standard Department policy. Snow and ice control shall be performed in accordance with the latest Department policy.

Sec. 13b-31e-4. Emergency repairs

Should the Commissioner declare an emergency, as specified under Section 13b-26(f) of the General Statutes, repairs will be made in a manner which will minimize, as much as reasonably possible, the effect upon the features for which the highway was designated as scenic.

Statement of purpose: To provide regulations for the designation of State highways as scenic roads in accordance with Public Act No. 87-280.

Be it known that the foregoing regulations are adopted by the aforesaid agency pursuant to Public Act No. 87-280 of the Public Acts, after publication in the Connecticut Law Journal on March 8, 1988, of the notice of the proposal to adopt such regulations.

Wherefore, the foregoing regulations are hereby adopted, effective when filed with the Secretary of the State.

In Witness Whereof: March 28, 1989, J. William Burns, Commissioner.

Approved by the Attorney General as to legal sufficiency in accordance with Sec. 4-169, as amended, General Statutes: March 31, 1989.

Approved by the Legislative Regulation Review Committee in accordance with Sec. 4-170, as amended, of the General Statutes: April 18, 1989.

Two certified copies received and filed, and one such copy forwarded to the Commission on Official Legal Publications in accordance with Sec. 4-172, as amended, of the General Statutes, Secretary of State: May 1, 1989.

TABLE OF CONTENTS

	Page
1.0 Connecticut Department of Transportation Mission/Principal/Value and Public Outreach Policy	1
2.0 Introduction	2
3.0 Planning Process	5
4.0 Facility Design/Rights-of-Way/Program Development	10
5.0 Construction/Implementation/Maintenance	11
6.0 Public Meetings	13

1.0 CONNECTICUT DEPARTMENT OF TRANSPORTATION -
MISSION / PRINCIPLE / VALUES - PUBLIC OUTREACH POLICY

MISSION: It is the mission of the Connecticut Department of Transportation to provide a safe, efficient, and cost effective transportation system that meets the mobility needs of its users.

PRINCIPLE: To engage stakeholders in a consultative process from the earliest stages of project development.

VALUE: Customer Service - Committed to understanding and satisfying the needs of our customers through a total quality effort.

It is the policy of the Connecticut Department of Transportation (DOT) to consult with stakeholders and customers of the transportation system. In accomplishing this, the DOT shall:

1. Identify those who may be affected or interested in transportation plans, programs or projects.
2. Comply with all Federal and State requirements in developing and implementing public outreach programs throughout transportation planning, project design, project construction, and system maintenance.
3. Develop and implement public outreach programs throughout transportation planning, project design, project construction, and system maintenance.
4. Periodically review public outreach efforts to modify and improve such efforts as necessary.

2.0 INTRODUCTION

Public Outreach is the process implemented to inform and offer the opportunity to the public, to participate in the development of a proposed transportation action. "Partners" are participants with comparable status, with equal legitimacy. The emphasis is on developing transportation decisions as a product of partners' collaborative work. It is a result of debate and choices made jointly by a variety of government and non-government parties working through an on-going, interactive process.

This Executive Summary presents an overview of the key elements of the Connecticut Department of Transportation's (DOT) complete "Guide For Public Outreach" (Guide), for developing public outreach processes throughout the development of transportation actions (study, program or project). The Guide has been prepared for use by the DOT, and provides a menu for developing and implementing an effective process for informing the public and for community participation. The Guide identifies the coordination required between the DOT, federal and other state agencies, local governments, elected officials and Regional Planning Organizations (RPO), and the citizens of Connecticut throughout the development of proposed transportation actions, from concept to completion. The complete Guide is available for viewing at the Connecticut Department of Transportation Library, Room G-114, 2800 Berlin Turnpike, P.O. Box 317546, Newington, Connecticut 06131-7546.

The complete Guide is structured to provide a menu for public outreach plans throughout three general phases of program or project development: Planning, Facility Design/Rights-of-Way/Program Development, and Construction/Implementation/Maintenance. In addition to an explanation of terms used, and specific federal and state regulatory requirements, Appendices are also included in the complete Guide which address the following:

- Appendix A: Definitions And Explanations of Abbreviations
- Appendix B: Flow Diagrams and Summary Tables
- Appendix C: Public Outreach Strategies
- Appendix D: Mailing List "Interested and Affected Parties"
- Appendix E: Public Noticing Media Strategies and Public Notice Information
- Appendix F: Major Metropolitan Transportation Investments
- Appendix G: DOT Bureau of Public Transportation Public Outreach Activities
- Appendix H: DOT Bureau of Aviation and Ports Public Outreach Activities
- Appendix I: Connecticut Department of Transportation Policy Public Involvement/Public Hearings for Highway Layouts (Corridor) and Design (October, 1995)

- Appendix J: "Property Acquisition for Transportation Projects" (Connecticut Department of Transportation, 1991)
"Relocation Assistance Program" (Connecticut Department of Transportation)
- Appendix K: Connecticut Department of Transportation Office of Construction Public Outreach/Involvement Procedures
- Appendix L: Sample Public Outreach Effectiveness Review Survey Questionnaire
- Appendix M: "Innovations in Public Involvement for Transportation Planning" (FHWA/FTA), (January, 1994)
- Appendix N: "Public Outreach Handbook For Departments of Transportation" (NCHRP Report # 364,)

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) is the most recent legislation which emphasizes public participation in the transportation planning process. Under the terms of federal legislation (recent and historic), there is a general need for an effective proactive and meaningful public outreach process which is informative and provides opportunity for participation. It is the DOT's responsibility to provide government agencies, citizens, affected public agencies, private providers of transportation, and other parties (collectively identified as stakeholders) information and the opportunity to participate in the development of proposed transportation actions.

Public outreach programs are by necessity strongly individualistic, and tailored to local circumstances. Generalization of public outreach efforts is difficult and the development of standardized procedures is impossible. Multiple approaches may be required to elicit the involvement of different stakeholders. Emphasis is focused upon transportation actions which can directly affect neighborhoods and communities for the long term.

Any public outreach program should incorporate the following:

1. Outreach needs to be effective; i.e., adequate notice must be provided to the general public and targeted audiences.
2. Public input needs to take place early enough in the planning process that it can be assimilated.
3. Sufficient information needs to be provided to the public to allow their input to be informed.
4. The public's input should be responded to, explaining why it was either accepted or rejected.

The characteristics of successful participation are: inclusiveness, early involvement, and clear accurate information. Community involvement programs must be tailored to the community, the audience, and the issues. Tools identified in the Guide for

effective public outreach include: public meetings, charrettes, visioning, brainstorming, citizen's advisory committees, transportation fairs, focus groups, collaborative task forces, workshops, public opinion surveys, interviews, polls and media strategies (e.g. newsletters, paid advertisements, television). Many of the suggested procedures and tools identified in this document have been applied at least in some form, by the DOT for specific programs and projects. This guide draws upon the DOT's applications with an effort to enhance and improve them.

The tools identified here, however, are not intended to be exhaustive. The Federal Highway Administration (FHWA) and Federal Transit Administration (FTA) have jointly published information regarding public outreach entitled "Innovations in Public Involvement for Transportation Planning" (January, 1994). Explanations of many of the tools identified in the Guide are based upon this FHWA/FTA document.

3.0 PLANNING PROCESS

3.1 General:

One of the areas most affected by ISTEA is public involvement in the transportation planning processes. These federal rules affect both state and local officials in that they mandate certain requirements for public input in transportation decision-making. The requirements as presented here pertain directly to the Statewide planning process. Distinct requirements have also been defined in ISTEA which pertain directly to the Metropolitan Planning Organizations (MPO). The MPO's each are required to establish and document their respective public outreach procedures.

The DOT's planning process is defined here as three elements: development of the State Long Range Transportation Plan, development of the State Transportation Improvement Program, and project planning. As part of these elements, the DOT must develop, adopt and implement formalized procedures for effective community participation in the development of the following State planning documents:

- Statewide Long Range Transportation Plan (Plan)
- Statewide Transportation Improvement Program (STIP)
- Statewide Transportation Improvement Program Amendments
(for amendments which may have a significant affect upon air quality)
- Federal Environmental Impact Statement
- State Environmental Impact Evaluation
- Federal Environmental Assessment
- State Finding of No Significant Impact
- Environmental permit applications

Federal requirements apply to the development and major amendments of both the Plan and the STIP. The transportation planning process must include a proactive public involvement process. The rules spell out seven distinct criteria that must be included in a state's public participation process:

1. Early and continuing public involvement opportunities;
2. Timely information;
3. Reasonable public access to technical and policy information;
4. Adequate public notice of public involvement activities and time for public review and comment at key decision points;
5. A process for demonstrating explicit consideration and response to public input;
6. A process for seeking out and considering the needs of those traditionally underserved;
7. Periodic review of the effectiveness of the public involvement process.

These must be adhered to as the DOT structures a formalized public involvement process for the development of both the Plan and STIP. The development, documentation and adoption of DOT's public outreach policies and procedures must be conducted through a public comment period of 45 days. These public outreach policies and procedures must be periodically reviewed to assure full and open access to all. This Guide represents the DOT's documentation of such policies and procedures.

- Public outreach for the development of the Plan, must included:
- Citizens, affected and other interested parties must be provided a reasonable opportunity to comment;
 - The proposed Plan shall be published, with reasonable notification of its availability, or otherwise made readily available for public review and comment;
 - The official statewide Plan shall be published; with reasonable notification of its availability, or otherwise made readily available for public information.

As part of informing the general public throughout the planning process, a mailing list of "Interested or Affected Parties" can be developed as a means of informing, and receiving information from those directly affected or interested in a proposed action. Participatory groups (such as a voluntary Advisory Committee or Focus Groups) may also be considered in the development of specific major actions. A summary of pertinent information can be made available for review by the general public (including "Interested or Affected Parties"). Public forums can be held to solicit input during the Draft Plan development, during Draft STIP development, and for major projects, at various decision points during project development. Public notifications should be made at the beginning of the draft stage of the Plan and STIP, and various decision points during project development.

3.2 STATE LONG RANGE TRANSPORTATION PLAN (PLAN):

The State must develop a statewide Long Range Transportation Plan for all areas of the state. The Plan is prepared by the DOT Office of Policy and reflects Transportation Plans prepared by each of Connecticut's fifteen Regional Planning Organizations. The Plan is a multi-modal transportation plan with a minimum 20 year planning horizon. The Plan must include both long-range and short-range strategies/actions that lead to the development of an integrated intermodal transportation system that facilitates the efficient movement of people and goods.

The update or preparation of a new Plan is initiated with the consolidation of previously identified projects, which remedy existing transportation deficiencies, and a review of broad policy issues. In conjunction with this, long range statewide transportation deficiencies are defined to identify the needs of

the state's transportation system for the Plan projected horizon year.

The DOT will prepare and make the Draft Plan available to the general public for inspection for a reasonable period (thirty days) within which written comments can be submitted. The DOT will also schedule a public meeting during this period to discuss issues and collect additional comments.

The DOT will prepare the final Plan, using the information obtained from public input opportunities. The final Plan will be made available to the community. Notices of availability will be published.

3.3 STATE TRANSPORTATION IMPROVEMENT PROGRAMS (STIP):

The DOT Office of Policy coordinates the preparation of a STIP. A STIP must be developed for the entire state through a cooperative effort between the State, the RPO and transit districts. The STIP outlines which specific projects are being funded over the next three years, and the sources of funds for those projects. A project cannot be included in a STIP if there is no reasonable expectation for funding.

The DOT prepares a Draft STIP for review and comment by each of the fifteen RPOs. The Draft STIP is also made available by the DOT to the general public for comment.

The DOT and MPOs will determine the final list of projects for the STIP, incorporating the information received from previous input opportunities. All significant public comments received and the DOT's responses will be made part of the final endorsed STIP. DOT submits the endorsed STIP to the FHWA and FTA for approval. The endorsement and federal approval process also includes an air quality analysis which must demonstrate air quality benefits anticipated with the implementation of the projects identified in the STIP.

Once accepted by FHWA and FTA the general public (including the "Interested and Affected Parties") is notified of the DOT's adoption of a final STIP. The adopted STIP will be made available for public viewing.

3.4 STATE TRANSPORTATION PLAN AND STIP REVISIONS:

Revisions to an endorsed Plan or STIP are often required, due to a number of reasons (e.g. adding or deleting major projects or major scope revisions of listed projects). ISTEPA requires that major amendments to either must undergo the same public involvement procedures as that for Plan or STIP development.

Minor revisions (e.g. projects which are air quality neutral and fiscally constrained) can be accommodated with less rigorous public outreach procedures. A mechanism to obtain community input for such changes is through regularly scheduled RPO meetings.

Notification of major revisions will be made to the general public. The portion of the regularly scheduled RPO meeting which is to address STIP revisions should be used for the DOT to explain the suggested changes, and to collect comments regarding the changes. Public notification of the adopted Plan or STIP revisions will be made.

3.5 PROJECT PLANNING:

Project Planning focuses upon the individual studies, programs, and projects identified in the STIP. Major projects (such as new or substantially modified transportation systems) are, in most cases, conceptual (and need further study) when initially identified in the STIP. For major transportation investments, project planning assesses potential alternatives in the selection of a preferred action, and develops documentation to define and address social and environmental concerns.

Interaction with the community during project planning should be a continuance of the public outreach efforts implemented during the development of the Plan or STIP. A public outreach plan should be initiated by the project sponsor/lead agency in consultation with the RPO, at the onset of the development of any proposed action, prior to conducting detailed analysis. The extent of the public outreach plan for each proposed action is dependent upon the anticipated extensiveness of the study corridor or proposed action, and the potential effects a proposed action may have upon the region and neighborhoods. The type of environmental documentation will also dictate the minimum requirements for public outreach in accordance with federal regulations.

Public outreach during project planning, is focused upon a specific proposed action(s). For relatively minor actions, informing the public of the anticipated activity can be accomplished through the municipality and media strategies. These actions typically do not involve substantial modifications to an existing transportation program or system, and do not require consideration of alternatives. For proposed actions which may be more extensive, the public outreach effort should also be more comprehensive.

At a minimum, public outreach efforts should be focused on those directly affected by the transportation action being considered. Public forums can be used to enhance this effort. Generally,

public outreach should occur at critical stages (decision points) during the development of a proposed action. In addition, public outreach should also take place with major changes in a proposed action.

The establishment of a voluntary Advisory Committee (optional) to assist in developing a specific major transportation action can aid in identifying issues of concern and areas of opportunity.

A public outreach action plan for major proposed actions can include establishing a mailing list of "Interested or Affected Parties". (This list can be based upon information from the RPO in the affected study or project area). Information should be made available to the general public (including "Interested or Affected Parties" and participatory groups, if established). They should be offered the opportunity to participate in decisions to be made and notified of the outcome during various phases of this process.

A public meeting(s) can be used at various decision points to present information and identify citizen concerns and interests regarding the action being considered.

Project planning for major transportation investments typically consists of a needs/deficiencies assessment, an evaluation of alternatives, environmental documentation, and the selection of preferred action.

For transportation actions associated with public transit, the DOT's Bureau of Public Transportation coordinates with specific organizations established by legislation, as well as task forces and committees.

Broadly speaking, airport and port actions generally involve the public outreach process utilized for highway actions. Public meetings for environmental permits, property acquisition, etc. are similar to those used for highway actions. The specialized nature of airport and port actions, however, involves contacts with a number of groups having specialized interests related to airport and port facilities. These include tenants and user groups, as well as committees.

4.0 FACILITY DESIGN / RIGHTS-OF-WAY / PROGRAM DEVELOPMENT

Once a determination has been made of what specific transportation action(s) (facility or program) can be supported for implementation, a detailed design of that action is initiated in the design phase of project development. Program details, facility design and property acquisition requirements are determined. Public outreach for this phase of development should be a continuance of the public outreach efforts implemented during project planning.

Documentation prepared during design includes detailed facility plans and specifications, special studies, or program criteria and administrative procedures. Once an action has been initiated for design, notification should be made by the sponsoring agency to the general public (including "Interested and Affected Parties" and participatory groups, if established in the planning phase), of the intent to initiate the recommended action.

The design of a transportation facility is typically undertaken in stages of completion (i.e. Preliminary Engineering, Semi-Final Design, and Final Design). At the Preliminary Engineering design completion stage, the opportunity for a public meeting(s) would be offered to the municipality(s) directly affected by the proposed action. This meeting could provide the opportunity for officials and the public to participate and comment on the specifics of the action early in the design process. This opportunity can be made available again, at each of the Semi-Final and Final design completion stage. Public outreach may also take place prior to major changes in a proposed action.

The DOT follows rigid procedures in acquiring properties and assisting in relocations. These procedures are outlined in "Property Acquisition for Transportation Projects" and Relocation Assistance Program". Both are available from the DOT, Office of Rights-Of-Way.

Similar notifications and opportunities for public meetings can be made during design development of a transportation program.

5.0 CONSTRUCTION / IMPLEMENTATION / MAINTENANCE

Construction

Public outreach during construction of transportation facilities is focused toward the specific needs and issues associated with the project area and those who use it during and following construction. Once a project has been awarded for construction, the general public (including "Interested and Affected Parties" and any participatory group, if previously established) should be notified by the sponsoring agency of the initiation of construction.

Once construction has begun (prior to the disturbance of the area), a public meeting may be held. This meeting would provide an early opportunity for officials and the public to inquire and comment on the construction activities. This opportunity could be made available again, during construction completion.

Program Implementation

Public outreach during implementation of a transportation program (new or major revision) is focused toward the specific needs and issues associated with those directly affected by the program. Once a program has been implemented, the general public (including "Interested and Affected Parties" and any participatory group, if previously established) should be notified by the sponsoring agency of the program implementation. This notification should include an outline of the program requirements, qualifications, and critical dates.

Communication may be conducted as needed, with specific neighborhoods, community groups and businesses, or individuals to address specific concerns.

Maintenance

The DOT Office of Maintenance conducts numerous activities throughout the state on a daily basis which can affect travelers, residences and businesses. These activities can range from pot hole repair to roadway resurfacing. Public outreach for these activities which will result in one day or more disturbance of traffic movement can be conducted using media strategies. For roadway resurfacing projects, a specific procedure has been established which includes:

1. A letter is sent to Town Officials from the District Maintenance Manager advising them of the termini and incidentals that will be completed as part of the resurfacing project.
2. Town Officials are contacted by DOT District representatives to assure they received the letter and discuss any questions.

3. The RPO's are notified by the DOT Bureau of Policy and Planning.
4. A copy of the resurfacing list is also sent to:
Bituminous Producers Association
Connecticut Construction Industries Association
Utility Companies
5. The DOT Office of Communications is also provided with a copy of the list, and a news release is published prior to the start of work.

6.0 PUBLIC MEETINGS

Public meetings can be an effective means of giving stakeholders the opportunity to receive information regarding a program or project, and for the program or project sponsors to obtain information from the public regarding their concerns. Public meetings can be sponsored by a state and/or federal agency, a municipality, an RPO or by a group (e.g. Citizens' Advisory Committee, Focus Groups, or Collaborative Task Forces/"Blue Ribbon" Commission). Meetings provide the opportunity to present graphical displays which can be more explanatory than other media such as newsletters or newspaper advertisements. Two general types of public meetings can be used. They are the "Open" forum and the "Formal" forum.

The Open forum Meeting (also identified as an Information Meeting or Open House) is an informal atmosphere, with the opportunity to attend any time during specified time period(s). In the case of the Formal forum meeting, public participation is accomplished both through a structured presentation and in informally prior to and following a presentation. The Formal meeting has a structured start time for those who wish to hear/view the presentation of information by the program or project sponsor.

A notice of a public meeting should be published. A comment period (thirty days is suggested) should be established which allows submission of written comments from the date of the meeting notice to a reasonable period following the meeting(s). Information on the proposed action should be made available at public locations for inspection for a reasonable time (fourteen days is suggested) prior to the meeting. (Environmental documentation is made available for public viewing at least thirty calendar days prior to a public meeting). All written comments and responses should be documented. An official written transcript of a meeting (when required) is made available to the public.

A number of public fora in addition to formal and open forum public meetings and electronic town meeting, are available for use in any public outreach program. These include: Charrettes, Visioning, Citizens' Advisory Committees, Transportation Fairs/Major Special Events, Focus Groups, and Collaborative Task Forces/"Blue Ribbon" Commissions. An explanation of these fora is included in the FHWA/FITA document "Innovations in Public Involvement for Transportation Planning" (January, 1994).

Chapter Two

GEOMETRIC DESIGN OF EXISTING HIGHWAYS (3R Non-Freeway Projects)

Table of Contents

	<u>Page</u>
2-1.0 INTRODUCTION	2-1(1)
2-2.0 GENERAL	2-2(1)
2-2.01 <u>Background</u>	2-2(1)
2-2.01.01 Federal 3R Regulations	2-2(1)
2-2.01.02 Special Report 214	2-2(1)
2-2.01.03 FHWA Technical Advisory T5040.28	2-2(2)
2-2.02 <u>Objectives</u>	2-2(3)
2-2.03 <u>Approach</u>	2-2(4)
2-2.04 <u>Application</u>	2-2(5)
2-2.05 <u>3R Project Evaluation</u>	2-2(6)
2-3.0 3R GEOMETRIC DESIGN CRITERIA	2-3(1)
Figure 2-3A Multi-Lane Rural Arterials (3R Projects)	2-3(2)
Figure 2-3B Two-Lane Rural Arterials (3R Projects)	2-3(4)
Figure 2-3C Rural Collector Roads (3R Projects)	2-3(6)
Figure 2-3D Rural Local Roads (3R Projects)	2-3(8)
Figure 2-3E Multi-Lane Principal Urban Arterials (3R Projects)	2-3(10)
Figure 2-3F Two-Lane Principal Urban Arterials (3R Projects)	2-3(12)
Figure 2-3G Minor Urban Arterials (3R Projects)	2-3(14)
Figure 2-3H Urban Collector Streets (3R Projects)	2-3(16)
Figure 2-3I Local Urban Streets (3R Projects)	2-3(18)
2-4.0 DESIGN CONTROLS	2-4(1)
2-4.01 <u>Design Speed</u>	2-4(1)
2-4.02 <u>Highway Capacity</u>	2-4(2)
2-4.03 <u>Exceptions to Geometric Design Criteria</u>	2-4(2)
2-5.0 HORIZONTAL ALIGNMENT	2-5(1)
2-5.01 <u>Rural Highways and High-Speed Urban Highways</u>	2-5(1)
2-5.02 <u>Low-Speed Urban Streets</u>	2-5(1)

Table of Contents**(Continued)**

	<u>Page</u>
2-6.0 VERTICAL ALIGNMENT	2-6(1)
2-6.01 <u>Grades</u>	2-6(1)
2-6.02 <u>Crest Vertical Curves</u>	2-6(1)
2-6.03 <u>Sag Vertical Curves</u>	2-6(1)
2-7.0 CROSS SECTIONS	2-7(1)
2-7.01 <u>Widths</u>	2-7(1)
2-7.02 <u>Bridges</u>	2-7(1)
2-7.02.01 Bridge Rehabilitation/Reconstruction	2-7(1)
2-7.02.02 Bridges to Remain in Place	2-7(3)
2-7.03 <u>Climbing Lanes</u>	2-7(3)
2-7.04 <u>Other Cross Section Elements</u>	2-7(5)
2-8.0 SPECIAL DESIGN ELEMENTS	2-8(1)
2-8.01 <u>General</u>	2-8(1)
2-8.02 <u>Traffic Calming</u>	2-8(1)
2-9.0 ROADSIDE SAFETY	2-9(1)
2-9.01 <u>Clear Zones</u>	2-9(1)
2-9.01.01 Basic 3R Criteria	2-9(1)
2-9.01.02 Rock Removal	2-9(2)
2-9.02 <u>Safety Appurtenances</u>	2-9(3)
2-10.0 INTERSECTIONS AT-GRADE	2-10(1)
2-10.01 <u>Intersection Sight Distance</u>	2-10(1)
2-10.02 <u>Turning Radii</u>	2-10(1)
2-10.03 <u>Auxiliary Turning Lanes</u>	2-10(2)
2-10.04 <u>Driveway Design</u>	2-10(2)
2-11.0 REFERENCES	2-11(1)

Chapter Two

GEOMETRIC DESIGN OF EXISTING HIGHWAYS (3R Non-Freeway Projects)

2-1.0 INTRODUCTION

The geometric design of projects on existing highways must be viewed from a different perspective than that for a new construction project. These 3R projects are often initiated for reasons other than geometric design deficiencies (e.g., pavement deterioration), and they often must be designed within restrictive right-of-way, financial limitations and environmental constraints. Therefore, the design criteria for new construction are often not attainable without major and, frequently, unacceptable adverse impacts. These 3R projects are initiated in communities where land use and cultural characteristics are well established. For these projects, it is essential to consider the community, land use, visual, historical and natural resources surrounding the proposed roadway improvement. Designers must be aware of the community context in which these projects are being proposed and select the design criteria accordingly. At the same time, however, the designer should take the opportunity to consider cost-effective, practical improvements to the geometric design of existing highways and streets when accident data suggest it is appropriate. The design produced should integrate these wide ranging and sometime conflicting issues to produce a safe and attractive transportation facility.

Designers should be aware of projects that are located within State- or town-designated “Scenic Roads” or “Scenic Byways.” The Department has produced a number of corridor studies for State- designated scenic roads. These documents have been prepared in cooperation with the Department, local Regional Planning Agencies and other local interested parties. To protect the scenic character of these roadways, these studies include recommendations on land use, landscaping, view/scenic enhancements and geometric considerations. To ensure that proposed improvements on these scenic roadways will fit within the existing character of the roadway, along with protecting their scenic and visual quality, the recommendations of these studies should be considered. Although these studies were prepared for specific segments of roadway, designers should become familiar with the design tools presented in these documents and consider their inclusion on other projects. Designers should also be aware of locally designated scenic roadways. Local governing authorities may have specific criteria established for these roadways. The Department must be sensitive to these local issues and should incorporate their criteria where appropriate.

For these reasons, the Department has adopted revised limits for geometric design criteria for projects on existing highways which are, in many cases, lower than the values for new construction. These criteria are based on a sound, engineering assessment of the underlying principles behind geometric design and on how the criteria for new construction can be legitimately modified to apply to existing highways without sacrificing highway safety.

Chapter Two presents the Department's criteria for 3R non-freeway projects, and Chapter Three presents the criteria for 4R freeway projects and spot improvements (non-freeways). These criteria are intended to find the balance among many competing and conflicting objectives. These include the objective of improving Connecticut's existing highways; the objective of minimizing the adverse impacts of highway construction on existing highways; and the objective of improving the greatest number of kilometers within the available funds.

2-2.0 GENERAL

2-2.01 Background

2-2.01.01 Federal 3R Regulations

On June 10, 1982, the FHWA issued its Final Rule entitled *Design Standards for Highways; Resurfacing, Restoration and Rehabilitation of Streets and Highways Other Than Freeways*. This Final Rule modified 23CFR Part 625 to adopt a flexible approach to the geometric design of 3R projects. Part 625 was modified again on March 31, 1983 to explicitly state that one objective of 3R projects is to enhance highway safety. In the Final Rule FHWA determined that it was not practical to adopt 3R design criteria for nationwide application. Instead, each State can develop its own criteria and/or procedures for the design of 3R projects, subject to FHWA approval. This allows each State to tailor its design criteria for the 3R program according to the conditions which prevail within that State. This approach is in contrast to the application of criteria for new construction and major reconstruction, for which the AASHTO *A Policy on Geometric Design of Highways and Streets* provides nationwide criteria for application.

2-2.01.02 Special Report 214

In 1987, the Transportation Research Board published Special Report 214 *Designing Safer Roads; Practices for Resurfacing, Restoration and Rehabilitation*. This study was mandated by the Surface Transportation Assistance Act of 1982. The objective of the TRB study was to examine the safety cost-effectiveness of highway geometric design criteria and to recommend minimum design criteria for 3R projects on non-freeways. The final TRB report (SR214):

1. reviewed the existing 3R design practices of 15 State highway agencies and several local highway agencies;
2. examined the relationship between highway accident potential and geometric design elements, based on the existing research literature and on special research projects commissioned as part of the TRB study;
3. examined the relationship between the extent of geometric design improvements and the cost of 3R projects;
4. discussed the issue of cost-effectiveness relative to geometric design improvements on 3R projects;
5. reviewed the literature on tort liability and geometric design;

6. presented a safety-conscious design process; and
7. presented specific numerical criteria for the geometric design of 3R projects for the following elements:
 - a. lane and shoulder widths,
 - b. horizontal curvature and superelevation,
 - c. vertical curvature,
 - d. bridge width,
 - e. side slopes, and
 - f. pavement cross slopes.

The SR214 information has been incorporated, where considered appropriate for Connecticut, into the Department's criteria and procedures for 3R projects. The designer should reference SR214 for more discussion on 3R projects.

2-2.01.03 FHWA Technical Advisory T5040.28

Pursuant to its adoption of SR214, FHWA issued on October 17, 1988, Technical Advisory T5040.28 "Developing Geometric Design Criteria and Processes for Non-Freeway RRR Projects." The purpose of the Advisory is to provide guidance on developing or modifying criteria for the design of Federal-aid, non-freeway 3R projects. The Advisory:

1. discusses the procedures for developing 3R criteria;
2. discusses the factors which should be evaluated in a safety-conscious design process;
3. discusses the application of design exceptions for the FHWA controlling design criteria on 3R projects; and
4. presents specific criteria for the design of 3R projects based on SR 214.

The information from the Technical Advisory has been incorporated, where considered appropriate for Connecticut, into the Department's criteria and procedures for 3R projects.

2-2.02 Objectives

From an overall perspective, the 3R program is intended to improve the greatest number of highway kilometers within the available funds for highway projects. "Improve" is meant to apply to all aspects which determine a facility's serviceability, including:

1. the structural integrity of the pavement, bridges and culverts;
2. the drainage design of the facility to, among other objectives, minimize ponding on the highway, to protect the pavement structure from failure, and to prevent roadway flooding during the design-year storm;
3. from a highway capacity perspective, the level of service provided for the traffic flow;
4. the adequacy of access to abutting properties;
5. the geometric design of the highway to safely accommodate expected vehicular speeds and traffic volumes;
6. the roadside safety design to reduce, within some reasonable boundary, the adverse impacts of run-off-the-road vehicles; and
7. the traffic control devices to provide the driver with critical information and to meet driver expectancies.

These objectives are competing for the limited funds available for 3R projects on existing highways. The Department's responsibility is to realize the greatest overall benefit from the available funds. Therefore, on individual projects, some compromises may be necessary to achieve the goals of the overall highway program. Specifically for geometric design and roadside safety, the compromise is between new construction criteria and what is practical for the specific conditions of each highway project.

Therefore, considering the above discussion, the Department has adopted and FHWA has approved its approach to the geometric design of 3R projects. The overall objective of the Department's criteria is to fulfill the requirements of the FHWA regulation and Technical Advisory which govern the 3R program. These objectives may be summarized as follows:

1. 3R projects are intended to extend the service life of the existing facility and to return its features to a condition of structural or functional adequacy.
2. 3R projects are intended to enhance highway safety.

3. 3R projects are intended to incorporate cost-effective, practical improvements to the geometric design of the existing facility.

2-2.03 Approach

The Department's approach to the geometric design of 3R projects is to adopt, where justifiable, a revised set of numerical criteria. The design criteria throughout the other *Manual* chapters provide the frame of reference for the 3R criteria. The following summarizes the approach which has been used:

1. Design Speed. Figures 2-3A through 2-3I provide the values for design speed. Where the design speed is based on actual speeds measured in the field, see Section 2-4.01 for the procedure that should be used for determining the recommended design speed. The design speed selected should be consistent with respect to topography, the adjacent land use and the functional classification of highway.
2. Speed-Related Criteria. Many geometric design values are calculated directly from the design speed (e.g., vertical curves, horizontal curve radii). The design speed is used to determine these speed-related criteria. For many of these elements, Chapter Two presents an acceptable threshold value for the element which is considerably below the selected design speed. For example, if the design speed of an existing crest vertical curve is within 30 km/h of the 85th percentile speed and there is not an adverse accident history, this is considered acceptable for the project without a design exception.
3. Cross Section Widths. The criteria in Chapters Four and Five have been evaluated relative to the typical constraints of 3R projects. Where justifiable, the lower values of the cross section width criteria have been reduced. The upper values from Chapters Four and Five have been incorporated into the 3R criteria to provide an upper range. This provides an expanded range of acceptable values for application on 3R projects. Where an existing roadway section exceeds the design minimum lane and shoulder widths, a proposed improvement should not result in a reduction to the existing cross section without approval from the appropriate Division Manager. See Section 2-7.0 for more discussion on cross section widths.
4. Other Design Criteria. The Department's *Highway Design Manual* contains many other details on proper geometric design techniques. These criteria are directly applicable to new construction and major reconstruction. For 3R projects, these criteria have been evaluated and a judgment has been made on their proper application to 3R projects. Unless stated otherwise in this chapter, the criteria in other chapters apply to 3R projects and should be incorporated, if practical.

5. Evaluation. The designer should evaluate available data (e.g., accident experience) when determining the geometric design of 3R projects. The necessary evaluations presented for 3R projects are based on the FHWA Technical Advisory T5040.28 “Developing Geometric Design Criteria and Processes for Non-freeway RRR Projects.” Section 2-2.05 discusses 3R project evaluation in more detail.

2-2.04 Application

The designer should realize the following factors when applying the design criteria in this chapter:

1. Trigger Values. The designer will be evaluating the existing geometric design against the criteria in this chapter. If an existing geometric design feature does not at least meet the lower criteria, the designer must evaluate the practicality of improving the feature. Note that to use the design criteria in Sections 2-5.0 and 2-6.02, the selected design speed is based on the 85th percentile speed.
2. Improvement Level. The Department has determined that, once the decision is made to improve a geometric design element, the level of improvement should be compatible with the project objective. Where a range of values is presented, the designer should strive to avoid selecting criteria from the lower range. The minimum acceptable level of improvement will be designated as one of the following:
 - a. In some cases, the 3R trigger value may be acceptable. For example, it will be acceptable to redesign sag vertical curves to meet the comfort criteria rather than the headlight sight distance criteria. See Section 2-6.03.
 - b. In some cases, the trigger value may only be applicable to evaluating the need for an improvement, but a different value becomes the minimum acceptable level of improvement. For example, Figure 2-5A is used to evaluate the need for improvements to a horizontal curve, but the criteria in Section 8-2.0 are used to make any improvements.
3. Exception Process. Desirably, the geometric design of 3R projects will meet all of the criteria presented in this chapter. However, only key geometric design elements (i.e., the controlling design criteria) require a formal exception when not met. The 3R design exception process is discussed in Section 2-4.03, which is the same as the exception process for new construction and major reconstruction (Section 6-6.0).

2-2.05 3R Project Evaluation

Sections 2-3.0 to 2-10.0 present the specific geometric design and roadside safety criteria which will be used to determine the design of 3R projects. In addition, several other factors must be considered in a 3R project, and the designer should conduct applicable technical evaluations using appropriate Department units as may be necessary. The possible evaluations are discussed below:

1. Conduct Field Review. The designer will normally conduct a thorough field review of the proposed 3R project. Other personnel should accompany the designer as appropriate, including personnel from traffic, maintenance, construction, FHWA (NHS projects), etc. The objective of the field review should be to identify potential safety hazards and potential safety improvements to the facility.
2. Document Existing Geometrics. The designer will normally review the most recent highway plans and combine this with the field review to determine the existing geometrics within the project limits. The review includes lane and shoulder widths, horizontal and vertical alignment, intersection geometrics and the roadside safety design.
3. Accident Experience. The accident data within the limits of the 3R project will be evaluated. Accident data is available from the Bureau of Planning. The following accident data analyses should be conducted:
 - a. Accident Rate versus Statewide Average (for that type facility). This will provide an overall indication of safety problems within the 3R project limits.
 - b. Accident Analysis by Type. This will indicate if certain types of accidents are a particular problem. For example, a large number of head-on and/or sideswipe accidents may indicate inadequate roadway width. A large number of fixed object accidents may indicate an inadequate roadside clear zone.
 - c. Accident Analysis by Location. Accidents may cluster about certain locations, such as a horizontal curve or intersection. In particular, the analysis should check to see if any locations on the Department's Suggested Surveillance Study Sites, as identified by the Department's accident data system, fall within the proposed project limits.
4. Speed Studies. As indicated in Section 2-4.01, the Division of Traffic Engineering will review existing speed studies in the vicinity of the project and, if necessary, conduct a field study to determine the design speed of the 3R project. In addition, it may be desirable to conduct spot speed studies in specific locations (e.g., in advance of a specific horizontal or vertical curve) to assist in the determination of geometric design improvements. The speed study should be conducted before the field review.

5. Traffic Volumes. As indicated in Section 2-4.02, the traffic volumes used for design will range between the current traffic volumes and those determined using a ten-year projection. This will generate traffic volumes for any necessary highway capacity analyses. The designer should also note that, in some cases, the Department's 3R geometric design criteria will allow the acceptance of geometric design values which may be considerably below those for new construction/major reconstruction (e.g., for horizontal and vertical curves).
6. Early Coordination for Right-of-Way Acquisition. Significant ROW acquisitions are typically outside the scope of 3R projects. However, the field, accident and/or speed studies may indicate the need for selective safety improvements which would require ROW purchases. Therefore, the designer should determine improvements which will be incorporated into the project design as early as feasible and initiate the ROW acquisition process, if required.
7. Pavement Condition. 3R projects which are programmed because of a significant deterioration of the pavement structure will generally be determined from the Department's Pavement Management Program. The extent of deterioration will influence the decision on whether a project can be designed using the 3R design criteria or whether it should be designed using major reconstruction criteria. A 3R project may include pavement reconstruction for up to **a** of the project length. The **a** limit may be exceeded on a case-by-case basis with the approval from the appropriate Division Manager.

Whenever the proposed pavement improvement is major, it may be practical to include significant geometric improvements (e.g., lane and shoulder widening) in the project design. However, the proper level of geometric improvement is often determined by many additional factors other than the extent of pavement improvement. These include available right-of-way, traffic volumes, accident experience and available funds for the project. Therefore, it may be appropriate for the 3R project to include, for example, full-depth pavement reconstruction and minimal geometric improvement, if deemed proper, to meet the safety and operational objectives of the 3R program.

8. Geometric Design of Adjacent Highway Sections. The designer should examine the geometric features and operating speeds of highway sections adjacent to the 3R project. This will include investigating whether or not any highway improvements are in the planning stages. The 3R project should provide design continuity with the adjacent sections. This involves a consideration of factors such as driver expectancy, geometric design consistency and proper transitions between sections of different geometric designs.
9. Physical Constraints. The physical constraints within the limits of the 3R project will often determine what geometric improvements are practical and cost-effective. These include topography, adjacent development, available right-of-way, utilities and environmental constraints (e.g., wetlands).

10. Traffic Control Devices. All signing and pavement markings on 3R projects must meet the criteria of the *Manual on Uniform Traffic Control Devices* (MUTCD). The Division of Traffic Engineering is responsible for selecting and locating the traffic control devices on the project. The designer should work with the Division of Traffic Engineering to identify possible geometric and safety deficiencies which will remain in place (i.e., no improvement will be made). These include:
- a. narrow bridges,
 - b. horizontal and vertical curves which do not meet the 3R criteria, and
 - c. roadside hazards within the clear zone.

2-3.0 3R GEOMETRIC DESIGN CRITERIA

Figures 2-3A through 2-3I present the Department's criteria for the design of 3R projects for both rural and urban areas. The designer should consider the following in the use of the 3R design criteria:

1. Functional/Design Classification. The selection of design values for 3R projects depends on the functional and design classification of the highway facility. This is discussed in Section 6-1.0.

For rural highways, the design classification is based on the average number of access points per kilometer per side. The designer should realize that the values in the figures are for guidance only; they should not be used as rigid criteria for determining the design classification on rural highways.

2. Cross Section Elements. The designer should realize that some of the cross section elements included in the figure (e.g., median width) are not automatically warranted in the project design. The values in the figures will only apply after the decision has been made to include the element in the highway cross section.
3. Manual Section References. These figures are intended to provide a concise listing of design values for easy use. However, the designer should review the *Manual* section references for greater insight into the design elements.

Figure 2-3A
MULTI-LANE RURAL ARTERIALS
3R Projects

Design Element		*	Manual Section	Design Values (by Type of Roadside Development)			
				Open	Moderate Density	High Density	
Design Controls	Typical Number of Access Points/Kilometer/Side		6-1.03	0 - 10	10 - 20	> 20	
	Design Forecast Year		2-4.02	Current - 10 years	Current - 10 years	Current - 10 years	
	Design Speed	x	2-4.01	See Section 2-4.01	See Section 2-4.01	See Section 2-4.01	
	Control of Access		6-4.0	Partial/Control by Regulation	Control by Regulation	Control by Regulation	
	Level of Service		6-3.0	B - C	B - C	B - C	
Cross Section Elements	Travel Lane Width	x	2-7.01	See Figure 2-7A			
	Shoulder Width	Right	x	2-7.01	1.2 m - 2.4 m	1.2 m - 2.4 m	1.2 m - 2.4 m
		Left	x	10-1.02	0.6 m - 2.4 m	0.6 m - 2.4 m	0.6 m - 2.4 m
	Typical Cross Slope	Travel Lane	x	10-1.01	1.5-2.0% for lanes adjacent to crown; 2.0% for lanes away from crown		
		Shoulder (W<1.2m)			Same as Adjacent Travel Lane		
		Shoulder (W≥1.2m)	x	10-1.02	4%	4%	Uncurbed: 4% Curbed: 6%
	Turn Lanes	Lane Width			0.3 m Less than Travel Lane Width — Same as Travel Lane		
		Shoulder Width	x		0.6 m - 1.2 m		
	Median Width (Includes Left Shoulders)	Depressed		10-3.0	Project-by-Project Basis		
		Raised Island (V=80 km/h)			Project-by-Project Basis		
	Bicycle Lane	Width		15-4.0	1.5 m or Shoulder Width, whichever is greater		
		Cross Slope			2%		
Bridge Width/Cross Slope	x	2-7.02	See Figure 2-7B for Width; Meet Roadway Cross Slope	Sidewalk Width: 1.7 m			
Underpass Width		10-4.02	Meet Approach Roadway Width Plus Clear Zones				
Right-of-Way Width		10-5.0	Project-by-Project Basis				
Roadside Clear Zones	x	2-9.01	Figure 13-2A or R/W width, whichever is less				
Fill/Cut Slopes		10-2.02	Existing — See Figure 4G				

*Controlling design criteria (see Section 6-6.0)

Figure 2-3A (continued)

**MULTI-LANE RURAL ARTERIALS
3R Projects**

Design Element		*	Manual Section	Design Values (Based on Design Speed)			
				100 km/h	90 km/h	80 km/h	
Alignment Elements	Stopping Sight Distance		x	7-1.0	160 m - 205 m	135 m - 170 m	115 m - 140 m
	Decision Sight Distance	Maneuver		7-2.0	315 m	275 m	230 m
		Stop			225 m	185 m	155 m
	Minimum Radius (e = 6.0%)		x	2-5.01	See Section 2-5.01		
	Superelevation	e _{max}		2-5.01	6.0%		
		Rate	x		See Section 2-5.01		
	Horizontal Sight Distance			8-2.04	See Section 8-2.04		
	Maximum Grade		x	2-6.01	6%	7%	7%
	Minimum Grade			9-2.03	0.5%		
	Vertical Curvature (K-Value)	Crest		2-6.02	See Section 2-6.02		
		Sag		2-6.03	26	21	17
	Minimum Vertical Clearance: Arterial Under ...	New Highway Bridge	x	9-4.0	5.05 m		
Existing Highway Bridge		x	4.35 m				
Pedestrian Bridge/Overhead Sign		x	5.35 m				
Minimum Vertical Clearance (Arterial over Railroad)		x	9-4.0	Electrified: 6.858 m All Others: 6.248 m			

* Controlling design criteria (see Section 6-6.0)

Figure 2-3B
TWO-LANE RURAL ARTERIALS
3R Projects

Design Element		*	Manual Section	Design Values (by Type of Roadside Development)			
				Open	Moderate Density	High Density	
Design Controls	Typical Number of Access Points/Kilometers/Side		6-1.03	0 - 10	10 - 20	> 20	
	Design Forecast Year		2-4.02	Current - 10 years	Current - 10 years	Current - 10 years	
	Design Speed	x	2-4.01	See Section 2-4.01	See Section 2-4.01	See Section 2-4.01	
	Control of Access		6-4.0	Partial/Control by Regulation	Control by Regulation	Control by Regulation	
	Level of Service		6-3.0	B - C	B - C	B - C	
Cross Section Elements	Travel Lane Width	x	2-7.01	See Figure 2-7A			
	Shoulder Width	x	2-7.01 10-1.02	1.2 m - 2.4 m	1.2 m - 2.4 m	1.2 m - 2.4 m	
	Typical Cross Slope	Travel Lane	x	10-1.01	1.5-2.0%	1.5-2.0%	1.5-2.0%
		Shoulder	x	10-1.02	4%	4%	Uncurbed: 4% Curbed: 6%
	Turn Lanes	Lane Width	x	10-1.03	0.3 m Less Than Travel Lane Width — Same as Travel Lane		
		Shoulder Width	x		0.6 m - 1.2 m		
	Bicycle Lane	Width		15-4.0	1.5 m or Shoulder Width, whichever is greater		
		Cross Slope			2%		
	Bridge Width/Cross Slope	x	2-7.02	See Figure 2-7B for Width; Meet Roadway Cross Slope	Sidewalk Width: 1.7 m		
	Underpass Width		10-4.02	Meet Approach Roadway Width Plus Clear Zones			
	Right-of-Way Width		10-5.0	Project-by-Project Basis			
	Roadside Clear Zones	x	2-9.01	Figure 13-2A or R/W width, whichever is less			
Fill/Cut Slopes		10-2.02	Existing — See Figure 4G				

*Controlling design criteria (see Section 6-6.0)

Figure 2-3B (continued)

**TWO-LANE RURAL ARTERIALS
3R Projects**

Design Element		*	Manual Section	Design Values (Based on Design Speed)			
				100 km/h	90 km/h	80 km/h	70 km/h
Stopping Sight Distance			7-1.0	160 m - 205 m	135 m - 170 m	115 m - 140 m	95 m - 115 m
Decision Sight Distance	Maneuver		7-2.0	315 m	275 m	230 m	200 m
	Stop			225 m	185 m	155 m	125 m
Minimum Radius (e = 6.0%)		x	2-5.01	See Section 2-5.01			
Superelevation	e _{max}		2-5.01	6.0%			
	Rate	x		See Section 2-5.01			
Horizontal Sight Distance			8-2.04	See Section 8-2.04			
Maximum Grade		x	2-6.01	6%	7%	7%	8%
Minimum Grade			9-2.03	0.5%			
Vertical Curvature (K-Value)	Crest		2-6.02	See Section 2-6.02			
	Sag		2-6.03	26	21	17	13
Minimum Vertical Clearance: Arterial Under ...	New Highway Bridge	x	9-4.0	5.05 m			
	Existing Highway Bridge	x		4.35 m			
	Pedestrian Bridge/Overhead Sign	x		5.35 m			
Minimum Vertical Clearance (Arterial over Railroad)		x	9-4.0	Electrified: 6.858 m All Others: 6.248 m			

* Controlling design criteria (see Section 6-6.0)

Figure 2-3C
RURAL COLLECTOR ROADS
3R Projects

Design Element		*	Manual Section	Design Values (by Type of Roadside Development)			
				Open	Moderate Density	High Density	
Design Controls	Typical Number of Access Points/Kilometers/Side		6-1.03	0 - 10	10 - 20	> 20	
	Design Forecast Year		2-4.02	Current - 10 years	Current - 10 years	Current - 10 years	
	Design Speed	AAADT < 400	x	2-4.01	Posted Legal Speed Limit	Posted Legal Speed Limit	Posted Legal Speed Limit
		AAADT: 400 - 2000			60 km/h - 80 km/h	60 km/h - 80 km/h	60 km/h - 80 km/h
		AAADT > 2000			See Section 2-4.01	See Section 2-4.01	See Section 2-4.01
	Control of Access		6-4.0	Control by Regulation	Control by Regulation	Control by Regulation	
Level of Service		6-3.0	C - D	C - D	C - D		
Cross Section Elements	Travel Lane Width	AAADT < 400	x	2-7.01	See Figure 2-7A	See Figure 2-7A	See Figure 2-7A
		AAADT: 400 - 1500					
		AAADT: 1500 - 2000					
		AAADT > 2000					
	Shoulder Width		x	2-7.01 10-1.02	0.6 m - 2.4 m	0.6 m - 2.4 m	0.6 m - 2.4 m
	Typical Cross Slope	Travel Lane	x	10-1.01	1.5-2.0% for lanes adjacent to crown; 2.0% for lanes away from crown		
		Shoulder (W<1.2m)			Same as Adjacent Travel Lanes		
		Shoulder (W≥1.2m)	x	10-1.02	4%	Uncurbed: 4% Curbed: 6%	Uncurbed: 4% Curbed: 6%
	Turn Lanes	Lane Width	x	10-1.03	0.3 m Less Than Travel Lane Width — Same as Travel Lane		
		Shoulder Width	x		0.6 m - 1.2 m		
	Bicycle Lane	Width		15-4.0	1.5 m or Shoulder Width, whichever is greater		
		Cross Slope			2%		
Bridge Width/Cross Slope		x	2-7.02	See Figure 2-7B for Width; Meet Roadway Cross Slope	Sidewalk Width: 1.7 m		
Underpass Width			10-4.02	Meet Approach Roadway Width Plus Clear Zones			
Right-of-Way Width			10-5.0	Project-by-Project Basis			
Roadside Clear Zones		x	2-9.01	Figure 13-2A or R/W width, whichever is less			
Fill/Cut Slopes			10-2.02	Existing — See Figure 4G			

*Controlling design criteria (see Section 6-6.0)

Figure 2-3C (continued)

**RURAL COLLECTOR ROADS
3R Projects**

Design Element		*	Manual Section	Design Values (Based on Design Speed)					
				90 km/h	80 km/h	70 km/h	60 km/h	50 km/h	
Alignment Elements	Stopping Sight Distance	x	7-1.0	135 m - 170 m	115 m - 140 m	95 m - 115 m	75 m - 85 m	60 m - 65 m	
	Decision Sight Distance	Maneuver		7-2.0	275 m	230 m	200 m	175 m	145 m
		Stop			185 m	155 m	125 m	95 m	75 m
	Minimum Radius (e = 6.0%)	x	2-5.01	See Section 2-5.01					
	Superelevation	e _{max}		2-5.01	6.0%				
		Rate	x		See Section 2-5.01				
	Horizontal Sight Distance			8-2.04	See Section 8-2.04				
	Maximum Grade		x	2-6.01	9%	9%	10%	10%	11%
	Minimum Grade			9-2.03	0.5%				
	Vertical Curvature (K-Value)	Crest		2-6.02	See Section 2-6.02				
		Sag		2-6.03	21	17	13	10	7
	Minimum Vertical Clearance: Collector Under ...	New Highway Bridge	x	9-4.0	4.5 m				
Existing Highway Bridge		x	4.35 m						
Minimum Vertical Clearance (Collector over Railroad)		x	9-4.0	Electrified: 6.858 m All Others: 6.248 m					

* Controlling design criteria (see Section 6-6.0)

Figure 2-3D
RURAL LOCAL ROADS
3R Projects

Design Element		*	Manual Section	Design Values (by Type of Roadside Development)			
				Open	Moderate Density	High Density	
Design Controls	Typical Number of Access Points/Kilometers/Side		6-1.03	0 - 10	10 - 20	> 20	
	Design Forecast Year		2-4.02	Current - 10 years	Current - 10 years	Current - 10 years	
	Design Speed	x	2-4.01	Posted Legal Speed Limit	Posted Legal Speed Limit	Posted Legal Speed Limit	
	Control of Access		6-4.0	Control by Regulation	Control by Regulation	Control by Regulation	
	Level of Service		6-3.0	C - D	C - D	C - D	
Cross Section Elements	Travel Lane Width	x	2-7.01	2.7 m - 3.6 m	2.7 m - 3.6 m	2.7 m - 3.6 m	
	Shoulder Width	x	2-7.01 10-1.02	0.0 m - 1.2 m	0.0 m - 1.2 m	0.0 m - 1.2 m	
	Typical Cross Slope	Travel Lane	x	10-1.01	1.5-2.0%	1.5-2.0%	1.5-2.0%
		Shoulder (W<1.2m)			Same as Adjacent Travel Lane		
		Shoulder (W≥1.2m)	x	10-1.02	4%	Uncurbed: 4% Curbed: 6%	Uncurbed: 4% Curbed: 6%
	Turn Lanes	Lane Width	x	10-1.03	2.7 m - 3.6 m		
		Shoulder Width	x		0.0 m - 0.6 m		
	Bicycle Lane	Width		15-4.0	1.5 m or Shoulder Width, whichever is greater		
		Cross Slope			2%		
	Bridge Width/Cross Slope	x	2-7.02	See Figure 2-7B for Width; Meet Roadway Cross Slope	Sidewalk Width: 1.7 m		
	Underpass Width		10-4.02	Meet Approach Roadway Width Plus Clear Zones			
	Right-of-Way Width		10-5.0	Project-by-Project Basis			
	Roadside Clear Zones	x	2-9.01	Figure 13-2A or R/W width, whichever is less			
Fill/Cut Slopes		10-2.02	Existing — See Figure 4G				

*Controlling design criteria (see Section 6-6.0)

Figure 2-3D (continued)

**RURAL LOCAL ROADS
3R Projects**

Design Element		*	Manual Section	Design Values (Based on Design Speed)						
				80 km/h	70 km/h	60 km/h	50 km/h	40 km/h	30 km/h	
Alignment Elements	Stopping Sight Distance		x	7-1.0	115 m - 140 m	95 m - 115 m	75 m - 85 m	60 m - 65 m	45 m	30 m
	Decision Sight Distance	Maneuver		7-2.0	230 m	200 m	175 m	145 m	N/A	N/A
		Stop			155 m	125 m	95 m	75 m		
	Minimum Radius (e = 6.0%)		x	2-5.01	See Section 2-5.01					
	Superelevation	e _{max}		2-5.01	6.0%					
		Rate	x		See Section 2-5.01					
	Horizontal Sight Distance			8-2.04	See Section 8-2.04					
	Maximum Grade		x	2-6.01	10%	11%	12%	12%	13%	13%
	Minimum Grade			9-2.03	0.5%					
	Vertical Curvature (K-Value)	Crest		2-6.02	See Section 2-6.02					
Sag			2-6.03	17	13	10	7	5	3	
Minimum Vertical Clearance: Local Road Under ...	New Highway Bridge	x	9-4.0	4.5 m						
	Existing Highway Bridge	x		4.35 m						
Minimum Vertical Clearance (Local Road over Railroad)		x	9-4.0	Electrified: 6.858 m All Others: 6.248 m						

* Controlling design criteria (see Section 6-6.0)

Figure 2-3E

MULTI-LANE PRINCIPAL URBAN ARTERIALS
3R Projects

Design Element		*	Manual Section	Design Values (By Type of Area)			
				Suburban	Intermediate	Built-up	
Design Controls	Design Forecast Year		2-4.02	Current - 10 years	Current - 10 years	Current - 10 years	
	Design Speed	x	2-4.01	See Section 2-4.01	See Section 2-4.01	See Section 2-4.01	
	Access Control		6-4.0	Partial/Control By Regulation	Control By Regulation	Control By Regulation	
	Level of Service		6-3.0	B - D	B - D	B - D	
	On-Street Parking		10-1.04	None	None	Sometimes	
Cross Section Elements	Travel Lane Width	x	2-7.01	3.3 m - 3.6 m	3.3 m - 3.6 m	3.0 m - 3.6 m	
	Shoulder Width	Right (Non-NHS)	x	2-7.01 10-1.02	0.6 m - 2.4 m	0.6 m - 2.4 m	0.6 m - 2.4 m
		Right (NHS)	x		1.2 m - 2.4 m	1.2 m - 2.4 m	1.2 m - 2.4 m
		Left (All)	x		0.6 m - 1.2 m	0.6 m - 1.2 m	0.6 m - 1.2 m
	Cross Slope	Travel Lane	x	10-1.01	1.5-2.0% for lanes adjacent to crown; 2.0% for lanes away from crown		
		Shoulder (W < 1.2 m)	x	10-1.02	Same as Adjacent Travel Lane		
		Shoulder (W ≥ 1.2 m)	x		4% - 6%	4% - 6%	4% - 6%
	Turn Lanes	Lane Width	x	10-1.03	0.3 m Less Than Travel Lane Width — Same as Travel Lane		
		Shoulder Width	x		0.3 m - 1.2 m	0.3 m - 1.2 m	0.3 m - 1.2 m
	Parking Lane Width			10-1.04	N/A	N/A	3.0 m - 3.3 m
	Median Width (Includes Left Shoulders)	Depressed		10-3.0	Project-by-Project Basis		
		Raised Island (V#80 km/h)			Project-by-Project Basis		
	Sidewalk Width			10-2.01	1.5 m Minimum	1.5 m Minimum	1.5 m Minimum
	Bicycle Lane	Width		15-4.0	1.5 m	1.5 m	1.5 m
		Cross Slope			2%	2%	2%
Bridge Width/Cross Slope		x	2-7.02	See Figure 2-7B for Width; Meet Roadway Cross Slope		Sidewalk Width: 1.7 m	
Underpass Width			10-4.02	Meet Approach Roadway Width Plus Clear Zones			
Right-of-Way Width			10-5.0	Project-by-Project Basis			
Roadside Clear Zones		x	2-9.01	See Section 2-9.01			
Fill/Cut Slopes			10-2.02	Existing — See Figure 5H			

* Controlling design criteria (see Section 6-6.0).

Figure 2-3E (Continued)

MULTI-LANE PRINCIPAL URBAN ARTERIALS
3R Projects

Design Element		*	Manual Section	Design Values (Based on Design Speed)						
				100 km/h	90 km/h	80 km/h	70 km/h	60 km/h	50 km/h	
Alignment Elements	Stopping Sight Distance	x	7-1.0	160 m - 205 m	135 m - 170 m	115 m - 140 m	95 m - 115 m	75 m - 85 m	60 m - 65 m	
	Decision Sight Distance		7-2.0	U: 405 m	U: 360 m	U: 315 m	U: 275 m	U: 235 m	U: 200 m	
				SU: 365 m	SU: 320 m	SU: 275 m	SU: 240 m	SU: 205 m	SU: 160 m	
				415 m	360 m	300 m	250 m	205 m	160 m	
	Minimum Radius	x	2-5.01/ 2-5.02	See Section 2-5.01			190 m (e = 4%)	130 m (e = 4%)	80 m (e = 4%)	
	Superelevation Rate	e _{max}		2-5.01/ 2-5.02	6.0%	6.0%	6.0%	4.0%	4.0%	4.0%
		Rate	x		See Section 2-5.01			See Figure 8-3C		
	Horizontal Sight Distance			8-2.04	See Section 8-2.04					
	Maximum Grade		x	2-6.01	8%	8%	9%	9%	10%	11%
	Minimum Grade			9-2.03	0.5%					
	Vertical Curvature (K-values)	Crest		2-6.02	See Section 2-6.02					
		Sag		2-6.03	26	21	17	13	10	7
Minimum Vertical Clearance: Arterial Under...	New Highway Bridge	x	9-4.0	5.05 m						
	Existing Highway Bridge	x		4.35 m						
	Pedestrian Bridge/ Overhead Sign	x		5.35 m						
Minimum Vertical Clearance (Arterial over Railroad)		x	9-4.0	Electrified: 6.858 m All Others: 6.248 m						

U: Urban

SU: Suburban

* Controlling design criteria (see Section 6-6.0).

Figure 2-3F
TWO-LANE PRINCIPAL URBAN ARTERIALS
3R Projects

Design Element		*	Manual Section	Design Values (By Type of Area)			
				Suburban	Intermediate	Built-up	
Design Controls	Design Forecast Year		2-4.02	Current - 10 years	Current - 10 years	Current - 10 years	
	Design Speed	x	2-4.01	See Section 2-4.01	See Section 2-4.01	See Section 2-4.01	
	Access Control		6-4.0	Partial/Control By Regulation	Control By Regulation	Control By Regulation	
	Level of Service		6-3.0	B - D	B - D	B - D	
	On-Street Parking		10-1.04	None	None	Sometimes	
Cross Section Elements	Travel Lane Width	x	2-7.01	3.3 m - 3.6 m	3.3 m - 3.6 m	3.0 m - 3.6 m	
	Shoulder Width	Non-NHS	x	2-7.01	0.6 m - 2.4 m	0.6 m - 2.4 m	0.6 m - 2.4 m
		NHS	x	10-1.02	1.2 m - 2.4 m	1.2 m - 2.4 m	1.2 m - 2.4 m
	Cross Slope	Travel Lane	x	10-1.01	1.5-2.0%	1.5-2.0%	1.5-2.0%
		Shoulder (W<1.2 m)	x		Same as Adjacent Travel Lane		
		Shoulder (W≥1.2 m)	x	4%-6%	4%-6%	4%-6%	
	Turn Lanes	Lane Width	x	10-1.03	0.3 m Less Than Travel Lane Width — Same as Travel Lane		
		Shoulder Width	x		0.3 m - 1.2 m	0.3 m - 1.2 m	0.3 m - 1.2 m
	Parking Lane Width			10-1.04	N/A	N/A	3.0 m - 3.3 m
	Sidewalk Width			10-2.01	1.5 m Minimum	1.5 m Minimum	1.5 m Minimum
	Bicycle Lane	Width		15-4.0	1.5 m	1.5 m	1.5 m
		Cross Slope			2%	2%	2%
	Bridge Width/Cross Slope	x		2-7.02	See Figure 2-7B for Width; Meet Roadway Cross Slope		Sidewalk Width: 1.7 m
	Underpass Width			10-4.02	Meet Approach Roadway Width Plus Clear Zones		
Right-of-Way Width			10-5.0	Project-by-Project Basis			
Roadside Clear Zones	x		2-9.01	See Section 2-9.01			
Fill/Cut Slopes			10-2.02	Existing — See Figure 5I			

* Controlling design criteria (see Section 6-6.0).

Figure 2-3F (Continued)

**TWO-LANE PRINCIPAL URBAN ARTERIALS
3R Projects**

Design Element		*	Manual Section	Design Values (Based on Design Speed)					
				90 km/h	80 km/h	70 km/h	60 km/h	50 km/h	
Alignment Elements	Stopping Sight Distance	x	7-1.0	135 m - 170 m	115 m - 140 m	95 m - 115 m	75 m - 85 m	60 m - 65 m	
	Decision Sight Distance	Maneuver	7-2.0	U: 360 m SU: 320 m	U: 315 m SU: 275 m	U: 275 m SU: 240 m	U: 235 m SU: 205 m	U: 200 m SU: 160 m	
		Stop		360 m	300 m	250 m	205 m	160 m	
	Minimum Radius		x	2-5.01/ 2-5.02	See Section 2-5.01		190 m (e = 4%)	130 m (e = 4%)	80 m (e = 4%)
	Superelevation Rate	e _{max}	x	2-5.01/ 2-5.02	6.0%	6.0%	4.0%	4.0%	4.0%
		Rate		See Section 2-5.01		See Figure 8-3C			
	Horizontal Sight Distance			8-2.04	See Section 8-2.04				
	Maximum Grade		x	2-6.01	8%	9%	9%	10%	11%
	Minimum Grade			9-2.03	0.5%				
	Vertical Curvature (K-values)	Crest		2-6.02	See Section 2-6.02				
		Sag		2-6.03	21	17	13	10	7
	Minimum Vertical Clearance: Arterial Under...	New Highway Bridge	x	9-4.0	5.05 m				
Existing Highway Bridge		x	4.35 m						
Pedestrian Bridge/ Overhead Sign		x	5.35 m						
Minimum Vertical Clearance (Arterial over Railroad)		x	9-4.0	Electrified: 6.848 m All Others: 6.248 m					

U: Urban

SU: Suburban

* Controlling design criteria (see Section 6-6.0).

Figure 2-3G
MINOR URBAN ARTERIALS
3R Projects

Design Element		*	Manual Section	Design Values (By Type of Area)			
				Suburban	Intermediate	Built-up	
Design Controls	Design Forecast Year		2-4.02	Current - 10 years	Current - 10 years	Current - 10 years	
	Design Speed	x	2-4.01	See Section 2-4.01	See Section 2-4.01	See Section 2-4.01	
	Access Control		6-4.0	Control By Regulation	Control By Regulation	Control By Regulation	
	Level of Service		6-3.0	B - D	B - D	B - D	
	On-Street Parking		10-1.04	None	Sometimes	Sometimes	
Cross Section Elements	Travel Lane Width	x	2-7.01	3.3 m - 3.6 m	3.0 m - 3.6 m	3.0 m - 3.6 m	
	Shoulder Width	Right (Non-NHS)	x	2-7.01 10-1.02	0.6 m - 2.4 m	0.6 m - 2.4 m	0.6 m - 2.4 m
		Right (NHS)	x		1.2 m - 2.4 m	1.2 m - 2.4 m	1.2 m - 2.4 m
		Left (All)	x		0.6 m - 1.2 m	0.6 m - 1.2 m	0.6 m - 1.2 m
	Cross Slope	Travel Lane	x	10-1.01	1.5-2.0% for lanes adjacent to crown; 2% for lanes away from crown		
		Shoulder (W<1.2 m)	x	10-1.02	Same as Adjacent Travel Lane		
		Shoulder (W≥1.2 m)	x		4%-6%	4%-6%	4%-6%
	Turn Lanes	Lane Width	x	10-1.03	0.3 m Less Than Travel Lane Width — Same as Travel Lane		
		Shoulder Width	x		0.3 m - 1.2 m	0.3 m - 1.2 m	0.3 m - 1.2 m
	Parking Lane Width			10-1.04	N/A	2.7 m - 3.3 m	2.4 m - 3.3 m
	Sidewalk Width			10-2.01	1.5 m Minimum	1.5 m Minimum	1.5 m Minimum
	Bicycle Lane	Width		15-4.0	1.5 m	1.5 m	1.5 m
		Cross Slope			2%	2%	2%
Bridge Width/Cross Slope	x		2-7.02	See Figure 2-7B for Width; Meet Roadway Cross Slope	Sidewalk Width: 1.7 m		
Underpass Width			10-4.02	Meet Approach Roadway Width Plus Clear Zones			
Right-of-Way Width			10-5.0	Project-by-Project Basis			
Roadside Clear Zones	x		2-9.01	See Section 2-9.01			
Fill/Cut Slopes			10-2.02	Existing — See Figure 5I			

* Controlling design criteria (see Section 6-6.0).

Figure 2-3G (Continued)

**MINOR URBAN ARTERIALS
3R Projects**

Design Element		*	Manual Section	Design Values (Based on Design Speed)			
				80 km/h	70 km/h	60 km/h	50 km/h
Stopping Sight Distance		x	7-1.0	115 m - 140 m	95 m - 115 m	75 m - 85 m	60 m - 65 m
Decision Sight Distance	Maneuver		7-2.0	U: 315 m SU: 275 m	U: 275 m SU: 240 m	U: 235 m SU: 205 m	U: 200 m SU: 160 m
	Stop			300 m	250 m	205 m	160 m
Minimum Radius		x	2-5.01/ 2-5.02	See Section 2-5.01	190 m (e = 4%)	130 m (e = 4%)	80 m (e = 4%)
Superelevation	e _{max}		2-5.01/ 2-5.02	6.0%	4.0%	4.0%	4.0%
	Rate	x		See Section 2-5.01	See Figure 8-3C		
Horizontal Sight Distance			8-2.04	See Section 8-2.04			
Maximum Grade		x	2-6.01	9%	9%	10%	11%
Minimum Grade			9-2.03	0.5%			
Vertical Curvature (K-Value)	Crest		2-6.02	See Section 2-6.02			
	Sag		2-6.03	17	13	10	7
Minimum Vertical Clearance: Arterial Under ...	New Highway Bridge	x	9-4.0	5.05 m			
	Existing Highway Bridge	x		4.35 m			
Minimum Vertical Clearance (Arterial over Railroad)		x	9-4.0	Electrified: 6.858 m All Others: 6.248 m			

* Controlling design criteria (see Section 6-6.0)

U: Urban

SU: Suburban

Figure 2-3H
URBAN COLLECTOR STREETS
3R Projects

Design Element	*	Manual Section	Design Values (By Type of Area)				
			Suburban	Intermediate	Built-up		
Design Controls	Design Forecast Year		2-4.02	Current - 10 years	Current - 10 years	Current - 10 years	
	Design Speed	x	2-4.01	See Section 2-4.01	See Section 2-4.01	See Section 2-4.01	
	Access Control		6-4.0	Control By Regulation	Control By Regulation	Control By Regulation	
	Level of Service		6-3.0	C - D	C - D	C - D	
	On-Street Parking		10-1.04	Sometimes	Sometimes	Sometimes	
Cross Section Elements	Travel Lane Width	x	2-7.01	3.0 m - 3.6 m	3.0 m - 3.6 m	3.0 m - 3.6 m	
	Shoulder Width	x	2-7.01 10-1.02	0.6 m - 2.4 m	0.6 m - 2.4 m	0.6 m - 2.4 m	
	Cross Slope	Travel Lane (w/curb)			1.5-3.0%	1.5-3.0%	1.5-3.0%
		Travel Lane(w/o curb)	x	10-1.01	1.5-2.0% for lanes adjacent to crown; 2% for lanes away from crown		
		Shoulder (W<1.2 m)	x		Same as Adjacent Travel Lane		
		Shoulder (W≥1.2 m)	x		4%-6%	4%-6%	4%-6%
	Turn Lanes	Lane Width	x	10-1.03	0.3 m Less Than Travel Lane Width — Same as Travel Lane		
		Shoulder Width	x		0.3 m - 1.2 m	0.3 m - 1.2 m	0.3 m - 1.2 m
	Parking Lane Width			10-1.04	2.1 m - 3.0 m	2.1 m - 3.0 m	2.1 m - 3.0 m
	Sidewalk Width			10-2.01	1.5 m Minimum	1.5 m Minimum	1.5 m Minimum
	Bicycle Lane	Width		15-4.0	1.5 m	1.5 m	1.5 m
		Cross Slope			2%	2%	2%
	Bridge Width/Cross Slope	x	2-7.02		See Figure 2-7B for Width; Meet Roadway Cross Slope	Sidewalk Width: 1.7 m	
	Underpass Width			10-4.02	Meet Approach Roadway Width Plus Clear Zones		
	Right-of-Way Width			10-5.0	Project-by-Project Basis		
Roadside Clear Zones	x	2-9.01		See Section 2-9.01			
Fill/Cut Slopes			10-2.02	See Figure 5I — Existing			

* Controlling design criteria (see Section 6-6.0).

Figure 2-3H (Continued)

URBAN COLLECTOR STREETS
3R Projects

Design Element		*	Manual Section	Design Values (Based on Design Speed)			
				70 km/h	60 km/h	50 km/h	
Alignment Elements	Stopping Sight Distance		x	7-1.0	95 m - 115 m	75 m - 85 m	60 m - 65 m
	Decision Sight Distance	Maneuver		7-2.0	U: 275 m SU: 240 m		U: 235 m SU: 205 m
		Stop			250 m	205 m	160 m
	Minimum Radius (e = 4%)		x	2-5.02	190 m	130 m	80 m
	Superelevation	e _{max}		2-5.02	4.0%	4.0%	4.0%
		Rate	x		See Figure 8-3C		
	Horizontal Sight Distance			8-2.04	See Section 8-2.04		
	Maximum Grade		x	2-6.01	11%	12%	13%
	Minimum Grade			9-2.03	0.5%		
	Vertical Curvature (K-Value)	Crest		2-6.02	See Section 2-6.02		
Sag			2-6.03	13	10	7	
Minimum Vertical Clearance: Collector Under ...	New Highway Bridge	x	9-4.0	4.5 m			
	Existing Highway Bridge	x		4.35 m			
Minimum Vertical Clearance (Collector over Railroad)		x	9-4.0	Electrified: 6.858 m All Others: 6.248 m			

* Controlling design criteria (see Section 6-6.0)

U: Urban SU: Suburban

Figure 2-3I
LOCAL URBAN STREETS
3R Projects

Design Element		*	Manual Section	Design Values (By Type of Area)			
				Suburban	Intermediate	Built-up	
Design Controls	Design Forecast Year		2-4.02	Current - 10 years	Current - 10 years	Current - 10 years	
	Design Speed	x	2-4.01	See Section 2-4.01	See Section 2-4.01	See Section 2-4.01	
	Access Control		6-4.0	Control By Regulation	Control By Regulation	Control By Regulation	
	Level of Service		6-3.0	C - D	C - D	C - D	
	On-Street Parking		10-1.04	Sometimes	Sometimes	Sometimes	
Cross Section Elements	Travel Lane Width	x	2-7.01	3.0 m - 3.3 m	3.0 m - 3.3 m	2.7 m - 3.3 m	
	Shoulder Width	x	2-7.01	0.6 m - 1.2 m	0.6 m - 1.2 m	0.6 m - 1.2 m	
		Travel Lane	x	10-1.01	1.5-2.0% (1.5-3.0% w/curbing)	1.5-2.0% (1.5-3.0% w/curbing)	1.5-2.0% (1.5-3.0% w/curbing)
		Shoulder (W < 1.2 m)	x	10-1.02	Same as Adjacent Travel Lane		
		Shoulder (W ≥ 1.2 m)	x		4%-6%	4%-6%	4%-6%
	Turn Lanes	Lane Width	x	10-1.03	0.3 m Less Than Travel Lane Width (2.7 m Min.) — Same as Travel Lane		
		Shoulder Width	x		0.3 m - 1.2 m	0.3 m - 1.2 m	0.3 m - 1.2 m
	Parking Lane Width			10-1.04	2.1 m - 3.0 m	2.1 m - 3.3 m	2.1 m - 3.3 m
	Sidewalk Width			10-2.01	1.5 m Minimum	1.5 m Minimum	1.5 m Minimum
	Bicycle Lane	Width		15-4.0	1.5 m	1.5 m	1.5 m
		Cross Slope			2%	2%	2%
	Bridge Width/Cross Slope		x	2-7.02	See Figure 2-7B for Width; Meet Roadway Cross Slope		Sidewalk Width: 1.7 m
	Underpass Width			10-4.02	Meet Approach Roadway Width Plus Clear Zones		
	Right-of-Way Width			10-5.0	Project-by-Project Basis		
Roadside Clear Zones		x	2-9.01	See Section 2-9.01			
Fill/Cut Slopes			10-2.02	Existing — See Figure 5I			

* Controlling design criteria (see Section 6-6.0).

Figure 2-3I (Continued)

LOCAL URBAN STREETS
3R Projects

Design Element		*	Manual Section	Design Values (Based on Design Speed)			
				50 km/h	40 km/h	30 km/h	
Alignment Elements	Stopping Sight Distance		x	7-1.0	60 m - 65 m	45 m	30 m
	Decision Sight Distance	Maneuver		7-2.0	U: 200 m SU: 160 m	N/A	N/A
		Stop			160 m	N/A	N/A
	Minimum Radius (e = 4%)		x	2-5.02	80 m	45 m	20 m
	Superelevation	e _{max}		2-5.02	4.0%	4.0%	4.0%
		Rate	x		See Figure 8-3C		
	Horizontal Sight Distance			8-2.04	See Section 8-2.04		
	Maximum Grade		x	2-6.01	12%	13%	13%
	Minimum Grade			9-2.03	0.5%		
	Vertical Curvature (K-Value)	Crest		2-6.02	See Section 2-6.02		
Sag			2-6.03	7	5	3	
Minimum Vertical Clearance: Local Street Under ...	New Highway Bridge	x	9-4.0	4.5 m			
	Existing Highway Bridge	x		4.35 m			
Minimum Vertical Clearance (Local Street over Railroad)		x	9-4.0	Electrified: 6.858 m All Others: 6.248 m			

* Controlling design criteria (see Section 6-6.0)

U: Urban

SU: Suburban

2-4.0 DESIGN CONTROLS

2-4.01 Design Speed

Reference: Section 6-2.02

Unless the design speed is specified in Figures 2-3A through 2-3I, use the following procedure on 3R projects to determine the design speed, which is based on the actual speed measured in the field:

1. The Division of Traffic Engineering will be requested to provide existing speed studies in the vicinity of the proposed project. If there are no recent studies available, then field measurements may be required. The designer should carefully evaluate the speed data to determine an 85th percentile speed which represents the operating characteristics of a lengthy segment of the road, not just a short segment near the proposed project.
2. Based on the Department's adopted traffic engineering practices, the Division of Traffic Engineering will determine the 85th percentile of the existing traffic speeds.
3. The designer will select the 3R design speed according to Figure 2-4A. This design speed will be used to evaluate the geometric design features of the existing highway for those elements based on design speed.

85th Percentile "V" (km/h)	Design Speed (km/h)
0 # V # 30	30
30 # V # 40	30/40
40 # V # 50	40/50
50 # V # 60	50/60
60 # V # 70	60/70
70 # V # 80	70/80
80 # V # 90	80/90
90 # V # 100	90/100
V > 100	100/110

DESIGN SPEEDS FOR 3R PROJECTS
(Based on 85th Percentile Speeds)

Figure 2-4A

2-4.02 Highway Capacity

Reference: Section 6-3.0

Three major factors determine the results of a capacity analysis. Their specific application to 3R projects is discussed below:

1. Level of Service (LOS). Figures 2-3A through 2-3I provide the range of LOS criteria for 3R projects.
2. Design Volume. The highway facility should be designed to accommodate the LOS for the selected DHV and/or AADT. The design volume may range from the current traffic volumes to ten years beyond the expected construction completion date.
3. Capacity Analysis. The analytical techniques in the *Highway Capacity Manual* will be used to conduct the capacity analysis.

2-4.03 Exceptions to Geometric Design Criteria

Reference: Section 6-6.0

The discussion in Section 6-6.0 on exceptions applies equally to the geometric design of 3R projects. The designer will be evaluating the proposed design against the criteria presented in Chapter Two.

2-5.0 HORIZONTAL ALIGNMENT

Chapter Eight discusses horizontal alignment criteria for all highways. These criteria will apply to 3R projects, except where discussed in the following sections.

2-5.01 Rural Highways and High-Speed Urban Highways

Reference: Section 8-2.0

Figure 2-5A will be used to determine the design speed of an existing horizontal curve. This should be compared to the 85th percentile speed. In the absence of an adverse accident history, all existing horizontal curves with a design speed within 25 km/h of the 85th percentile speed are acceptable. No formal design exception is required for horizontal curves within this range; however, it should be documented in the project files.

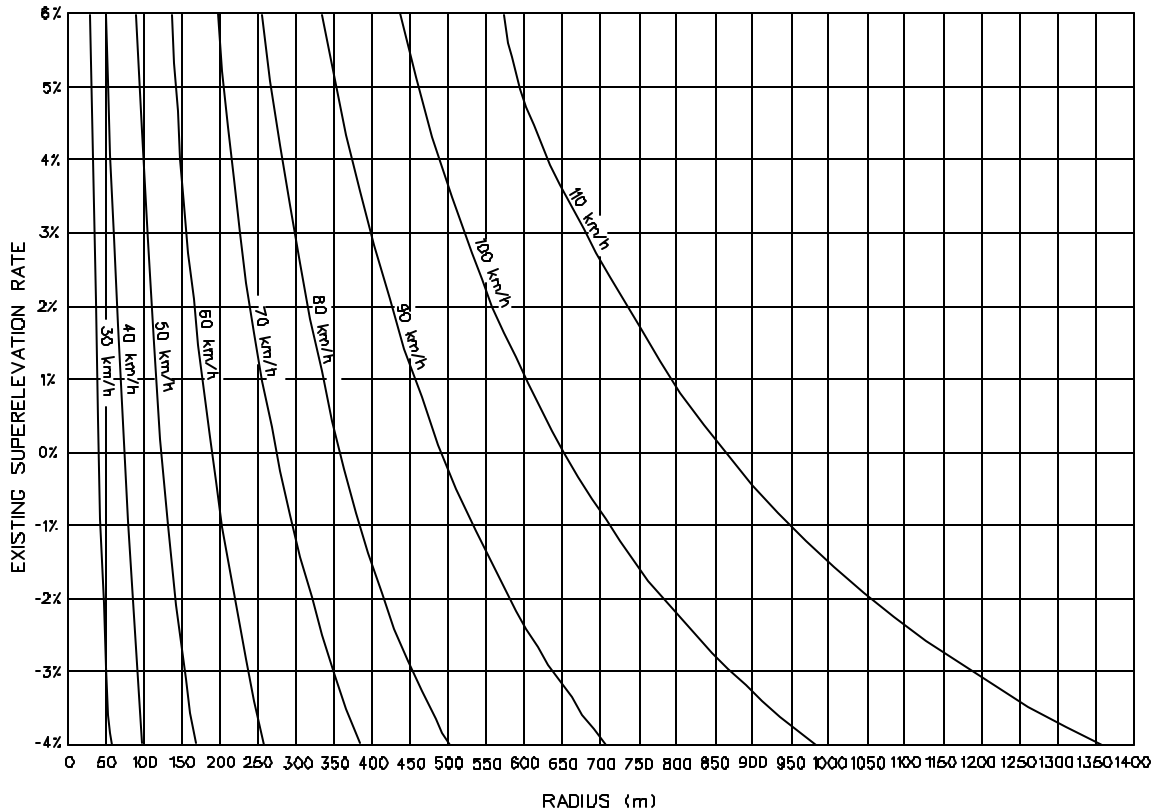
Figure 2-5A can be used only to decide if corrective action should be considered. Once the decision has been made to improve the curve, the designer should use the criteria in Figure 8-2A to determine the proper combination of curve radius and superelevation to meet the 3R design speed.

If the existing curve satisfies the above criteria for design speed, the designer will not normally need to check other details of the horizontal curve (e.g., superelevation transition length, distribution of superelevation between tangent and curve).

2-5.02 Low-Speed Urban Streets

Reference: Section 8-3.0

Section 8-3.0 discusses horizontal alignment criteria for low-speed urban streets (design speed of 70 km/h and below), and Figure 8-3C can be used to determine the design speed of an existing horizontal curve. Once this is determined, the 3R evaluation of the horizontal curve on a low-speed urban street will be similar to that for rural highways/high-speed urban highways in Section 2-5.01.



Example

Given: The 85th percentile speed for the 3R project will be 90 km/h. An existing curve within the project limits has the following data:

$$\begin{aligned} R &= 400 \text{ m} \\ e &= 3.0\% \end{aligned}$$

Problem: Determine if improvements should be considered.

Solution: Using the figure, the existing curve is adequate for a design speed of 90 km/h. Therefore, no improvement is necessary. Note that if Figure 8-2A were used, the necessary superelevation rate would be 5.9%.

This figure will be used to determine if an existing horizontal curve is acceptable. Use Figure 8-2A if any improvements are made to the curve. Use Figure 8-3C for low speed urban streets.

RADI FOR RETAINING EXISTING HORIZONTAL CURVES (3R Projects)

Figure 2-5A

2-6.0 VERTICAL ALIGNMENT

2-6.01 Grades

Reference: Section 9-2.0

Figures 2-3A through 2-3I present the Department's criteria for maximum and minimum grades on 3R projects. The maximum grades are 2% steeper than those for new construction/major reconstruction.

2-6.02 Crest Vertical Curves

Reference: Section 9-3.02

Section 9-3.02 presents the Department's criteria for the design of crest vertical curves. This information will be used to determine the design speed of an existing crest vertical curve, which will then be compared to the 85th percentile speed. The following summarizes the 3R design criteria for crest vertical curves:

1. Crest Vertical Curves. In the absence of an adverse accident history, all existing crest vertical curves with a design speed within 30 km/h of the 85th percentile speed are acceptable. No formal design exception is required for crest vertical curves within this range; however, it should be documented in the project files.
2. Angle Points. It is acceptable to retain an existing "angle" point (i.e., no vertical curve) of 1.0 percent or less.

If the decision is made to flatten the crest vertical curve, the designer should design the reconstructed curve to meet the criteria for new construction/major reconstruction in Section 9-3.02.

2-6.03 Sag Vertical Curves

Reference: Section 9-3.03

Section 9-3.03 presents the Department's criteria for the design of sag vertical curves for new construction and major reconstruction. These criteria are based on designing the sag to allow the vehicle's headlights to illuminate the pavement for a distance equal to the stopping sight distance for the design speed. For 3R projects, the following will apply:

1. Evaluation. The comfort criteria represent the minimum criteria for the retention of an existing sag vertical curve. Figure 2-6A presents the comfort criteria. If an existing sag does not meet these criteria, then the designer should consider flattening the sag vertical curve.
2. Corrective Action. If the decision is made to flatten the sag, the design should meet the criteria for headlight sight distance in Section 9-3.03. As an alternative, the re-designed sag may meet the comfort criteria in Figure 2-6A, if there is proper illumination of the sag vertical curve.
3. Angle Points. It is acceptable to retain an existing "angle" point (i.e., no vertical curve) of 1.0 percent or less.

Design Speed (km/h)	K-Values ($K = V^2/395$)
30	3
40	5
50	7
60	10
70	13
80	17
90	21
100	26
110	31

**K-VALUES FOR SAG VERTICAL CURVES
(3R Projects)**

Figure 2-6A

2-7.0 CROSS SECTIONS

2-7.01 Widths

Reference: Chapters Four and Five

Chapters Four and Five present the Department's criteria for cross section elements for new construction and major reconstruction. Figure 2-7A presents the travel lane widths for rural 3R collectors and arterials. The figures in Section 2-3.0 present the shoulder widths for rural 3R projects and present the travel lane and shoulder widths for urban 3R projects. In general, the 3R widths have been established considering the minimum acceptable width for the element from an operational and safety perspective; considering what will be available for a practical improvement on a "typical" 3R project; and considering that, in general, it is better to improve more kilometers to a lower level than to improve fewer kilometers to a higher level. All of these considerations are consistent with the overall objectives of the Department's 3R program.

2-7.02 Bridges

Reference: Section 10-4.01

2-7.02.01 Bridge Rehabilitation/Reconstruction

A bridge or several bridges may be within the limits of the 3R project. The bridge substructure and/or superstructure may be partially or entirely reconstructed as part of the 3R project. If this work includes rehabilitation of the bridge deck, the full approach width, including shoulders, will be carried across the structure. *Note: CGS 13a-86 requires a minimum bridge width of 8.534 m on any two-lane highway maintained by the Commissioner, exclusive of any sidewalk width. No exceptions to this criteria will be allowed on State-maintained highways unless, in the judgment of the Commissioner, a lesser width is warranted. The criteria in CGS 13a-86 does not apply to bridges on highways maintained by a municipality.*

If a bridge rehabilitation/reconstruction project will involve the replacement of the bridge deck or more to the superstructure, then Comment #'s 2, 3 and 4 on Narrow Bridges, Bridge Rails and Approach Transitions in Section 2-7.02.02 also apply.

Design Year AADT	Functional Class	Design Speed (km/h)	Lane Width	
			T \$ 10%	T < 10%
1 - 400	Collector/ Arterial	# 70	3.0 m	2.7 m
		\$ 80	3.0 m	3.0 m
400 - 750	Collector/ Arterial	#70	3.0 m	2.7 m
		\$ 80	3.0 m	3.0 m
750 - 1500	Collector	#70	3.3 m	3.0 m
		\$80	3.3 m	3.3 m
	Arterial	# 70	3.3 m	3.0 m
		\$ 80	3.6 m	3.3 m
1500 - 2000	Collector/ Arterial	# 70	3.3 m	3.0 m
		\$ 80	3.6 m	3.3 m
> 2000	Collector/ Arterial	All	3.6 m	3.6 m

Note: T = Trucks

**TRAVEL LANE WIDTHS
(Rural 3R Projects)**

Figure 2-7A

2-7.02.02 Bridges to Remain in Place

If an existing bridge is structurally sound and if it meets the Department's design loading structural capacity, it is unlikely to be cost effective to improve the geometrics of the bridge. However, the geometric deficiencies may be severe, and/or there may be an adverse accident experience at the bridge. The following will apply to all bridges to remain in place with no proposed improvements:

1. Width. The width of the existing bridge should be evaluated against the criteria in Figure 2-7B. If the existing bridge does not meet these criteria, it should be evaluated for widening, including a review of the accident experience at the bridge.
2. Narrow Bridges. All bridges which are narrower than the approach roadway width (including shoulders) should be evaluated for special narrow bridge treatments. At a minimum, the signing and pavement markings must meet the criteria of the MUTCD. In addition, NCHRP 203 *Safety at Narrow Bridge Sites* provides criteria specifically for narrow bridges (e.g., special pavement markings). The designer, in coordination with the Division of Traffic Engineering, should evaluate the value of these additional treatments at the bridge site.
3. Bridge Rails. All existing bridge rails on the project should be evaluated to determine if they are structurally adequate and meet the Department's current safety performance criteria.
4. Approach Guide Rail Transitions. The approaching guide rail transitions will be evaluated to determine if they meet the Department's current criteria. If the transitions do not, they will be upgraded. The Department's latest standard sheets will be used to make these determinations.

2-7.03 Climbing Lanes

Reference: Section 9-2.0

The design criteria in Section 9-2.0 will apply to existing or proposed climbing lanes within the limits of 3R projects; however, for non-freeway projects, the following criteria are acceptable:

1. Lane Width. The minimum width of the climbing lane will be 3.3 m.
2. Shoulder Width. The minimum width of the shoulder adjacent to the climbing lane will be 1.2 m.

Design Year AADT	Functional Class	Clear Bridge Width (Note 1)
0 - 750	All	Approach Traveled Way Width
750 - 1500	Local/ Collector	Approach Traveled Way Width Plus 0.6 m OR 6.6 m, whichever is less.
	Arterial	Approach Traveled Way Width Plus 0.6 m
1500 - 2000	Local/Collector	Approach Traveled Way Width Plus 0.6 m OR 7.2 m, whichever is less.
	Arterial	Approach Traveled Way Width Plus 0.6 m
2000 - 4000	All	Approach Traveled Way Width Plus 1.2 m
>4000	Local/Collector	Approach Traveled Way Width Plus 1.2 m OR 8.4 m, whichever is less.
	Arterial	Approach Traveled Way Width Plus 1.2 m

Notes:

1. Clear Bridge Width. This is the width between curbs or rails, whichever is less.
2. Long Bridges (Locals/Collectors). For bridges on these facilities with a total length greater than 30 m, the widths in the table do not apply. These structures should be analyzed individually considering the existing width, safety, traffic volumes, remaining structural life, design speed, costs to widen, etc.

**WIDTHS FOR EXISTING BRIDGES TO REMAIN IN PLACE
(3R Projects)**

Figure 2-7B

2-7.04 Other Cross Section Elements

Reference: Chapters Four, Five and Ten

These chapters provide the Department's criteria and details for many other cross section elements, including:

1. location and type of parking lanes,
2. warrants for and types of curbs,
3. warrants for and design of sidewalks,
4. slope rounding,
5. roadside ditches,
6. median type, and
7. fill and cut slopes.

The designer should evaluate the cross section of the existing highway or street and, as part of the 3R project, should make any improvements which are considered cost effective. Some of the design information in Chapter Ten applies directly to 3R projects (e.g., warrants for curbs and sidewalks); some of the design information will only apply if practical (e.g., slope rounding).

2-8.0 SPECIAL DESIGN ELEMENTS

2-8.01 General

Reference: Chapter Fifteen

Chapter Fifteen provides the Department's criteria and design details for many special design elements. The designer should review this chapter to determine if these criteria apply to the 3R project. For example, Section 15-5.0 presents information on landscaping. Aesthetics can play a significant role in the community acceptance of a roadway improvement. Designers should aim to preserve or restore as much of the existing landscape as practical. Chapter Fifteen provides the necessary tools and references that should be considered to maintain or improve the visual quality of the roadway.

2-8.02 Traffic Calming

Traffic calming measures (TCM) consist of a variety of techniques and treatments designed to mitigate the impacts of vehicular travel. Traffic calming is typically limited to municipal streets but may be considered on State-maintained facilities off the NHS. TCMs typically refer to an assortment of physical features placed within the limits of the roadway environment including; but not limited to the following:

1. intersection diverters,
2. roundabouts,
3. channelization,
4. speed humps,
5. speed tables,
6. street narrowing,
7. angle point/chicanes,
8. driveway links,
9. gateway/perimeter treatments, and
10. street closure.

Municipalities that have developed TCM guidelines may explore traffic calming strategies on a project-by-project basis. An effective traffic calming strategy may integrate more than one TCM into a comprehensive traffic calming program for the study area. For additional information on traffic calming strategies and measures, see the following publications:

1. *Traffic Calming In Practice*, ITE;
2. *State of the Art: Residential Traffic Management*, FHWA;
3. *State-of-the-Art Design of Roundabouts*, TRB;
4. *Take Back Your Streets - How to Protect Communities from Asphalt and Traffic*, Conservation Law Foundation;
5. *Residential Street Design and Traffic Control*, ITE;
6. *Guidelines for the Design and Application of Speed Humps, A Recommended Practice*, ITE;
7. *Roundabouts, Diverts and Humps*, ITE; and
8. *Effective Utilization of Street Width on Urban Arterials*, ITE;

2-9.0 ROADSIDE SAFETY

2-9.01 Clear Zones

Reference: Section 13-2.0

2-9.01.01 Basic 3R Criteria

Section 13-2.0 presents the Department's criteria for roadside clear zones on new construction and major reconstruction projects. The clear zone criteria for 3R projects will be as follows:

1. The designer should make every reasonable effort to provide a clear zone equal to the criteria in Section 13-2.0.
2. For 3R projects, the criteria in Section 13-2.0 may be modified as follows: On urban and rural collector and local roads where the 3R design speed is 70 km/h and below, the minimum clear zone should be 3.0 m. If practical, the clear zone should be increased where the side slope is 1:6 or steeper. The criteria in Section 13-2.0 can be used to determine the applicable adjustments.
3. It will often be impractical on 3R projects to obtain additional right-of-way specifically to meet the criteria in Section 13-2.0 or, sometimes, even the minimum clear zone criteria from #2 above. Therefore, for the purpose of deciding when a design exception is necessary, the proposed clear zone will be measured against Section 13-2.0, as modified by # 2 above, or against the existing right-of-way, whichever is less. If the clear zone used in design is the existing right-of-way line and if existing utility poles are as near as practical to the right-of-way line, then the utility poles can intrude into the clear zone without the need for a design exception.

Attempting to achieve a roadside clear zone on a 3R project can cause significant problems. The roadside environment is typically cluttered with any number of natural and man-made obstacles. To remove or relocate these obstacles can present formidable problems and public opposition, and it can be very costly. On the other hand, the designer cannot ignore the consequences to a run-off-the-road vehicle. Therefore, the designer must exercise considerable judgment when determining the appropriate clear zone on the 3R project. The designer should consider the following:

1. Accident Data. The designer should review the accident data to estimate the extent of the roadside safety problem. In particular, there may be sites where clusters of run-off-the-road accidents have occurred.

2. Utilities. Utility poles are a common roadside obstacle on 3R projects. Relocation is mandatory when the utility poles physically interfere with construction. Relocations for safety benefits must be evaluated on a project-by-project basis. Poles should be located as near as practical to the right-of-way line. In restricted right-of-way areas, every effort should be made to provide the clear zone used in design. The use of armless single-pole construction with vertical configuration of wires and cables and/or other special construction, as may be appropriate, should be considered. In urban areas, the designer should also consider burying the utilities underground when relocation is impractical.
3. Application. The designer may consider a selective application of the roadside clear zone criteria. Along some sections of highway, it may be practical to provide the clear zone criteria from Section 13-2.0 while, along other sections, it may be impractical. In addition, some obstacles will be more hazardous than others. Judgment will be necessary for the application of the clear zone criteria.
4. Public. Public acceptance of widened clear zones can be a significant issue, especially when the removal of trees is being considered. The designer must judge the community impact and subjectively factor this into the decision-making process.
5. Safety Appurtenances. Installing guide rail or crash cushions is an alternative to providing a wider clear zone. Section 13-3.0 presents warrants for guide rail, and Section 13-7.0 presents warrants for crash cushions. However, this can lead to lengthy runs of guide rail along the roadside. The designer should realize that the guide rail warrants are based on the relative severity between hazard and guide rail; they do not address the question of whether or not a guide rail installation is cost-effective. Therefore, on 3R projects, the designer must judge whether or not guide rail should be installed to shield a hazard within the clear zone. See Section 2-9.02 for more discussion.

2-9.01.02 Rock Removal

Because of the often considerable expense to remove rock to meet the Department's roadside clear zone criteria, the Department has adopted a policy specifically for this design element. If the costs and associated impacts with removing rock to meet the 3R clear zone criteria are insignificant, the designer should implement the improvement. If, however, there are negative impacts and/or the costs are significant, the designer should evaluate the following factors:

1. Project Scope. Based on the overall project objectives, the designer should judge if the potential benefits and costs of the rock removal are consistent with the project scope of work.

2. Accident Data. The designer should review the accident data along the 3R project route to identify the specific roadside hazards related to the presence of rock.
3. Other Benefits. The rock removal may generate benefits other than those for roadside safety. These include:
 - a. improving intersection sight distance;
 - b. improving sight distance around horizontal curves; or
 - c. improving any rock stability, ground water and/or icing problems.

Any additional benefits should be considered when determining the extent of rock removal.

4. Alternative Improvements. Where the designer determines that the existing rock presents a significant roadside hazard, the designer should consider alternative improvements to rock removal. These include:
 - a. installing a half-section concrete barrier or guide rail, and
 - b. providing a positive slope (with rounding at its toe) up to the face of the rock (1:4 or steeper) to provide limited vehicular redirection.
5. Application. If rock is within the clear zone and more than 5.5 m from the edge of traveled way, the ConnDOT Design Exception Committee will review the case and will either:
 - a. determine that rock removal is appropriate because of its accident potential, or
 - b. grant a design exception of the clear zone criteria.

Designers should also document whether or not the rock is in such a condition that it imperils the traveling public because of flaking, falling or icing conditions, and they should evaluate the need for roadside barrier protection. This should be documented in the project file and verification sought from the Design Exception Committee.

2-9.02 Safety Appurtenances

Reference: Chapter Thirteen

During the design of a 3R project, all existing safety appurtenances should be examined to determine if they meet the Department's current safety performance and design criteria. This includes guide rail, median barriers, crash cushions, sign supports, luminaire supports, etc. Normally, all existing safety appurtenances

will be upgraded to meet the most recent criteria. Chapter Thirteen presents the Department's criteria for the layout of guide rail, median barriers and crash cushions.

Guide rail warrants on 3R projects can be especially difficult to resolve. Basically, the evaluation process will be:

1. Determine if guide rail is warranted. However, also see Comment #5 in Section 2-9.01. As part of this process, the designer must decide if the guide rail will create a greater hazard than the obstacle which it is shielding.
2. If an existing run of guide rail is located where none is warranted, remove the guide rail.
3. If guide rail is warranted, consider removing or relocating the hazard; reducing the hazard (e.g., flattening a slope); or making it breakaway.
4. If the hazard cannot be eliminated and guide rail is considered cost effective, then install guide rail. For existing runs of guide rail, ensure that they meet the applicable performance and design criteria, including:
 - a. operational acceptability (hardware, height, etc.),
 - b. dynamic deflection criteria,
 - c. length of need,
 - d. flare rate,
 - e. lateral placement,
 - f. placement on slopes and behind curbs,
 - g. terminal treatments, and
 - h. transitions.

A common problem on 3R projects will be the height of existing guide rail because of the pavement overlay or rehabilitation. Each existing guide rail run which will remain must be considered individually. The designer should replace existing guide rail when its height will not fall within the following tolerances after construction:

<u>Type</u>	<u>Standard</u>	
	<u>Height*</u>	<u>Tolerance</u>
Three cable	762 mm	690 mm - 762 mm
Type R-I	838 mm	765 mm - 838 mm
Type R-B	686 mm	615 mm - 686 mm

* *Guide rail height is measured to top of longitudinal rail element from the surface of the road. (See Chapter Thirteen.)*

2-10.0 INTERSECTIONS AT-GRADE

Reference: Chapter Eleven

Chapter Eleven provides criteria for the detailed design of intersections at-grade. Where practical, these criteria apply to 3R projects and should be implemented. The following sections indicate areas where modifications to the intersection criteria may be made for 3R projects.

2-10.01 Intersection Sight Distance

Reference: Section 11-2.0

The criteria in Section 11-2.0 on intersection sight distance will apply to 3R projects.

2-10.02 Turning Radii

Reference: Section 11-3.0

Section 11-3.0 presents criteria for the selection of a design vehicle, for acceptable encroachment, and for turning radii criteria at intersections. Where practical, these criteria should be met on 3R projects and, typically, this is practical in rural areas. However, in urban areas space limitations and existing curb radii have a significant impact on selecting a practical design for right-turning vehicles. The designer should consider the following when determining the appropriate right-turn treatment for urban intersections on 3R projects:

1. Simple radii of 4.5 m to 7.5 m are adequate for passenger vehicles. These radii may be retained on 3R projects on existing streets and arterials at:
 - a. intersections with minor roads where very few trucks will be turning;
 - b. intersections where the encroachment of SU and semitrailer vehicles onto adjacent lanes is acceptable; and
 - c. intersections where a parking lane is present, and it is restricted a sufficient distance from the intersection, and it is used as a parking lane throughout the day.
2. Where practical, simple radii of 9 m or simple radii with tapers (for an SU design vehicle) should be used at all major intersections and at all minor intersections with some truck turning volumes.

3. At intersections where semitrailer combinations and buses turn frequently, a simple radius of 12 m or more should be provided. Preferably, the designer will use a radius with taper offsets for the selected design vehicle.

2-10.03 Auxiliary Turning Lanes

Reference: Section 11-5.0

Section 11-5.0 presents warrants for right- and left-turn lanes. These criteria apply to 3R projects. Section 11-5.0 also presents design details for auxiliary turning lanes, and these should be met for 3R projects. However, in urban areas these criteria may be impractical because of restricted conditions. In these cases, the designer will provide the best design practical for the existing field conditions.

2-10.04 Driveway Design

Reference: Section 11-8.0

The criteria in Section 11-8.0 on driveway design will apply to 3R projects.

2-11.0 REFERENCES

1. *A Policy on Geometric Design of Highways and Streets*, AASHTO, 1994.
2. Special Report 214 *Designing Safer Roads; Practices for Resurfacing, Restoration and Rehabilitation*, TRB, 1987.
3. Technical Advisory T5040.28 “Developing Geometric Design Criteria and Processes for Non-Freeway RRR Projects,” FHWA, 1988.
4. *Preserving Connecticut’s Scenic Roads, Corridor Management Handbook*, ConnDOT.
5. *Roxbury Scenic Corridor Management Plan, Routes 67 and 317*, ConnDOT.
6. *Route 7 Scenic Corridor Management Plan, towns of Kent, Cornwall and Sharon*, ConnDOT.
7. *Sharon Scenic Corridor Management Plan, Routes 4 and 41*, ConnDOT.

Chapter Three

GEOMETRIC DESIGN OF EXISTING HIGHWAYS (4R Freeway Projects)(Spot Improvements)

Table of Contents

	<u>Page</u>
3-1.0 4R FREEWAY PROJECTS	3-1(1)
3-1.01 <u>Background</u>	3-1(1)
3-1.02 <u>Objectives</u>	3-1(2)
3-1.03 <u>Approach</u>	3-1(2)
3-1.04 <u>Geometric Design of 4R Freeway Projects</u>	3-1(3)
3-1.04.01 Design Speed	3-1(3)
3-1.04.02 Traffic Volumes	3-1(4)
3-1.04.03 Vertical Clearances	3-1(4)
3-1.04.04 Bridges	3-1(4)
3-1.04.05 Safety Appurtenances	3-1(6)
3-1.04.06 Interchanges	3-1(6)
3-2.0 SPOT IMPROVEMENTS (Non-Freeways)	3-2(1)
3-2.01 <u>Objectives</u>	3-2(1)
3-2.02 <u>Approach</u>	3-2(2)
3-2.03 <u>Geometric Design of Highway Bridge Replacement/ Rehabilitation Program (HBRRP) Projects</u>	3-2(3)
3-2.04 <u>Design Procedures for Local Bridge Projects</u>	3-2(4)
3-2.04.01 Scope	3-2(4)
3-2.04.02 Applicability	3-2(4)
3-2.04.03 Implementation	3-2(4)
3-2.04.04 Procedures	3-2(5)

Chapter Three

GEOMETRIC DESIGN OF EXISTING HIGHWAYS (4R Freeway Projects) (Spot Improvements)

Chapter Three presents the Department's criteria for the geometric design of existing highways for the following project types:

1. 4R freeway projects, and
2. spot improvements on non-freeways.

For projects on the Merritt Parkway, the geometric design criteria will be determined on a case-by-case basis.

3-1.0 4R FREEWAY PROJECTS

3-1.01 Background

The Department began construction of its freeway system in the 1950's and, today, the Connecticut system is nearing completion. The freeway system has introduced a level of mobility and safety for the traveling public which was unattainable without its special features, such as full control of access, wide roadway widths and high design speeds. In the past few decades, this system has carried traffic volumes in far greater proportion than its kilometers within the State.

The freeway system requires periodic repair and upgrading which exceeds the limits of normal maintenance. In general, these capital improvements are referred to as 4R freeway projects (resurfacing, restoration, rehabilitation and reconstruction), which applies to any project on an existing freeway. As with non-freeway 3R projects, it is often impractical to fully apply new construction criteria to 4R projects without some qualifications. Therefore, the geometric design of 4R freeway projects requires special design considerations which are discussed in the following sections.

3-1.02 Objectives

The objective of a 4R freeway project is, within practical limits, to return the freeway to its original level of serviceability or to improve its serviceability to meet current and future demands. This objective applies to all aspects of the freeway's serviceability, including:

1. structural adequacy,
2. drainage,
3. level of service for the traffic flow,
4. geometric design,
5. roadside safety, and
6. traffic control.

3-1.03 Approach

4R freeway projects are most often initiated to make a specific improvement to the freeway. Therefore, the Department's approach to the geometric design of 4R freeway projects is to selectively evaluate and improve the existing geometrics. The 4R approach is summarized as follows:

1. Nature of Improvement. Identify the specific improvement intended for the 4R project. For example, geometric improvements might include:
 - a. add through lanes to improve the level of service,
 - b. upgrade roadside safety,
 - c. increase the length of one or more acceleration lanes at an interchange,
 - d. widen an existing bridge as part of a bridge rehabilitation project,
 - e. eliminate a weaving area at an interchange, and/or
 - f. resurfacing.
2. Numerical Criteria. Apply the Department's new construction criteria specifically to the geometric design element which is improved, unless it is otherwise addressed in this chapter for 4R projects. The new construction criteria are presented in Chapters Four and Five. Chapter Ten discusses cross sections; Chapter Thirteen discusses roadside safety; and Chapter Twelve presents geometric design criteria for interchanges.
3. Secondary Impacts. Identify and evaluate any secondary impacts which may be precipitated by the freeway improvement. For example:

- a. The installation of a concrete median barrier may restrict horizontal sight distance.
 - b. The addition of through lanes on the outside may reduce the available roadside clear zone to below the Department's allowable criteria.
 - c. A pavement overlay may require the adjustment of guide rail height or reduce the vertical clearance.
4. Other Improvements. Identify other geometric design deficiencies within the project limits. The designer will exercise his/her judgment when determining any other improvements which can be practically corrected without exceeding the intended project scope of work. For example, when pavement is being constructed to improve acceleration lanes, it may be reasonable to construct pavement to improve deficient shoulders at the same time. Where a design feature can be improved for a portion of the project, these improvements should be incorporated.
5. Exceptions. The discussion in Section 6-6.0 on design exceptions applies equally to the geometric design of 4R freeway projects. However, it will only apply to the geometric design of the specific freeway improvement which resulted in project initiation, and it will also apply to any secondary impacts which may result from the improvement.

3-1.04 Geometric Design of 4R Freeway Projects

As stated in Section 3-1.03, the Department's design criteria for new construction also applies to 4R freeway projects. However, the designer must still make certain decisions, and there is some flexibility that can be applied. These are discussed in the following sections.

3-1.04.01 Design Speed

Chapters Four and Five present the Department's criteria for selecting the design speed for new freeway construction. These apply to 4R projects at a minimum. However, the designer may judge that these design speeds are less than the 85th percentile speeds for the project under design. Therefore, the designer has the option of requesting a speed study from the Division of Traffic Engineering to determine the 85th percentile speed on the existing freeway. The designer should follow the procedure in Section 2-4.0 for this determination.

3-1.04.02 Traffic Volumes

Some design elements on 4R freeway projects will require the selection of the DHV (e.g., level of service) or AADT (e.g., roadside clear zones). The freeway will be designed to meet the geometric design criteria for traffic volumes determined for 10 to 20 years beyond the expected construction completion date.

3-1.04.03 Vertical Clearances

The minimum vertical clearance for freeways passing beneath an existing bridge to remain in place should be 4.9 m over the entire roadway width, including auxiliary lanes and shoulders. (Note: Department practice is to post a "low-clearance" sign on structures with vertical clearances less than 4.35 m.)

3-1.04.04 Bridges

The following discusses the Department's design criteria for bridges on 4R freeway projects.

1. Bridges to Remain in Place. A 4R project may be primarily intended, for example, to improve the pavement condition over several kilometers. A bridge or several bridges may be within the limits of the 4R project. Desirably, the bridge widths will equal the full approach roadway width, including shoulders. However, this may not be the case. If the existing bridge is structurally sound and if it meets the Department's design loading structural capacity, it is unlikely to be cost effective to improve the geometrics of the bridge. However, the geometric deficiencies may be severe, and/or there may be an adverse accident experience at the bridge. In this case, it may be warranted to widen the bridge as part of the 4R project.

If a bridge remains in place, its minimum width must be equal to the approach traveled way +3.0 m (right shoulder) +1.1 m (left shoulder); otherwise, a design exception will be necessary. In addition, existing bridge rails on the project should be evaluated to determine if they meet the Department's current safety performance criteria.

2. Bridge Replacement/Rehabilitation. 4R freeway projects will often include bridge replacements or bridge rehabilitation and, in some cases, this will be the entire project scope of work. The following will apply to the geometric design of these projects:
 - a. Horizontal and Vertical Alignment. An existing bridge may have an alignment which does not meet the Department's current criteria. For bridge replacement projects, the designer

should evaluate the practicality of realigning the bridge to meet the applicable alignment criteria for new construction. For bridge rehabilitation projects, it is unlikely to be cost effective to realign the bridge to correct any alignment deficiencies.

- b. Width. The bridge width should equal the full approach roadway width, including shoulders, as determined by the criteria in Chapters Four and Five for the most likely level of future highway improvement on the approaches. If practical, this decision should be based on a capacity analysis for the selected DHV at the selected level of service. This analysis could determine the need for additional travel lanes and/or the need for wider shoulders. For example, if the predicted volume of trucks exceeds 250 DDHV, the future shoulder width on the approach should be 3.6 m. Because freeway bridges represent major economic investments with lengthy design lives, it may be warranted to provide the wider widths as part of a bridge replacement or rehabilitation project.

As another example, a capacity analysis may indicate the need for an additional through lane to meet the level-of-service criteria for the design year. The decision may be made to widen the bridge as part of the replacement/rehabilitation project. Until the roadway approach is widened, it may be necessary to indicate with pavement markings that the additional width on the bridge cannot be used by through traffic.

- c. Length. The length of the freeway bridge determines the width of the underpass for the facility passing beneath the freeway. Therefore, if practical, the freeway bridge should be long enough to accommodate any likely future widening of the underpassing roadway. This may involve an assessment of the potential for further development in the general vicinity of the underpass. The Bureau of Planning should be consulted for its traffic projections.
- d. Bridge Rails. All existing bridge rails on the project should be evaluated to determine if they are structurally adequate and meet the Department's current safety performance criteria.
- e. Approach Guide Rail Transitions. The approaching guide rail transitions will be evaluated to determine if they meet the Department's current criteria. If the transitions do not, they will be upgraded. The Department's latest standard sheets will be used to make these determinations.

3-1.04.05 Safety Appurtenances

One of the objectives of a 4R freeway project may be to upgrade roadside safety along the freeway. Guide rail warrants and design can present difficult problems (e.g., guide rail height). The discussion in Section 2-9.0 on 3R non-freeway projects also applies to safety appurtenances on 4R projects.

3-1.04.06 Interchanges

A 4R freeway project may include proposed work on a freeway interchange. The work may be to rehabilitate the entire interchange or to make only selective improvements to the interchange geometrics. Chapter Twelve will be used to design the interchange element.

3-2.0 SPOT IMPROVEMENTS (Non-Freeways)

3-2.01 Objectives

Spot improvements are intended to correct an identified deficiency at an isolated location on non-freeways. Occasionally, more than one location is included in a project for design or construction purposes. This project scope of work is consistent with the Department's responsibility to provide a safe driving environment for the motoring public which is free of unexpected demands on the driver. Experience has demonstrated the benefits of improving relatively short roadway sections or spot locations with recognized geometric deficiencies to at least a level consistent with the adjacent highway sections. This will provide drivers with a facility that is consistent with the principles of driver expectancy.

The deficiency which the spot improvement will correct may be related to structural, geometric, safety, drainage or traffic control problems. These projects are not intended to provide a general upgrading of the highway, as are projects categorized as new construction, major reconstruction or 3R. For these reasons, a flexible approach is necessary to determine the appropriate geometric design criteria which will apply to the spot improvement.

Spot improvement projects may also be affected by special criteria which may apply to a particular funding category. Two examples are:

1. Safety Projects. These projects are intended to provide cost-effective improvements to sites identified as having an unusually high number of accidents or accident rate. Typical projects are intersection improvements, flattening a horizontal curve, installing guide rail, or installing traffic control devices. Most often, projects will only be funded when the B/C ratio is estimated to be above 1.0. The Division of Traffic Engineering is responsible for conducting a preliminary evaluation of the site and recommending improvements. When roadway work is involved, the Office of Engineering is responsible for preparing the detailed project design.
2. Highway Bridge Replacement & Rehabilitation Program (HBRRP). The HBRRP is intended to correct structural and functional deficiencies on a priority basis. The priorities are determined by a Statewide bridge inspection program which leads to a sufficiency rating for each bridge. The rating is based on a weighted formula which reflects both structural and geometric deficiencies (e.g., inadequate roadway width, poor alignment or inadequate bridge rail or transitions). However, the structural deficiencies usually have the greater influence on the sufficiency rating. Therefore, this should be reflected in the consideration of any geometric improvements. Geometric design criteria for HBRRP projects are discussed separately in Section 3-2.03.

3-2.02 Approach

The Department has adopted a flexible approach to the geometric design of spot improvement projects. The following summarizes the approach:

1. Numerical Criteria. The designer should consider the level of improvement which will most likely be used to upgrade the highway in the future. If this is deemed to be major reconstruction, then the criteria in Chapters Four and Five for new construction/major reconstruction will provide the frame of reference for the spot improvement. Chapter Eleven will apply to an intersection project. If a 3R project is considered the most likely level of improvement, then the criteria in Chapter Two will apply.
2. Design Speed. The design speed of the adjacent sections should be used for the spot improvement; however, a speed less than the posted speed should not be used. The selection of the applicable design speed will be left to the judgment of the designer. Some factors that may be considered include:
 - a. the results from a speed study by the Division of Traffic Engineering, if requested;
 - b. the design speeds for new construction in Chapters Four and Five; and
 - c. the posted/legal speed limit (this will be a minimum).
3. Application. The designer should apply the selected criteria specifically to the geometric improvement related to the objective of the spot improvement project (e.g., install guide rail, flatten a horizontal curve, add a left-turn lane). In addition, the designer should evaluate other geometric design deficiencies within the project limits. The designer should consider improving any severe deficiencies, even if not related to the specific objective of the spot improvement. The designer will exercise his/her judgment when determining any other improvements which may be justified.
4. Exceptions. The design exception process in Section 6-6.0 applies to bridge widths, underpass widths and vertical clearances on spot improvement projects. For other geometric design elements, it will only apply to the geometric design of the specific geometric design improvement which resulted in project initiation, and it will also apply to any secondary impacts which may result from the improvement. For example, if a spot improvement is initiated to install an exclusive left-turn lane, it will not be necessary to seek a design exception for the intersection sight distance (ISD) if the ISD does not meet the Department's criteria, unless the deficiency is caused or made worse by the installation of the new lane.

3-2.03 Geometric Design of Highway Bridge Replacement/Rehabilitation Program (HBRRP) Projects

The spot improvement approach discussed in Section 3-2.02 also applies to HBRRP projects. The following offers additional factors to consider:

1. Horizontal and Vertical Alignment. Many existing bridges have alignments which do not meet the Department's current criteria. For bridge replacement projects, the designer should evaluate the practicality of realigning the bridge to meet the applicable alignment criteria (major reconstruction or 3R). For bridge rehabilitation projects, it is unlikely to be cost-effective to realign the bridge to correct any alignment deficiencies unless the bridge is within a future highway project area which has already been scheduled. The bridge designer should verify that no projects are scheduled before using the existing alignment.
2. Width. The bridge width should equal or exceed the full approach roadway width, including shoulders, as determined from the Department's criteria for the most likely level of future highway improvement on the approaches (major reconstruction or 3R). This width will be determined by the tables in Chapters Two, Four or Five. If the decision is made not to provide the applicable width, the designer must comply with the design exception process (Section 6-6.0). *Note: Section 13a-86 of the Connecticut Statutes requires a minimum bridge width of 28 ft (8.54 m), exclusive of any sidewalk width. No exceptions to this criteria will be allowed on State-maintained highways and bridges.*
3. Narrow Bridges. All bridges which are narrower than the approach roadway width (including shoulders) should be evaluated for widening and/or special narrow bridge treatments. At a minimum, the signing and pavement markings must meet the criteria of the MUTCD. In addition, NCHRP 203 *Safety at Narrow Bridge Sites* provides criteria specifically for narrow bridges (e.g., special pavement markings). The designer, in coordination with the Division of Traffic Engineering, should evaluate the value of these additional treatments at the bridge site.
4. Bridge Rails. All existing bridge rails on the project should be evaluated to determine if they are structurally adequate and meet the Department's current safety performance criteria.
5. Approach Guide Rail Transitions. The approaching guide rail transitions will be evaluated to determine if they meet the Department's current criteria. If the transitions do not, they will be upgraded. The Department's latest standard sheets will be used to make these determinations.
6. Exceptions. For municipally owned and maintained bridges, see Section 3-2.04.

3-2.04 Design Procedures for Local Bridge Projects

3-2.04.01 Scope

This Section establishes procedures for the design of municipally owned bridges which are funded in part by the State's Local Bridge Program and/or the Federal Highway Bridge Replacement/ Rehabilitation (HBRR) Program. These procedures have been developed as a result of passage of Public Act 97-214 *An Act Concerning The Rehabilitation Or Replacement Of Bridges In The State And Requiring A South East Corridor Transportation Study*. This act, which was effective on October 1, 1997, will apply to bridges located on roads functionally classified as "Rural Local Roads," "Rural Minor Collectors," or "Urban Local Streets." These procedures do not apply to bridges on roads with a functional classification greater than those listed above nor to State owned/maintained bridges.

3-2.04.02 Applicability

This procedure will apply to municipally owned and maintained bridges which are determined to be structurally deficient or functionally obsolete according to the *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges* (FHWA, December 1995). This determination is formulated by the Department's Bridge Inspection and Evaluation Unit according to parameters established in the *FHWA Coding Guide*.

The State's inventory of structurally deficient or functionally obsolete bridges is the major component in formulating Connecticut's apportionment of Federal funds in the HBRR Program. The primary purpose of this Program is to rectify the deficiencies in bridges which qualified for the funding. Projects funded by this Program should result in the removal of the subject bridge from the State's deficient bridge list, resulting in bridges which are 1) able to carry all legal loads, 2) structurally sound, and 3) functionally efficient.

3-2.04.03 Implementation

These procedures will apply to new projects initiated by the Department on or after October 1, 1997 and to any existing projects which do not have Preliminary Design approval as of October 1, 1997. Preliminary Design approval is issued by the Department after all engineering studies have been completed and accepted by the Department, the proposed bridge and approaches have been displayed graphically, Federal approval has been secured for all environmental and historical reviews, and the public has had an opportunity to view and comment on the proposal through the public informational process.

3-2.04.04 Procedures

An “assignment meeting” shall be conducted for each project. This meeting is typically attended by representatives from the town, the town’s designer, and the Department of Transportation, and the meeting results in the collective agreement of the “scope of project.” If a consensus cannot be reached on the most appropriate scope of work (i.e., rehabilitation or replacement), the town shall be allowed to prepare or have prepared a report which specifically addresses the following factors for consideration as specified in Section 1(b) of Public Act 97-214:

1. the functional classification of the highway;
2. the structural capacity and geometric constraints of the bridge within its existing footprint and the availability of alternative routes;
3. the comparative long-term costs, risks and benefits of rehabilitation and new construction;
4. the requirements of State geometric design criteria;
5. disruption to homes and businesses;
6. environmental impacts;
7. the potential effects on the local and State economics;
8. cost-effectiveness;
9. mobility;
10. safety, as determined by factors such as the accident history for motorists, pedestrians and bicyclists;
and
11. the impact on the historic, scenic and aesthetic values of the municipality in which the bridge is or may be located.

The cost to prepare this report is an allowable project cost, and the report shall be submitted to the Department of Transportation for review and comment. Final Department concurrence in the findings of the report must be in place before commencing design activities.

The design criteria for the development of plans on this program shall be the *Connecticut Highway Design Manual*. In consideration of site conditions, environmental factors, engineering factors or community standards and custom, it may be reasonable to depart from these design guidelines.

The municipality shall have the authority for approving any digressions from the *Connecticut Highway Design Manual* for projects funded by a Grant and/or Loan under the provisions of the Local Bridge Program (CGS 13a-175p through 13a-175w).

The Connecticut Department of Transportation, on behalf of the Federal Highway Administration, shall approve any digressions from the *Connecticut Highway Design Manual* for projects receiving Federal assistance under the provisions of the HBRR Program. Municipalities shall submit such requests in writing to the Administrator of the Federal Local Bridge Program for review. Each request shall have sufficient support documentation to justify the design exception. The Department shall review each request and render a decision without the need for a formal review by the Department's Design Exception Committee.

It should be noted that, under normal circumstances, the Department will not approve design exceptions which perpetuate a structurally deficient or functionally obsolete condition on bridges which are on the National Bridge Inventory (bridges with span lengths of 6 m or greater). In unusual circumstances (e.g., a historically significant bridge), the Department will entertain a request for an exception to the design guidelines that results in a bridge coding of "structurally deficient" or "functionally obsolete."

Chapter Four**RURAL HIGHWAYS AND ROADS
(New Construction/Major Reconstruction)****Table of Contents**

	<u>Page</u>
Figure 4A Rural Freeways	4(2)
Figure 4B Multi-Lane Rural Arterials	4(4)
Figure 4C Two-Lane Rural Arterials	4(6)
Figure 4D Rural Collector Roads	4(8)
Figure 4E Local Rural Roads	4(10)
Figure 4F Typical Depressed Median Section	4(12)
(Rural Freeways)	
Figure 4G Typical Two-Lane Section	4(14)
(Rural Arterial/Collector/Local Road)	
Figure 4H Miscellaneous Details, Various Classes	4(16)
Figure 4I Typical Median Section for Freeways	4(17)
(20 m or Less)	
Figure 4J Details of Cut Sections	4(18)

Chapter Four

RURAL HIGHWAYS AND ROADS

(New Construction/Major Reconstruction)

This chapter presents the Department's criteria for the design of rural highways and roads. They apply to new construction and major reconstruction projects. The designer should consider the following in the use of the tables:

1. Functional/Design Classification. The selection of design values for new construction and major reconstruction depends on the functional and design classification of the highway facility. This is discussed in Section 6-1.0. For non-freeways, the design classification is based on the average number of access points per kilometer per side. The designer should realize that the values in the tables are for guidance only; they should not be used as rigid criteria for determining the design classification on rural highways. Each project should be designed as part of the total environment, specifically designed to fit into the context of the area where it is to be constructed. Before selecting design values, the designer should take into consideration the community, land use, visual, historical and natural resources of the area. Designers should attempt to maintain the character of an area, but at the same time meet the transportation needs of the project.
2. Capacity Analyses. Section 6-3.0 discusses highway capacity. Several highway design elements (e.g., the number of travel lanes) will be determined in part by the capacity analysis. As discussed in Section 6-3.0, the capacity analysis will be based on:
 - a. the design hourly volume (DHV), usually 20 years from the construction completion date;
 - b. the level of service, as determined from the tables in this chapter; and
 - c. the capacity analysis, using the techniques in the HCM.
3. Cross Section Elements. The designer should realize that some of the cross section elements included in a table (e.g., median width) are not automatically warranted in the project design. The values in the tables will only apply after the decision has been made to include the element in the highway cross section.
4. Manual Section References. These tables are intended to provide a concise listing of design values for easy use. However, the designer should review the *Manual* section references for greater insight into the design elements.

Figure 4A
RURAL FREEWAYS
New Construction/Major Reconstruction

Design Element		*	Manual Section	Design Values	
Design Controls	Design Forecast Year		6-3.02	20 Years	
	Design Speed	x	6-2.02	110 km/h	
	Control of Access		6-4.0	Full Control	
	Level of Service		6-3.0	B - C	
Cross Section Elements	Lane Width	x	10-1.01	3.6 m	
	Shoulder Width (1)	Right	x	10-1.02	3.0 m
		Left — 4 Lanes	x		2.4 m (1.2 m Paved + 1.2 m Graded)
		Left — 6+ Lanes	x		3.0 m
	Typical Cross Slope	Travel Lane	x	10-1.01	1.5-2.0% for lanes adjacent to crown; 2.0% for lanes away from crown
		Shoulder	x	10-1.02	4%; with CMB, 4% - 6% for left shoulder
	Median Width (includes left shoulders)		10-3.0	See Figure 4I — 30 m	
	Bridge Width/Cross Slope	x	10-4.01	Meet Approach Roadway Width and Cross Slope	
	Underpass Width		10-4.02	Meet Approach Roadway Width Plus Clear Zones	
	Right-of-Way Width		10-5.0	Max: 30 m Beyond Edge of Traveled Way	
	Roadside Clear Zones	x	13-2.0	See Section 13-2.0	
Fill/Cut Slopes		10-2.02	See Figure 4F		

*Controlling design criteria (see Section 6-6.0)

Footnote:
(1) Shoulder Width. Where the truck volumes exceed 250 DDHV, both the right and left shoulders should be 3.6 m.

Figure 4A (continued)

RURAL FREEWAYS
New Construction/Major Reconstruction

Design Element		*	Manual Section	Design Values (Based on Design Speed)	
				110 km/h	
Alignment Elements	Stopping Sight Distance		x	7-1.0	180 m - 250 m
	Decision Sight Distance	Maneuver		7-2.0	335 m
		Stop			265 m
	Minimum Radius (e = 6.0%)		x	8-2.02	565 m
	Superelevation	e _{max}		8-2.02	6.0%
		Rate	x		See Figure 8-2A
	Horizontal Sight Distance			8-2.04	See Section 8-2.04
	Maximum Grade		x	9-2.03	4%
	Minimum Grade			9-2.03	0.5%
	Vertical Curvature (K-Value)	Crest		9-3.02	81 - 155
		Sag		9-3.03	44 - 63
	Minimum Vertical Clearance: Freeway Under ...	New Highway Bridge	x	9-4.0	5.05 m
Existing Highway Bridge		x	4.9 m		
Pedestrian Bridge/Overhead Sign		x	5.35 m		
Minimum Vertical Clearance (Freeway over Railroad)		x	9-4.0	Electrified: 6.858 m All Others: 6.248 m	

* Controlling design criteria (see Section 6-6.0)

Figure 4B
MULTI-LANE RURAL ARTERIALS
New Construction/Major Reconstruction

Design Element		*	Manual Section	Design Values (by Type of Roadside Development)			
				Open	Moderate Density	High Density	
Design Controls	Typical Number of Access Points/Kilometer/Side		6-1.03	0 - 10	10 - 20	> 20	
	Design Forecast Year		6-3.02	20 Years	20 Years	20 Years	
	Design Speed	x	6-2.02	80 - 100 km/h	80 - 90 km/h	80 - 90 km/h	
	Control of Access		6-4.0	Partial/Control by Regulation	Control by Regulation	Control by Regulation	
	Level of Service		6-3.0	B - C	B - C	B - C	
Cross Section Elements	Travel Lane Width	x	10-1.01	3.6 m	3.6 m	3.6 m	
	Shoulder Width	Right	x	10-1.02	1.2 m - 2.4 m	1.2 m - 2.4 m	1.2 m - 2.4 m
		Left	x		1.2 m - 2.4 m	1.2 m - 2.4 m	1.2 m - 2.4 m
	Typical Cross Slope	Travel Lane	x	10-1.01	1.5-2.0% for lanes adjacent to crown; 2.0% for lanes away from crown		
		Shoulder	x	10-1.02	4%	4%	Uncurbed: 4% Curbed: 6%
	Turn Lanes	Lane Width	x	10-1.03	3.6 m	3.6 m	3.3 m - 3.6 m
		Shoulder Width	x		0.6 m - 1.2 m		
	Median Width (Includes Left Shoulders)	Depressed		10-3.0	15 m - 27 m	15 m - 27 m	N/A
		Raised Island (V=80 km/h)			N/A	N/A	2.4 m - 6.0 m
	Bicycle Lane	Width		15-4.0	1.5 m or Shoulder Width, whichever is greater		
		Cross Slope			2%		
	Bridge Width/Cross Slope	x	10-4.01	Meet Approach Roadway Width and Cross Slope		Sidewalk Width: 1.7 m	
	Underpass Width		10-4.02	Meet Approach Roadway Width Plus Clear Zones			
	Right-of-Way Width		10-5.0	Project-by-Project Basis			
	Roadside Clear Zones	x	13-2.0	See Section 13-2.0			
Fill/Cut Slopes		10-2.02	See Figure 4G				

*Controlling design criteria (see Section 6-6.0)

Figure 4B (continued)

**MULTI-LANE RURAL ARTERIALS
New Construction/Major Reconstruction**

Design Element		*	Manual Section	Design Values (Based on Design Speed)			
				100 km/h	90 km/h	80 km/h	
Alignment Elements	Stopping Sight Distance		x	7-1.0	160 m - 205 m	135 m - 170 m	115 m - 140 m
	Decision Sight Distance	Maneuver		7-2.0	315 m	275 m	230 m
		Stop			225 m	185 m	155 m
	Minimum Radius (e = 6.0%)		x	8-2.02	440 m	340 m	255 m
	Superelevation	e _{max}		8-2.02	6.0%	6.0%	6.0%
		Rate	x		See Figure 8-2A		
	Horizontal Sight Distance			8-2.04	See Section 8-2.04		
	Maximum Grade		x	9-2.03	4%	5%	5%
	Minimum Grade			9-2.03	0.5%		
	Vertical Curvature (K-Value)	Crest		9-3.02	64 - 105	46 - 72	33 - 49
		Sag		9-3.03	38 - 51	31 - 41	26 - 33
	Minimum Vertical Clearance: Arterial Under ...	New Highway Bridge	x	9-4.0	5.05 m		
Existing Highway Bridge		x	4.35 m				
Pedestrian Bridge/Overhead Sign		x	5.35 m				
Minimum Vertical Clearance (Arterial over Railroad)		x	9-4.0	Electrified: 6.858 m All Others: 6.248 m			

* Controlling design criteria (see Section 6-6.0)

Figure 4C
TWO-LANE RURAL ARTERIALS
New Construction/Major Reconstruction

Design Element		*	Manual Section	Design Values (by Type of Roadside Development)			
				Open	Moderate Density	High Density	
Design Controls	Typical Number of Access Points/Kilometers/Side		6-1.03	0 - 10	10 - 20	> 20	
	Design Forecast Year		6-3.02	20 Years	20 Years	20 Years	
	Design Speed	x	6-2.02	80 - 100 km/h	80 - 90 km/h	70 - 80 km/h	
	Control of Access		6-4.0	Partial/Control by Regulation	Control by Regulation	Control by Regulation	
	Level of Service		6-3.0	B - C	B - C	B - C	
Cross Section Elements	Travel Lane Width	x	10-1.01	3.6 m	3.6 m	3.6 m	
	Shoulder Width	x	10-1.02	1.2 m - 2.4 m	1.2 m - 2.4 m	1.2 m - 2.4 m	
	Typical Cross Slope	Travel Lane	x	10-1.01	1.5-2.0%	1.5-2.0%	1.5-2.0%
		Shoulder	x	10-1.02	4%	4%	Uncurbed: 4% Curbed: 6%
	Turn Lanes	Lane Width	x	10-1.03	3.6 m	3.6 m	3.3 m - 3.6 m
		Shoulder Width	x		0.6 m - 1.2 m		
	Bicycle Lane	Width		15-4.0	1.5 m or Shoulder Width, whichever is greater		
		Cross Slope			2%		
	Bridge Width/Cross Slope	x	10-4.01	Meet Approach Roadway Width and Cross Slope		Sidewalk Width: 1.7 m	
	Underpass Width		10-4.02	Meet Approach Roadway Width Plus Clear Zones			
	Right-of-Way Width		10-5.0	Project-by-Project Basis			
	Roadside Clear Zones	x	13-2.0	See Section 13-2.0			
Fill/Cut Slopes		10-2.02	See Figure 4G				

*Controlling design criteria (see Section 6-6.0)

Figure 4C (continued)
TWO-LANE RURAL ARTERIALS
New Construction/Major Reconstruction

Design Element		*	Manual Section	Design Values (Based on Design Speed)				
				100 km/h	90 km/h	80 km/h	70 km/h	
Alignment Elements	Stopping Sight Distance		x	7-1.0	160 m - 205 m	135 m - 170 m	115 m - 140 m	95 m - 115 m
	Decision Sight Distance	Maneuver		7-2.0	315 m	275 m	230 m	200 m
		Stop			225 m	185 m	155 m	125 m
	Minimum Radius (e = 6.0%)		x	8-2.02	440 m	340 m	255 m	195 m
	Superelevation	e _{max}		8-2.02	6.0%	6.0%	6.0%	6.0%
		Rate	x		See Figure 8-2A			
	Horizontal Sight Distance			8-2.04	See Section 8-2.04			
	Maximum Grade		x	9-2.03	4%	5%	5%	6%
	Minimum Grade			9-2.03	0.5%			
	Vertical Curvature (K-Value)	Crest		9-3.02	64 - 105	46 - 72	33 - 49	23 - 33
		Sag		9-3.03	38 - 51	31 - 41	26 - 33	20 - 26
	Minimum Vertical Clearance: Arterial Under ...	New Highway Bridge	x	9-4.0	5.05 m			
Existing Highway Bridge		x	4.35 m					
Pedestrian Bridge/ Overhead Sign		x	5.35 m					
Minimum Vertical Clearance (Arterial over Railroad)		x	9-4.0	Electrified: 6.858 m All Others: 6.248 m				

* Controlling design criteria (see Section 6-6.0)

Figure 4D
RURAL COLLECTOR ROADS
New Construction/Major Reconstruction

Design Element		*	Manual Section	Design Values (by Type of Roadside Development)			
				Open	Moderate Density	High Density	
Design Controls	Typical Number of Access Points/Kilometers/Side		6-1.03	0 - 10	10 - 20	> 20	
	Design Forecast Year		6-3.02	20 Years	20 Years	20 Years	
	Design Speed	AA DT < 400	x	6-2.02	50 - 60 km/h	N/A	N/A
		AA DT: 400 - 2000			60 - 80 km/h	60 - 70 km/h	N/A
		AA DT > 2000			80 km/h	70 - 80 km/h	60 - 70 km/h
	Control of Access		6-4.0	Control by Regulation	Control by Regulation	Control by Regulation	
Level of Service		6-3.0	C - D	C - D	C - D		
Cross Section Elements	Travel Lane Width	AA DT < 400	x	10-1.01	3.0 m	N/A	N/A
		AA DT: 400 - 1500			3.3 m (V\$60); 3.0 m (V#50)	3.3 m (V\$60); 3.0 m (V#50)	N/A
		AA DT: 1500 - 2000			3.3 m	3.3 m	N/A
		AA DT > 2000			3.6 m	3.6 m	3.6 m
	Shoulder Width	AA DT # 1500	x	10-1.02	0.6 m - 2.4 m	0.6 m - 2.4 m	N/A
		AA DT > 1500			1.2 m - 2.4 m	1.2 m - 2.4 m	1.2 m - 2.4 m
	Typical Cross Slope	Travel Lane	x	10-1.01	1.5-2.0%	1.5-2.0%	1.5-2.0%
		Shoulder	x	10-1.02	4%	Uncurbed: 4% Curbed: 6%	Uncurbed: 4% Curbed: 6%
	Turn Lanes	Lane Width	x	10-1.03	0.3 m Less Than Travel Lane Width — Same as Travel Lane		
		Shoulder Width	x		0.6 m - 1.2 m		
	Bicycle Lane	Width		15-4.0	1.5 m or Shoulder Width, whichever is greater		
		Cross Slope			2%		
	Bridge Width/Cross Slope (1)		x	10-4.01	Meet Approach Roadway Width and Cross Slope	Sidewalk Width: 1.7 m	
	Underpass Width			10-4.02	Meet Approach Roadway Width Plus Clear Zones		
	Right-of-Way Width			10-5.0	Project-by-Project Basis		
Roadside Clear Zones		x	13-2.0	See Section 13-2.0			
Fill/Cut Slopes			10-2.02	See Figure 4G			

*Controlling design criteria (see Section 6-6.0)

Footnote:

(1) Bridge Width. See Section 3-2.04 for local bridge projects.

Figure 4D (continued)

RURAL COLLECTOR ROADS
New Construction/Major Reconstruction

Design Element		*	Manual Section	Design Values (Based on Design Speed)				
				80 km/h	70 km/h	60 km/h	50 km/h	
Alignment Elements	Stopping Sight Distance		x	7-1.0	115 m - 140 m	95 m - 115 m	75 m - 85 m	60 m - 65 m
	Decision Sight Distance	Maneuver		7-2.0	230 m	200 m	175 m	145 m
		Stop			155 m	125 m	95 m	75 m
	Minimum Radius (e = 6.0%)		x	8-2.02	255 m	195 m	135 m	90 m
	Superelevation	e _{max}		8-2.02	6.0%	6.0%	6.0%	6.0%
		Rate	x		See Figure 8-2A			
	Horizontal Sight Distance			8-2.04	See Section 8-2.04			
	Maximum Grade		x	9-2.03	7%	8%	8%	9%
	Minimum Grade			9-2.03	0.5%			
	Vertical Curvature (K-Value)	Crest		9-3.02	33 - 49	23 - 33	14 - 18	9 - 11
		Sag		9-3.03	26 - 33	20 - 26	15 - 18	11 - 13
	Minimum Vertical Clearance: Collector Under ...	New Highway Bridge	x	9-4.0	4.5 m			
		Existing Highway Bridge	x		4.35 m			
Minimum Vertical Clearance (Collector over Railroad)		x	9-4.0	Electrified: 6.858 m All Others: 6.248 m				

* Controlling design criteria (see Section 6-6.0)

Figure 4E
RURAL LOCAL ROADS
New Construction/Major Reconstruction

Design Element		*	Manual Section	Design Values (by Type of Roadside Development)				
				Open	Moderate Density	High Density		
Design Controls	Typical Number of Access Points/Kilometers/Side		6-1.03	0 - 10	10 - 20	> 20		
	Design Forecast Year		6-3.02	20 Years	20 Years	20 Years		
	Design Speed	AA DT < 50	x	6-2.02	30 - 50 km/h	N/A	N/A	
		AA DT: \$ 50			50 - 60 km/h	50 - 60 km/h	50 - 60 km/h	
	Control of Access		6-4.0	Control by Regulation	Control by Regulation	Control by Regulation		
Level of Service		6-3.0	C - D	C - D	C - D			
Cross Section Elements	Travel Lane Width	AA DT < 400	x	10-1.01	2.7 m (V#60); 3.0 m (V\$70)	N/A	N/A	
		AA DT: 400 - 1500			3.0 m (V#60); 3.3 m (V\$70)	3.0 m (V#60); 3.3 m (V\$70)	N/A	
		AA DT: 1500 - 2000			3.3 m	3.3 m	3.3 m	
		AA DT > 2000			3.6 m	3.6 m	3.6 m	
	Shoulder Width		x	10-1.02	0.6 m - 1.2 m	0.6 m - 1.2 m	0.6 m - 1.2 m	
	Typical Cross Slope	Travel Lane		x	10-1.01	1.5-2.0%	1.5-2.0%	1.5-2.0%
		Shoulder (W < 1.2m)				Same as Adjacent Travel Lane		
		Shoulder (W ≥ 1.2m)		x	10-1.02	4%	Uncurbed: 4% Curbed: 6%	Uncurbed: 4% Curbed: 6%
	Turn Lanes	Lane Width		x	10-1.03	0.3 m Less Than Travel Lane Width — Same as Travel Lane		
		Shoulder Width		x		0.6 m - 1.2 m		
	Bicycle Lane	Width			15-4.0	1.5 m or Shoulder Width, whichever is greater		
		Cross Slope				2%		
	Bridge Width/Cross Slope (1)			x	10-4.01	Meet Approach Roadway Width and Cross Slope	Sidewalk Width: 1.7 m	
	Underpass Width				10-4.02	Meet Approach Roadway Width Plus Clear Zones		
	Right-of-Way Width				10-5.0	Project-by-Project Basis		
Roadside Clear Zones			x	13-2.0	See Section 13-2.0			
Fill/Cut Slopes				10-2.02	See Figure 4G			

*Controlling design criteria (see Section 6-6.0)

Footnote:

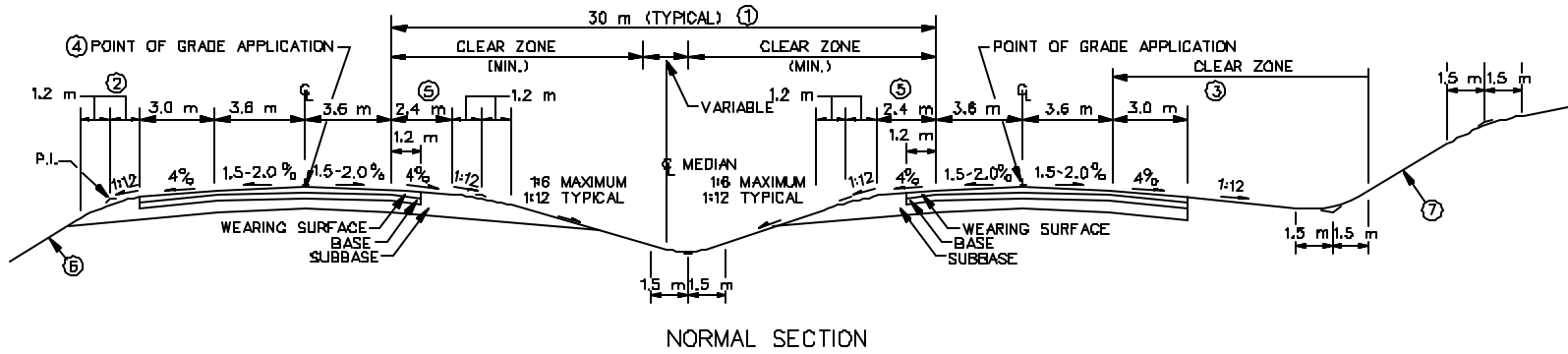
(1) Bridge Width. See Section 10-4.01 for additional information on minimum bridge widths. See Section 3-2.04 for local bridge projects.

Figure 4E (continued)

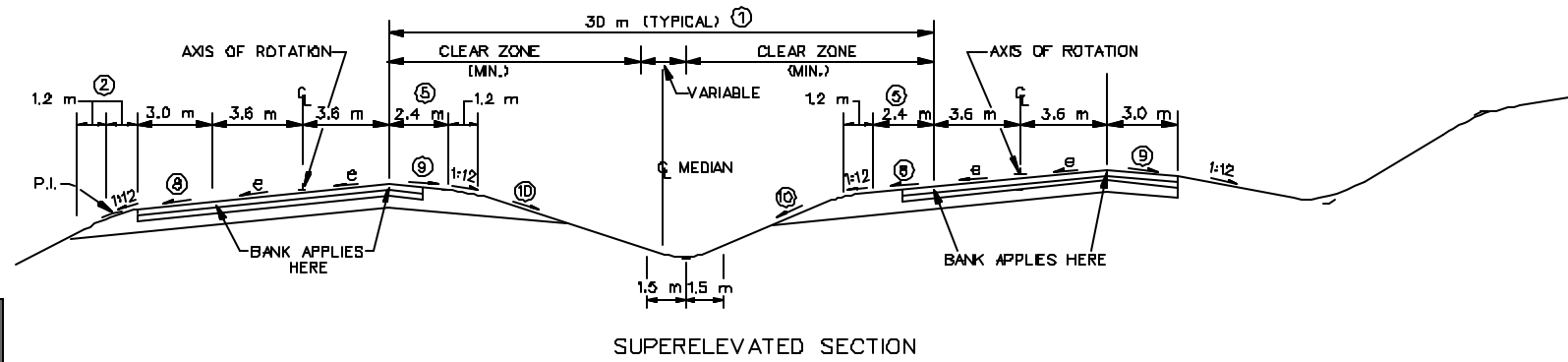
RURAL LOCAL ROADS
New Construction/Major Reconstruction

Design Element		*	Manual Section	Design Values (Based on Design Speed)						
				80 km/h	70 km/h	60 km/h	50 km/h	40 km/h	30 km/h	
Alignment Elements	Stopping Sight Distance	x	7-1.0	115 m - 140 m	95 m - 115 m	75 m - 85 m	60 m - 65 m	45 m	30 m	
	Decision Sight Distance	Maneuver		7-2.0	230 m	200 m	175 m	145 m	N/A	N/A
		Stop			155 m	125 m	95 m	75 m		
	Minimum Radius (e = 6.0%)	x	8-2.02	255 m	195 m	135 m	90 m	55 m	30 m	
	Superelevation	e _{max}	x	8-2.02	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%
		Rate			See Figure 8-2A					
	Horizontal Sight Distance			8-2.04	See Section 8-2.04					
	Maximum Grade		x	9-2.03	8%	9%	10%	10%	11%	11%
	Minimum Grade			9-2.03	0.5%					
	Vertical Curvature (K-Value)	Crest		9-3.02	33 - 49	23 - 33	14 - 18	9 - 11	6	3
		Sag		9-3.03	26 - 33	20 - 26	15 - 18	11 - 13	8	4
	Minimum Vertical Clearance: Local Road Under ...	New Highway Bridge	x	9-4.0	4.5 m					
Existing Highway Bridge		x	4.35 m							
Minimum Vertical Clearance (Local Road over Railroad)		x	9-4.0	Electrified: 6.858 m All Others: 6.248 m						

* Controlling design criteria (see Section 6-6.0)



NORMAL SECTION



SUPERELEVATED SECTION

**TYPICAL DEPRESSED MEDIAN SECTION
(Rural Freeways)**

Figure 4F

MARCH 2000

TYPICAL DEPRESSED MEDIAN SECTION (Rural Freeways)

Notes to Figure 4F

1. **Median:** This section will apply to all medians greater than 20 m. See Figure 4I for median widths of 20 m or less, which will warrant a median barrier.
2. **Slope Rounding:** This is the recommended treatment and, when used, the slope rounding should be 2.4 m. This will apply to all conditions, except where the design speed is 110 km/h and where an unprotected 1:4 slope is provided. In this case, the recommended rounding is 3.3 m. Rounding is not necessary on fill slopes protected by guide rail. See Figure 4H for detail if guide rail is used.
3. **Clear Zone:** The outside limit of rounding for the backslope should be outside of the clear zone as determined by Section 13-2.0. If this is within the clear zone, the backslope should be safely traversable (See Figure 13-3D).
4. **Point of Grade Application:** The following criteria will apply:

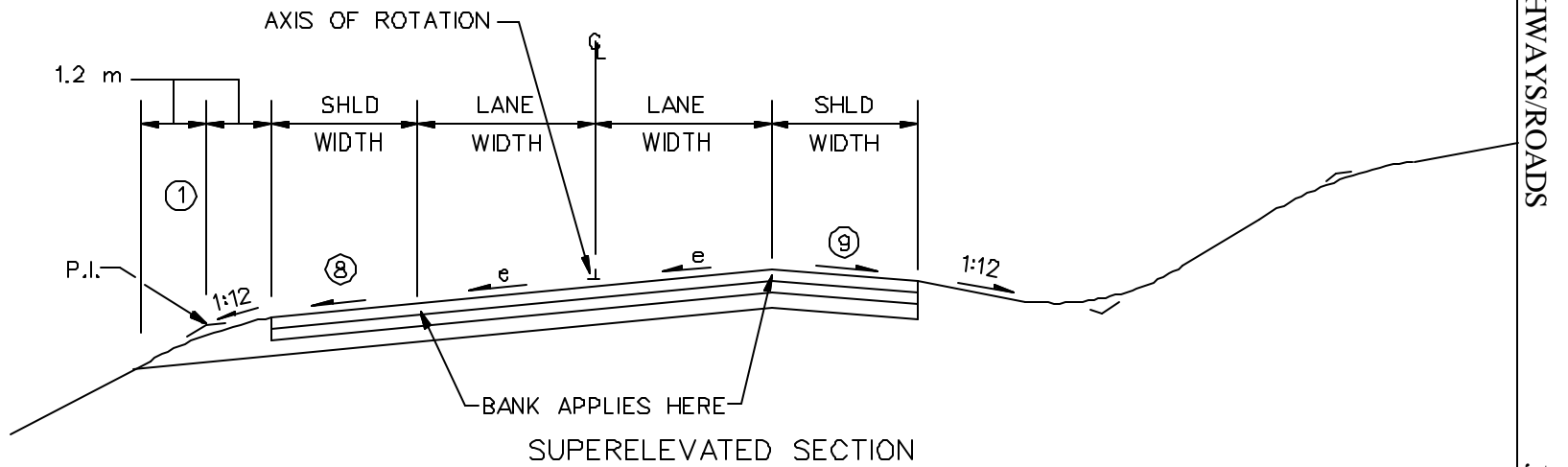
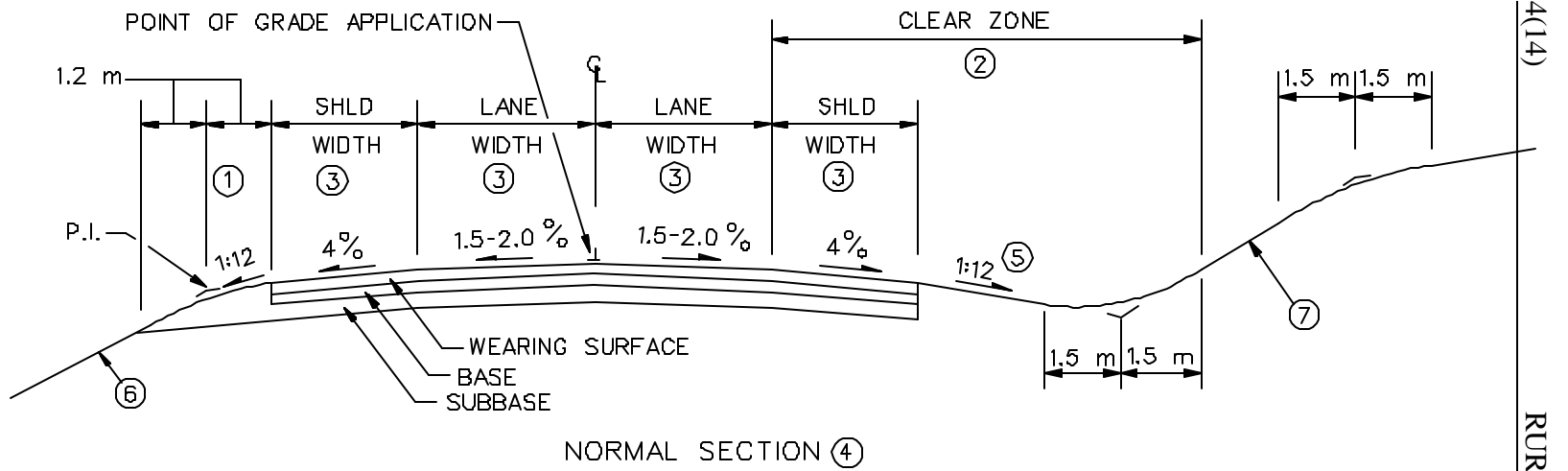
<u>Pavement Width</u>	<u>Point of Grade Application</u>
Two 3.6-m lanes	3.6 m from inside edge of traveled way
Three 3.6-m lanes	3.6 m from inside edge of traveled way
Four 3.6-m lanes	7.2 m from inside edge of traveled way

5. **Left Shoulder:** As indicated on the figure, the left shoulder is 1.8 m graded with 1.2 m paved. For three or more lanes in one direction, use a 3.0-m paved left shoulder.
6. **Fill Slope:** These should be as flat as practical. Consider the following criteria:

<u>Fill Height</u>	<u>Fill Slope</u>	<u>Guide Rail</u>
3.0 m	1:6	No
3.0 m - 7.5 m	1:4	No
>7.5 m	1:2	Yes

Also, see Figure 4H for treatment at bottom of fill slope and for guide rail placement on fill slopes.

7. **Cut Slope:** These should be as flat as practical, but should not exceed 1:2. Also see the clear zone discussion in Note #3. A uniform rate of slope should be maintained throughout a cut section. Where site conditions dictate a change from one rate of slope to another within a cut section, the length of transition will be as long as practical to effect a natural appearing contour. Figure 4J contains detailed information on earth and rock cuts.
8. **Shoulder Superelevation (Low-Side):** The slope of the shoulder should be 4% or "e", whichever is greater.
9. **Shoulder Superelevation (High-Side):** See Figure 4H for treatment of high-side shoulder. For the 2.4-m shoulder (two lanes in one direction), use 2.4 m when reading into the table in Figure 4H.
10. **Median Slope:** When the axis of rotation is at the centerline of the two roadways, a compensating median slope must be used on a superelevated section, or independent profiles must be used.



**TYPICAL TWO-LANE SECTION
(Rural Arterial/Collector/Local Road)**

TYPICAL TWO-LANE SECTION (Rural Arterial/Collector/Local Roads)

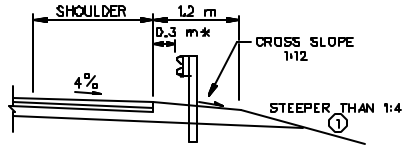
Notes to Figure 4G

1. Slope Rounding: This is the recommended treatment and, when used, the slope rounding should be 2.4 m. Rounding is not necessary on fill slopes protected by guide rail. See Figure 4H for detail if guide rail is used.
2. Clear Zone: The outside limit of rounding for the backslope should be outside of the clear zone as determined by Section 13-2.0. If this is within the clear zone, the backslope should be safely traversable (see Figure 13-3D).
3. Lane and Shoulder Width: See Figures 4C, 4D and 4E for criteria on lane and shoulder width.
4. Curb Sections: If curbing is required for drainage, see Figure 5I for typical section.
5. Sidewalks: See Figure 4H for typical treatment of sidewalks, if warranted.
6. Fill Slope: These should be as flat as practical. Consider the following criteria:

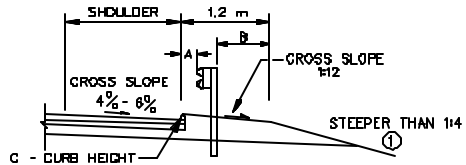
<u>Fill Height</u>	<u>Fill Slope</u>	<u>Guide Rail</u>
0.0 m - 3.0 m	1:6	No
3.0 m - 7.5 m	1:4	No
>7.5 m	1:2	Yes

Also, see Figure 4H for treatment at bottom of fill slope. If a curb is used, see Figure 4H for treatment of guide rail and curb used in combination.

7. Cut Slope: These should be as flat as practical, but should not exceed 1:2. Also, see the clear zone discussion in Note #2. A uniform rate of slope should be maintained throughout a cut section. Where site conditions dictate a change from one rate of slope to another within a cut section, the length of transition will be as long as practical to effect a natural appearing contour. Figure 4J contains detailed information on earth and rock cuts.
8. Shoulder Superelevation (Low-Side): The slope of the shoulder should be 4% or "e", whichever is greater.
9. Shoulder Superelevation (High-Side): See Figure 4H for treatment of high-side shoulder.



*TYPICAL OR FLUSH WITH EDGE OF PAVEMENT
RAILING PLACEMENT WITHOUT CURB

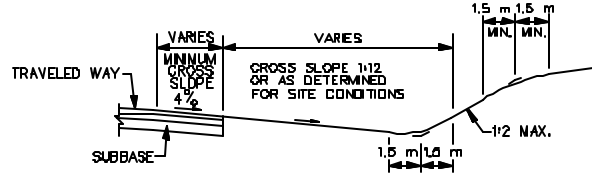


RAILING PLACEMENT WITH CURB

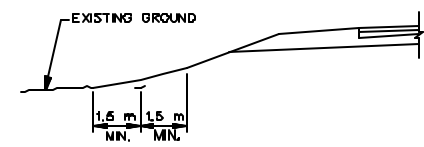
TYPE OF GUIDE RAIL	A	B	C
METAL BEAM RAIL (TYPE R-B 350)		MINIMUM	(MAXIMUM)
LOW SPEED (V < 80 km/h)	230 mm	810 mm	130 mm
HIGH SPEED (V ≥ 80 km/h)	0 mm	810 mm	100 mm
THREE-CABLE GUIDE RAILING (I-BEAM POST)	305 mm MAX.	610 mm	*

① USE METAL BEAM RAIL (TYPE R-B 350) OR THREE-CABLE GUIDE RAILING (I-BEAM POSTS) ON FILL SLOPES STEEPER THAN 1:4. WITH CURBING, SLOPES 1:4 OR STEEPER USE GUIDE RAIL. GUIDE RAIL MAY ALSO BE REQUIRED WHERE ROADSIDE HAZARDS ARE LOCATED WITHIN ROADSIDE CLEAR ZONE. SEE CHAPTER THIRTEEN.

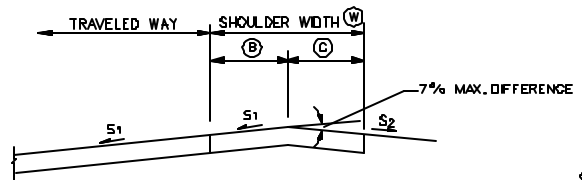
* CURBING, WHERE USED IN CONJUNCTION WITH THREE-CABLE GUIDE RAILING ON HIGH-SPEED ROADWAYS (V ≥ 80 km/h), SHALL BE 100 mm MAX. IN HEIGHT.



SIGHT LINE CUT OR WIDENED EARTH CUT



TREATMENT AT BOTTOM OF FILL SLOPES

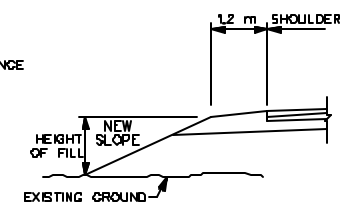


W	B	C
< 1.2 m	0 m TO 1.2 m	0 m
1.2 m TO < 2.4 m	0 m TO 1.2 m	1.2 m
≥ 2.4 m	0 m	≥ 2.4 m

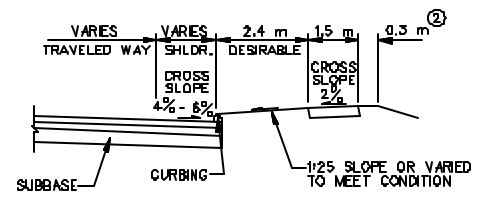
GENERAL NOTES:

1. MAY REQUIRE ATTACHABLE EXTENSIONS OR CUT-OFF PLATES ON PAVING EQUIPMENT.
2. WHERE S₂ IS FLATTER THAN 2%, THE CONTRACTOR SHALL VERIFY THE CROSS SLOPE AT EACH 10-m INTERVAL (PAYMENT TO BE INCLUDED IN THE COST OF THE BITUMINOUS CONCRETE PAY ITEM - THERE WILL BE NO DIRECT PAYMENT.)
3. S₂ SHALL BE 1% MINIMUM.
4. DO NOT PROVIDE CURBING ON 1.2-m SHOULDERS WITH SUPERELEVATION > 4%.
5. ALL OTHER TREATMENTS TO BE USED ONLY WITH PRIOR APPROVAL FROM THE HYDRAULICS AND DRAINAGE DESIGN DEVELOPMENT TEAM AND PAVEMENT MANAGEMENT UNIT.
6. INCLUDE NOTE 1 ON ALL CONTRACT DRAWINGS. INCLUDE NOTE 2 ON ALL CONTRACT DRAWINGS WHERE THE SUPERELEVATION RATES ARE STEEPER THAN 4%.

SHOULDER TREATMENT HIGH SIDE OF BANK



METHOD OF DETERMINING HEIGHT OF FILL AS RELATED TO SIDE SLOPE DESIGN

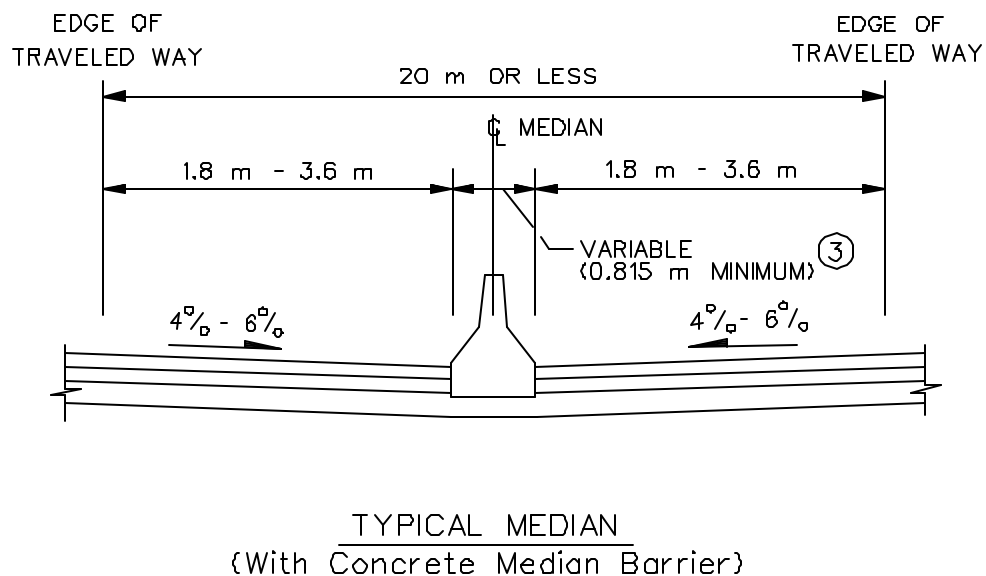
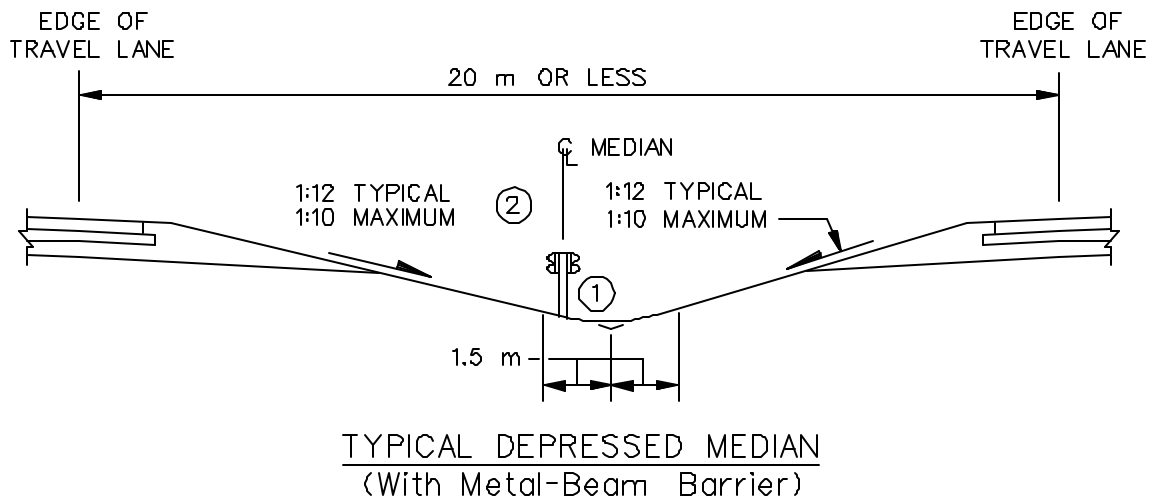


CURB AND WALK AREA

② IF GUIDE RAIL IS REQUIRED, IT WILL BE PLACED BEYOND SIDEWALK. THEREFORE, THIS DIMENSION WILL BE INCREASED AS NECESSARY TO ALLOW FOR PROPER GUIDE RAIL PLACEMENT.

MISCELLANEOUS DETAILS
VARIOUS CLASSES

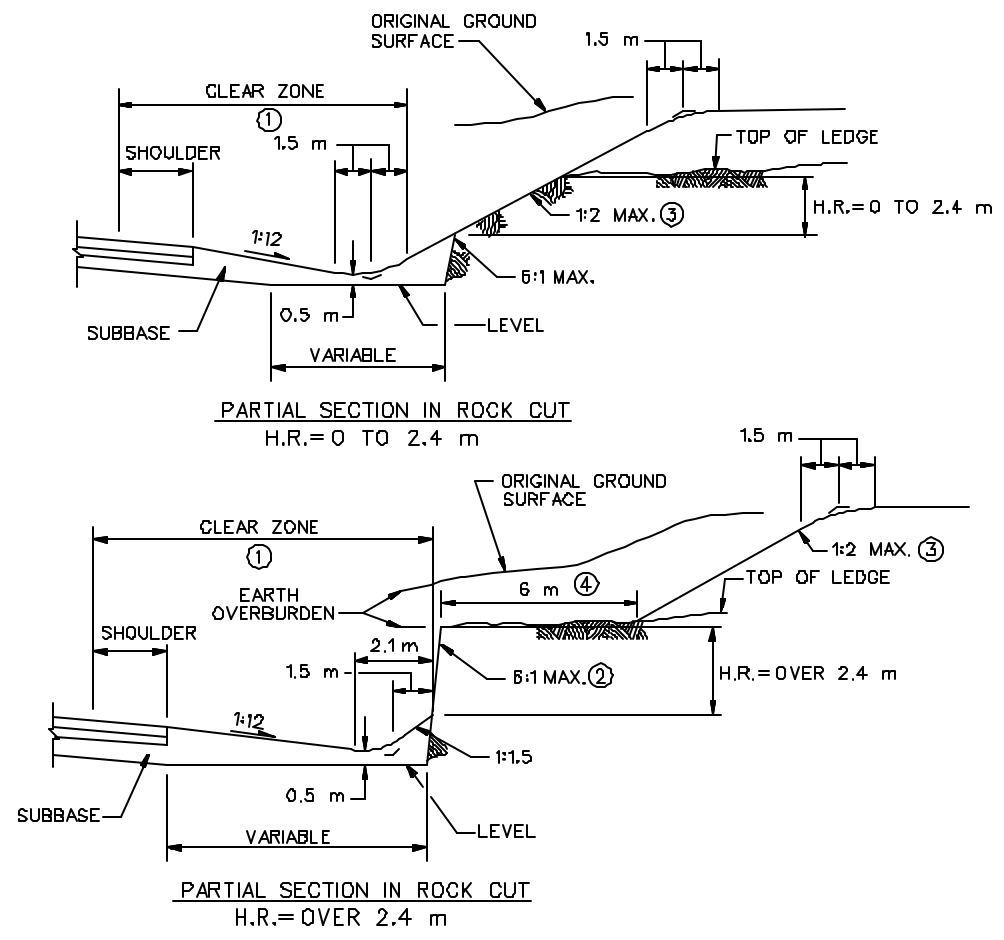
Figure 4H



1. **Placement of Median Barrier:** The preferred location of the median barrier is in the center of the median. This will require that the drainage system be offset from the center as indicated in the figure.
2. **Median Slope on Superelevated Sections:** The designer must ensure that the slope leading up to the median barrier does not exceed 1:10. This may require the use of independent profiles for the two roadways. Another option is to place the barrier near the edge of the shoulder; however, this is undesirable and should be avoided.
3. **CMB Width:** Consider providing a 2.54-m wide CMB to accommodate bridge piers for overpassing structures or other appurtenances in the median.

TYPICAL MEDIAN SECTION FOR FREEWAYS
(20 m or Less)

Figure 4I



- I To be increased as rock competence decreases or as height of rock cut increases.
- I Rock slopes should be determined by geological investigations and analysis.
- D Slopes flatter than the 1:2 maximum are preferred and should be used where site conditions allow. Generally a uniform rate of slope should be held throughout a section. Where site conditions dictate a change from one rate of slope to another within a cut section, the length of transition should be as long as possible to effect a natural appearing contour.
- N The 6-m rock shelf may be reduced to a minimum of 1.5 m when: (a) during construction, the rock elevation is found to be lower than anticipated during design, (b) it is desirable to reduce surplus excavation, and (c) it is desirable to minimize right-of-way needs.

DETAILS OF CUT SECTIONS
Figure 4J

Chapter Five

URBAN HIGHWAYS AND STREETS (New Construction/Major Reconstruction)

Table of Contents

		<u>Page</u>
Figure 5A	Urban Freeways	5(2)
Figure 5B	Multi-Lane Principal Urban Arterials	5(4)
Figure 5C	Two-Lane Principal Urban Arterials	5(6)
Figure 5D	Minor Urban Arterial	5(8)
Figure 5E	Urban Collector Streets	5(10)
Figure 5F	Local Urban Street	5(12)
Figure 5G	Typical Depressed Median Section	5(14)
	(Urban Freeways)	
Figure 5H	Typical Raised Median Section	5(16)
	(Urban Arterials)	
Figure 5I	Typical Two-Lane Section	5(18)
	(Urban Arterial/Collector/Local Streets)	
Figure 5J	Miscellaneous Details, Various Classes	5(20)
Figure 5K	Typical Median Section for Freeways	5(21)
	(20 m or Less)	
Figure 5L	Details of Cut Sections	5(22)
Figure 5M	Typical Section for Urban Freeways	5(23)
	(High-Volume/Incident Management Freeways)	

Chapter Five

URBAN HIGHWAYS AND STREETS (New Construction/Major Reconstruction)

This chapter presents the Department's criteria for the design of urban highways and streets. They apply to new construction and major reconstruction projects. The designer should consider the following in the use of the tables:

1. Functional/Design Classification. The selection of design values for new construction and major reconstruction depends on the functional and, for non-freeways, the design classification of the highway facility. This is discussed in Section 6-1.0.
2. Capacity Analyses. Section 6-3.0 discusses highway capacity. Several highway design elements (e.g., the number of travel lanes) will be determined in part by the capacity analysis. As discussed in Section 6-3.0, the capacity analysis will be based on:
 - a. the design hourly volume (DHV), usually 20 years from the construction completion date;
 - b. the level of service, as determined from the tables in this chapter; and
 - c. the capacity analysis, using the techniques in the HCM.
3. Cross Section Elements. The designer should realize that some of the cross section elements included in a table (e.g., median width) are not automatically warranted in the project design. The values in the tables will only apply after the decision has been made to include the element in the highway cross section.
4. Manual Section References. These tables are intended to provide a concise listing of design values for easy use. However, the designer should review the *Manual* section references for greater insight into the design elements.

Figure 5A
URBAN FREEWAYS
New Construction/Major Reconstruction

Design Element		*	Manual Section	Design Values (By Type of Area)		
				Suburban/Intermediate	Built-up	
Design Controls	Design Forecast Year		6-3.02	20 Years	20 Years	
	Design Speed	x	6-2.02	100 - 110 km/h	80-90 km/h	
	Control of Access		6-4.0	Full Control	Full Control	
	Level of Service		6-3.0	B - C	B - C	
Cross Section Elements	Lane Width	x	10-1.01	3.6 m	3.6 m	
	Shoulder Width (1)	Right	x	10-1.02	3.0 m	3.0 m
		Left — 4 Lanes	x		2.4 m (1.2 m Paved +1.2 m Graded)	2.4 m (1.2 m Paved +1.2 m Graded)
		Left — 6+ Lanes	x		3.0 m	3.0 m
	Typical Cross Slope	Travel Lane	x	10-1.01	1.5-2.0% for lanes adjacent to crown; 2.0% for lanes away from crown	
		Shoulder	x	10-1.02	4%; with CMB, 4% - 6% for left shoulder	4%; with CMB, 4% - 6% for left shoulder
	Median Width (includes left shoulders)			10-3.0	See Figure 5K - 27 m	See Figure 5K - 27 m
	Bridge Width/Cross Slope		x	10-4.01	Meet Approach Roadway Width and Cross Slope	
	Underpass Width			10-4.02	Meet Approach Roadway Width Plus Clear Zones	
	Right-of-Way Width			10-5.0	Max: 30 m Beyond Edge of Traveled Way	
Roadside Clear Zones		x	13-2.0	See Section 13-2.0		
Fill/Cut Slopes			10-2.02	See Figure 5G		

*Controlling design criteria (see Section 6-6.0)

Footnote:

- (1) Shoulder Width. Where the truck volumes exceed 250 DDHV, both the right and left shoulders should be 3.6 m. Where warranted for high-volume/incident management sites, use a 4.8-m left shoulder.

Figure 5A (continued)

URBAN FREEWAYS
New Construction/Major Reconstruction

Design Element		*	Manual Section	Design Values (Based on Design Speed)			
				110 km/h	100 km/h	90 km/h	80 km/h
Stopping Sight Distance		x	7-1.0	180 m - 250 m	160 m - 205 m	135 m - 170 m	115 m - 140 m
Decision Sight Distance	Maneuver		7-2.0	U: 435 m SU: 390 m	U: 405 m SU: 365 m	U: 360 m SU: 320 m	U: 315 m SU: 275 m
	Stop			455 m	415 m	360 m	300 m
Minimum Radius (e = 6.0%)		x	8-2.02	565 m	440 m	340 m	255 m
Superelevation	e _{max}		8-2.02	6.0%	6.0%	6.0%	6.0%
	Rate	x		See Figure 8-2A			
Horizontal Sight Distance			8-2.04	See Section 8-2.04			
Maximum Grade		x	9-2.03	4%	4%	5%	5%
Minimum Grade			9-2.03	0.5%			
Vertical Curvature (K-Value)	Crest		9-3.02	81 - 155	64 - 105	46 - 72	33 - 49
	Sag		9-3.03	44 - 63	38 - 51	31 - 41	26 - 33
Minimum Vertical Clearance: Freeway Under ...	New Highway Bridge	x	9-4.0	5.05 m			
	Existing Highway Bridge	x		4.9 m			
	Pedestrian Bridge/Overhead Sign	x		5.35 m			
Minimum Vertical Clearance (Freeway over Railroad)		x	9-4.0	Electrified: 6.858 m All Others: 6.248 m			

* Controlling design criteria (see Section 6-6.0)

U: Urban SU: Suburban

Figure 5B
MULTI-LANE PRINCIPAL URBAN ARTERIALS
New Construction/Major Reconstruction

Design Element		*	Manual Section	Design Values (By Type of Area)			
				Suburban	Intermediate	Built-up	
Design Controls	Design Forecast Year		6-3.02	20 Years	20 Years	20 Years	
	Design Speed	x	6-2.02	70 km/h - 100 km/h	60 km/h - 80 km/h	50 km/h - 70 km/h	
	Access Control		6-4.0	Partial/Control By Regulation	Control By Regulation	Control By Regulation	
	Level of Service		6-3.0	B - D	B - D	B - D	
	On-Street Parking		10-1.04	None	None	Sometimes	
Cross Section Elements	Travel Lane Width	x	10-1.01	3.6 m	3.6 m	3.3 m - 3.6 m	
	Shoulder Width	Right	x	10-1.02	1.2 m - 2.4 m	1.2 m - 2.4 m	1.2 m - 2.4 m
		Left	x		0.6 m - 1.2 m	0.6 m - 1.2 m	0.6 m - 1.2 m
	Cross Slope	Travel Lane	x	10-1.01	1.5-2.0% for lanes adjacent to crown; 2.0% for lanes away from crown		
		Shoulder (W<1.2 m)	x	10-1.02	Same as Adjacent Travel Lane		
		Shoulder (W≥1.2 m)	x		4% - 6%	4% - 6%	4% - 6%
	Turn Lanes	Lane Width	x	10-1.03	3.3 m - 3.6 m	3.3 m - 3.6 m	3.3 m - 3.6 m
		Shoulder Width	x		0.6 m - 1.2 m	0.6 m - 1.2 m	0.6 m - 1.2 m
	Parking Lane Width			10-1.04	N/A	N/A	3.0 m - 3.3 m
	Median Width (Includes Left Shoulders)	Depressed		10-3.0	15 m - 27 m	N/A	N/A
		Raised Island (V#80 km/h)			2.4 m - 6.0 m	2.4 m - 6.0 m	2.4 m - 6.0 m
	Sidewalk Width			10-2.01	1.5 m Minimum	1.5 m Minimum	1.5 m Minimum
	Bicycle Lane	Width		15-4.0	1.5 m	1.5 m	1.5 m
		Cross Slope			2%	2%	2%
	Bridge Width/Cross Slope		x	10-4.01	Curb-to-Curb: Meet Approach Roadway Width & Cross Slope		Sidewalk Width: 1.7 m
Underpass Width			10-4.02	Meet Approach Roadway Width Plus Clear Zones			
Right-of-Way Width			10-5.0	Project-by-Project Basis			
Roadside Clear Zones		x	13-2.0	See Section 13-2.0			
Fill/Cut Slopes			10-2.02	See Figure 5H			

* Controlling design criteria (see Section 6-6.0).

Figure 5B (Continued)

**MULTI-LANE PRINCIPAL URBAN ARTERIALS
New Construction/Major Reconstruction**

Design Element		*	Manual Section	Design Values (Based on Design Speed)						
				100 km/h	90 km/h	80 km/h	70 km/h	60 km/h	50 km/h	
Alignment Elements	Stopping Sight Distance		x	7-1.0	160 m - 205 m	135 m - 170 m	115 m - 140 m	95 m - 115 m	75 m - 85 m	60 m - 65 m
	Decision Sight Distance	Maneuver		7-2.0	U: 405 m SU: 365 m	U: 360 m SU: 320 m	U: 315 m SU: 275 m	U: 275 m SU: 240 m	U: 235 m SU: 205 m	U: 200 m SU: 160 m
		Stop			415 m	360 m	300 m	250 m	205 m	160 m
	Minimum Radius		x	8-2.02/ 8-3.02	440 m (e=6%)	340 m (e=6%)	255 m (e=6%)	190 m (e=4%)	130 m (e=4%)	80 m (e=4%)
	Superelevation Rate	e _{max}		8-2.02/ 8-3.02	6.0%	6.0%	6.0%	4.0%	4.0%	4.0%
		Rate	x		See Figure 8-2A			See Figure 8-3C		
	Horizontal Sight Distance			8-2.04	See Section 8-2.04					
	Maximum Grade		x	9-2.03	6%	6%	7%	7%	8%	9%
	Minimum Grade			9-2.03	0.5%					
	Vertical Curvature (K-values)	Crest		9-3.02	64 - 105	46 - 72	33 - 49	23 - 33	14 - 18	9 - 11
		Sag		9-3.03	38 - 51	31 - 41	26 - 33	20 - 26	15 - 18	11 - 13
	Minimum Vertical Clearance: Arterial Under...	New Highway Bridge	x	9-4.0	5.05 m					
Existing Highway Bridge		x	4.35 m							
Pedestrian Bridge/ Overhead Sign		x	5.35 m							
Minimum Vertical Clearance (Arterial over Railroad)		x	9-4.0	Electrified: 6.858 m All Others: 6.248 m						

U: Urban SU: Suburban

* Controlling design criteria (see Section 6-6.0).

Figure 5C
TWO-LANE PRINCIPAL URBAN ARTERIALS
New Construction/Major Reconstruction

Design Element		*	Manual Section	Design Values (By Type of Area)			
				Suburban	Intermediate	Built-up	
Design Controls	Design Forecast Year		6-3.02	20 Years	20 Years	20 Years	
	Design Speed	x	6-2.02	70 km/h - 90 km/h	60 km/h - 80 km/h	50 km/h - 70 km/h	
	Access Control		6-4.02	Partial/Control By Regulation	Control By Regulation	Control By Regulation	
	Level of Service		6-3.0	B - D	B - D	B - D	
	On-Street Parking		10-1.04	None	None	Sometimes	
Cross Section Elements	Travel Lane Width	x	10-1.01	3.6 m	3.3 m - 3.6 m	3.3 m - 3.6 m	
	Shoulder Width	x	10-1.02	1.2 m - 2.4 m	1.2 m - 2.4 m	1.2 m - 2.4 m	
	Cross Slope	Travel Lane	x	10-1.01	1.5-2.0%	1.5-2.0%	1.5-2.0%
		Shoulder	x		4% - 6%	4% - 6%	4% - 6%
	Turn Lanes	Lane Width	x	10-1.03	3.3 m - 3.6 m	3.3 m - 3.6 m	3.3 m - 3.6 m
		Shoulder Width	x		0.6 m - 1.2 m	0.6 m - 1.2 m	0.6 m - 1.2 m
	Parking Lane Width		10-1.04	N/A	N/A	3.0 m - 3.3 m	
	Sidewalk Width		10-2.01	1.5 m Minimum	1.5 m Minimum	1.5 m Minimum	
	Bicycle Lane	Width		15-4.0	1.5 m	1.5 m	1.5 m
		Cross Slope			2%	2%	2%
	Bridge Width/Cross Slope	x	10-4.01	Curb-to-Curb: Meet Approach Roadway Width and Cross Slope Sidewalk Width: 1.7 m			
	Underpass Width		10-4.02	Meet Approach Roadway Width Plus Clear Zones			
	Right-of-Way Width		10-5.0	Project-by-Project Basis			
	Roadside Clear Zones	x	13-2.0	See Section 13-2.0			
Fill/Cut Slopes		10-2.02	See Figure 5I				

* Controlling design criteria (see Section 6-6.0).

Figure 5C (Continued)
TWO-LANE PRINCIPAL URBAN ARTERIALS
New Construction/Major Reconstruction

Design Element		*	Manual Section	Design Values (Based on Design Speed)					
				90 km/h	80 km/h	70 km/h	60 km/h	50 km/h	
Alignment Elements	Stopping Sight Distance		x	7-1.0	135 m - 170 m	115 m - 140 m	95 m - 115 m	75 m - 85 m	60 m - 65 m
	Decision Sight Distance	Maneuver		7-2.0	U: 360 m SU: 320 m	U: 315 m SU: 275 m	U: 275 m SU: 240 m	U: 235 m SU: 205 m	U: 200 m SU: 160 m
		Stop			360 m	300 m	250 m	205 m	160 m
	Minimum Radius		x	8-2.02/ 8-3.02	340 m (e=6%)	255 m (e=6%)	190 m (e=4%)	130 m (e=4%)	80 m (e=4%)
	Superelevation Rate	e _{max}		8-2.02/ 8-3.02	6.0%	6.0%	4.0%	4.0%	4.0%
		Rate	x		See Figure 8-2A		See Figure 8-3C		
	Horizontal Sight Distance			8-2.04	See Section 8-2.04				
	Maximum Grade		x	9-2.03	6%	7%	7%	8%	9%
	Minimum Grade			9-2.03	0.5%				
	Vertical Curvature (K-values)	Crest		9-3.02	46 - 72	33 - 49	23 - 33	14 - 18	9 - 11
		Sag		9-3.03	31 - 41	26 - 33	20 - 26	15 - 18	11 - 13
	Minimum Vertical Clearance: Arterial Under...	New Highway Bridge	x	9-4.0	5.05 m				
Existing Highway Bridge		x	4.35 m						
Pedestrian Bridge/Overhead Sign		x	5.35 m						
Minimum Vertical Clearance (Arterial over Railroad)		x	9-4.0	Electrified: 6.858 m All Others: 6.248 m					

U: Urban

SU: Suburban

* Controlling design criteria (see Section 6-6.0).

Figure 5D
MINOR URBAN ARTERIALS
New Construction/Major Reconstruction

Design Element		*	Manual Section	Design Values (By Type of Area)			
				Suburban	Intermediate	Built-up	
Design Controls	Design Forecast Year		6-3.02	20 Years	20 Years	20 Years	
	Design Speed	x	6-2.02	70 km/h - 80 km/h	50 km/h - 70 km/h	50 km/h - 60 km/h	
	Access Control		6-4.0	Control By Regulation	Control By Regulation	Control By Regulation	
	Level of Service		6-3.0	B - D	B - D	B - D	
	On-Street Parking		10-1.04	None	Sometimes	Sometimes	
Cross Section Elements	Travel Lane Width	x	10-1.01	3.3 m - 3.6 m	3.3 m - 3.6 m	3.0 m - 3.6 m	
	Shoulder Width	Right	x	10-1.02	1.2 m - 2.4 m	1.2 m - 2.4 m	1.2 m - 2.4 m
		Left			0.6 m - 1.2 m	0.6 m - 1.2 m	0.6 m - 1.2 m
	Cross Slope	Travel Lane	x	10-1.01	1.5-2.0% for lanes adjacent to crown; 2% for lanes away from crown		
		Shoulder (W<1.2 m)	x	10-1.02	Same as Adjacent Travel Lane		
		Shoulder (W≥1.2 m)	x		4% - 6%	4% - 6%	4% - 6%
	Turn Lanes	Lane Width	x	10-1.03	3.3 m	3.3 m	3.3 m
		Shoulder Width	x		0.6 m - 1.2 m	0.6 m - 1.2 m	0.6 m - 1.2 m
	Parking Lane Width			10-1.04	N/A	3.0 m - 3.3 m	3.0 m - 3.3 m
	Sidewalk Width			10-2.01	1.5 m Minimum	1.5 m Minimum	1.5 m Minimum
	Bicycle Lane	Width		15-4.0	1.5 m	1.5 m	1.5 m
		Cross Slope			2%	2%	2%
	Bridge Width/Cross Slope	x		10-4.01	Curb-to-Curb: Meet Approach Roadway Width and Cross Slope		Sidewalk Width: 1.7 m
	Underpass Width			10-4.02	Meet Approach Roadway Width Plus Clear Zones		
	Right-of-Way Width			10-5.0	Project-by-Project Basis		
Roadside Clear Zones	x		13-2.0	See Section 13-2.0			
Fill/Cut Slopes			10-2.02	See Figure 5I			

* Controlling design criteria (see Section 6-6.0).

Figure 5D (Continued)

**MINOR URBAN ARTERIALS
New Construction/Major Reconstruction**

Design Element		*	Manual Section	Design Values (Based on Design Speed)				
				80 km/h	70 km/h	60 km/h	50 km/h	
Alignment Elements	Stopping Sight Distance		x	7-1.0	115 m - 140 m	95 m - 115 m	75 m - 85 m	60 m - 65 m
	Decision Sight Distance	Maneuver		7-2.0	U: 315 m SU: 275 m	U: 275 m SU: 240 m	U: 235 m SU: 205 m	U: 200 m SU: 160 m
		Stop			300 m	250 m	205 m	160 m
	Minimum Radius		x	8-2.02/ 8-3.02	255 m (e = 6%)	190 m (e = 4%)	130 m (e = 4%)	80 m (e = 4%)
	Superelevation	e _{max}		8-2.02/ 8-3.02	6.0%	4.0%	4.0%	4.0%
		Rate	x		See Fig. 8-2A	See Figure 8-3C		
	Horizontal Sight Distance			8-2.04	See Section 8-2.04			
	Maximum Grade		x	9-2.03	7%	7%	8%	9%
	Minimum Grade			9-2.03	0.5%			
	Vertical Curvature (K-Value)	Crest		9-3.02	33 - 49	23 - 33	14 - 18	9 - 11
		Sag		9-3.03	26 - 33	20 - 26	15 - 18	11 - 13
	Minimum Vertical Clearance: Arterial Under ...	New Highway Bridge	x	9-4.0	5.05 m			
Existing Highway Bridge		x	4.35 m					
Minimum Vertical Clearance (Arterial over Railroad)		x	9-4.0	Electrified: 6.858 m All Others: 6.248 m				

* Controlling design criteria (see Section 6-6.0)

U: Urban

SU: Suburban

Figure 5E
URBAN COLLECTOR STREETS
New Construction/Major Reconstruction

Design Element		*	Manual Section	Design Values (By Type of Area)			
				Suburban	Intermediate	Built-up	
Design Controls	Design Forecast Year		6-3.02	20 Years	20 Years	20 Years	
	Design Speed	x	6-2.02	60 km/h - 70 km/h	50 km/h - 70 km/h	50 km/h - 60 km/h	
	Access Control		6-4.0	Control By Regulation	Control By Regulation	Control By Regulation	
	Level of Service		6-3.0	C - D	C - D	C - D	
	On-Street Parking		10-1.04	Sometimes	Sometimes	Sometimes	
Cross Section Elements	Travel Lane Width	x	10-1.01	3.3 m - 3.6 m	3.3 m -3.6 m	3.0 m - 3.6 m	
	Shoulder Width	x	10-1.02	1.2 m - 2.4 m	1.2 m - 2.4 m	0.6 m - 2.4 m	
	Cross Slope	Travel Lane	x	10-1.01	1.5-2.0% (1.5-3.0% w/curbing)	1.5-2.0% (1.5-3.0% w/curbing)	1.5-2.0% (1.5-3.0% w/curbing)
		Shoulder (W<1.2m)			Same as Adjacent Travel Lane		
		Shoulder (W≥1.2m)	x		4% - 6%	4% - 6%	4% - 6%
	Turn Lanes	Lane Width	x	10-1.03	3.3 m	3.3 m	3.3 m
		Shoulder Width	x		0.6 m - 1.2 m	0.6 m - 1.2 m	0.6 m - 1.2 m
	Parking Lane Width			10-1.04	2.4 m - 3.0 m	2.4 m - 3.0 m	2.4 m - 3.0 m
	Sidewalk Width			10-2.01	1.5 m Minimum	1.5 m Minimum	1.5 m Minimum
	Bicycle Lane	Width		15-4.0	1.5 m	1.5 m	1.5 m
		Cross Slope			2%	2%	2%
	Bridge Width/Cross Slope		x	10-4.01	Curb-to-Curb: Meet Approach Roadway Width and Cross Slope		Sidewalk Width: 1.7 m
	Underpass Width			10-4.02	Meet Approach Roadway Width Plus Clear Zones		
	Right-of-Way Width			10-5.0	Project-by-Project Basis		
	Roadside Clear Zones		x	13-2.0	See Section 13-2.0		
Fill/Cut Slopes			10-2.02	See Figure 5I			

* Controlling design criteria (see Section 6-6.0).

Figure 5E (Continued)

URBAN COLLECTOR STREETS
New Construction/Major Reconstruction

Design Element		*	Manual Section	Design Values (Based on Design Speed)		
				70 km/h	60 km/h	50 km/h
Stopping Sight Distance		x	7-1.0	94 m - 115 m	75 m - 85 m	60 m - 65 m
Decision Sight Distance	Maneuver		7-2.0	U: 275 m SU: 240 m		U: 235 m SU: 205 m
	Stop			250 m	205 m	160 m
Minimum Radius (e = 4%)		x	8-3.02	190 m	130 m	80 m
Superelevation	e _{max}		8-3.02	4.0%	4.0%	4.0%
	Rate	x		See Figure 8-3C		
Horizontal Sight Distance			8-2.04	See Section 8-2.04		
Maximum Grade		x	9-2.03	9%	10%	11%
Minimum Grade			9-2.03	0.5%		
Vertical Curvature (K-Value)	Crest		9-3.02	23 - 33	14 - 18	9 - 11
	Sag		9-3.03	20 - 26	15 - 18	11 - 13
Minimum Vertical Clearance: Collector Under ...	New Highway Bridge	x	9-4.0	4.5 m		
	Existing Highway Bridge	x		4.35 m		
Minimum Vertical Clearance (Collector over Railroad)		x	9-4.0	Electrified: 6.858 m All Others: 6.248 m		

* Controlling design criteria (see Section 6-6.0)

U: Urban SU: Suburban

Figure 5F
LOCAL URBAN STREETS
New Construction/Major Reconstruction

Design Element		*	Manual Section	Design Values (By Type of Area)			
				Suburban	Intermediate	Built-up	
Design Controls	Design Forecast Year		6-3.02	20 Years	20 Years	20 Years	
	Design Speed	x	6-2.02	40 km/h - 50 km/h	40 km/h - 50 km/h	30 km/h - 40 km/h	
	Access Control		6-4.0	Control By Regulation	Control By Regulation	Control By Regulation	
	Level of Service		6-3.0	C - D	C - D	C - D	
	On-Street Parking		10-1.04	Sometimes	Sometimes	Sometimes	
Cross Section Elements	Travel Lane Width	x	10-1.01	3.0 m - 3.3 m	3.0 m - 3.3 m	3.0 m - 3.3 m	
	Shoulder Width	x	10-1.02	0.6 m - 1.2 m	0.6 m - 1.2 m	0.6 m - 1.2 m	
	Cross Slope	Travel Lane	x	10-1.01	1.5-2.0% (1.5-3.0% w/curbing)	1.5-2.0% (1.5-3.0% w/curbing)	1.5-2.0% (1.5-3.0% w/curbing)
		Shoulder (W < 1.2 m)	x	10-1.02	Same as Adjacent Travel Lane		
		Shoulder (W ≥ 1.2 m)	x		4% - 6%	4% - 6%	4% - 6%
	Turn Lanes	Lane Width	x	10-1.03	3.0 m - 3.3 m	3.0 m - 3.3 m	3.0 m - 3.3 m
		Shoulder Width	x		0.6 m - 1.2 m	0.6 m - 1.2 m	0.6 m - 1.2 m
	Parking Lane Width		10-1.04	2.2 m - 3.0 m	2.2 m - 3.3 m	2.2 m - 3.3 m	
	Sidewalk Width		10-2.01	1.5 m Minimum	1.5 m Minimum	1.5 m Minimum	
	Bicycle Lane	Width		15-4.0	1.5 m	1.5 m	1.5 m
		Cross Slope			2%	2%	2%
	Bridge Width/Cross Slope (1)	x	10-4.01	Curb-to-Curb: Meet Approach Roadway Width and Cross Slope Sidewalk Width: 1.7 m			
	Underpass Width		10-4.02	Meet Approach Roadway Width Plus Clear Zones			
	Right-of-Way Width		10-5.0	Project-by-Project Basis			
	Roadside Clear Zones	x	13-2.0	See Section 13-2.0			
Fill/Cut Slopes		10-2.02	See Figure 5I				

* Controlling design criteria (see Section 6-6.0).

Figure 5F (Continued)

LOCAL URBAN STREETS
New Construction/Major Reconstruction

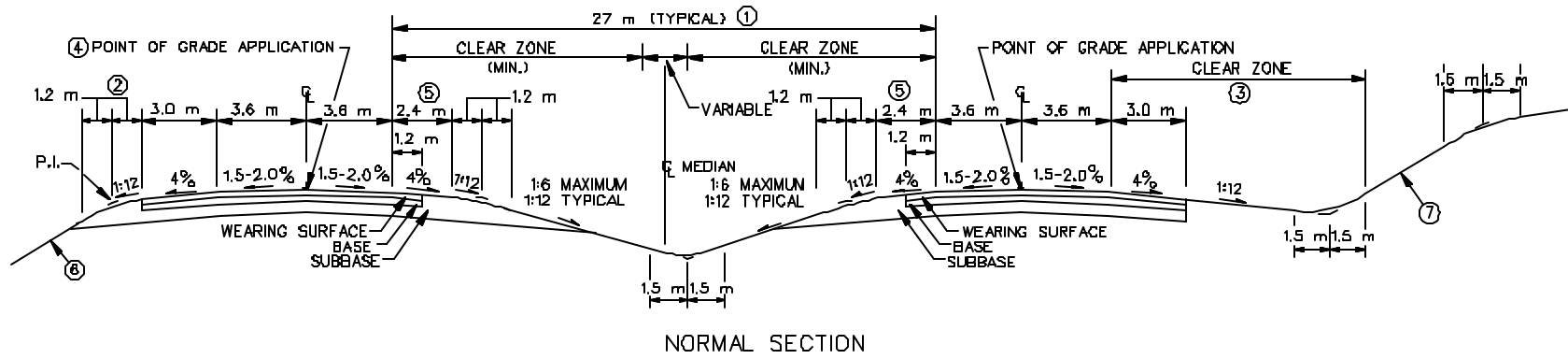
Design Element		*	Manual Section	Design Values (Based on Design Speed)			
				50 km/h	40 km/h	30 km/h	
Alignment Elements	Stopping Sight Distance		x	7-1.0	60 m - 65 m	45 m	30 m
	Decision Sight Distance	Maneuver		7-2.0	U: 200 m SU: 160 m	N/A	N/A
		Stop			160 m	N/A	N/A
	Minimum Radius (e = 4%)		x	8-3.02	80 m	45 m	20 m
	Superelevation	e _{max}		8-3.02	4.0%	4.0%	4.0%
		Rate	x		See Figure 8-3C		
	Horizontal Sight Distance			8-2.04	See Section 8-2.04		
	Maximum Grade		x	9-2.03	10%	11%	11%
	Minimum Grade			9-2.03	0.5%		
	Vertical Curvature (K-Value)	Crest		9-3.02	9 - 11	6	3
		Sag		9-3.03	11 - 13	8	4
	Minimum Vertical Clearance: Local Street Under ...	New Highway Bridge	x	9-4.0	4.5 m		
		Existing Highway Bridge	x		4.35 m		
Minimum Vertical Clearance (Local Street over Railroad)		x	9-4.0	Electrified: 6.858 m All Others: 6.248 m			

* Controlling design criteria (see Section 6-6.0)

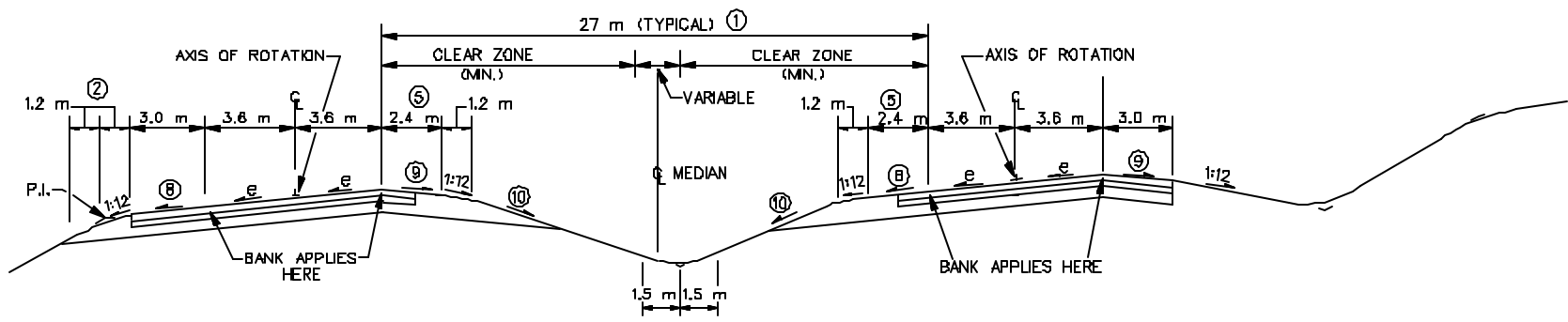
U: Urban

SU: Suburban

Footnote:
 (1) Bridge Width. See Section 3-2.04 for local bridge projects.



NORMAL SECTION



SUPERELEVATED SECTION

TYPICAL DEPRESSED MEDIAN SECTION (Urban Freeways)

Figure 5G

MARCH 2000

TYPICAL DEPRESSED MEDIAN SECTION (Urban Freeways)

Notes to Figure 5G

1. Median: This section will apply to all medians greater than 20 m. See Figure 5K for median widths of 20 m or less, which will warrant a median barrier.
2. Slope Rounding: This is the recommended treatment and, when used, the slope rounding should be 2.4 m. This will apply to all conditions, except where the design speed is 110 km/h and where an unprotected 1:4 slope is provided. In this case, the recommended rounding is 3.3 m. Rounding is not necessary on fill slopes protected by guide rail. See Figure 5J for detail if guide rail is used.
3. Clear Zone: The outside limit of rounding for the backslope should be outside of the clear zone as determined by Section 13-2.0. If this is within the clear zone, the backslope should be safely traversable (See Figure 13-3D).
4. Point of Grade Application: The following criteria will apply:

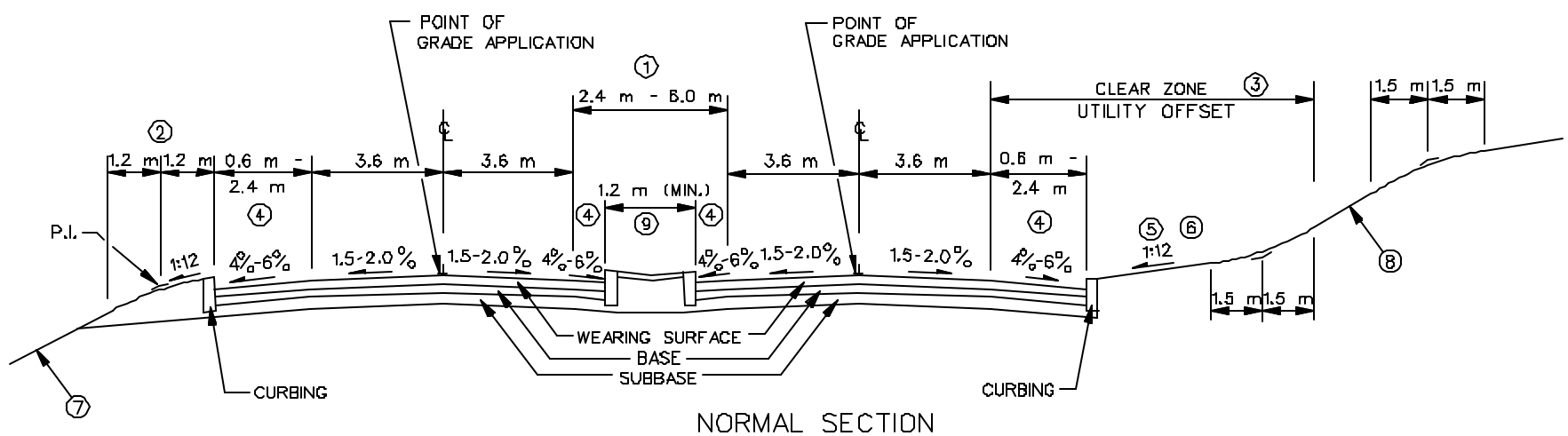
<u>Pavement Width</u>	<u>Point of Grade Application</u>
Two 3.6-m lanes	3.6 m from inside edge of traveled way
Three 3.6-m lanes	3.6 m from inside edge of traveled way
Four 3.6-m lanes	7.2 m from inside edge of traveled way

5. Left Shoulder: As indicated on the figure, the left shoulder is 1.8 m graded with 1.2 m paved. For three or more lanes in one direction, use a 3.0-m paved left shoulder.
6. Fill Slope: These should be as flat as practical. Consider the following criteria:

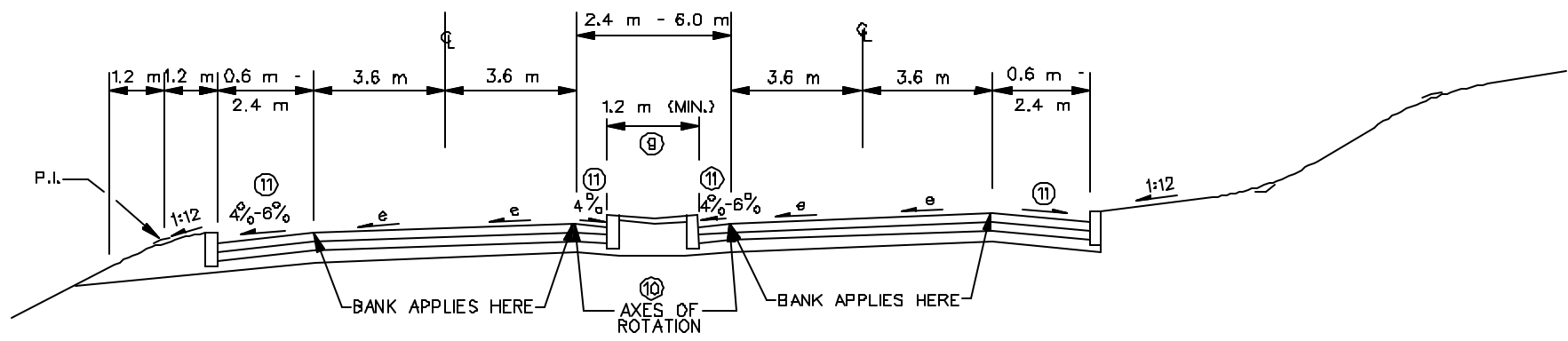
<u>Fill Height</u>	<u>Fill Slope</u>	<u>Guide Rail</u>
0.0 m - 3.0 m	1:6	No
3.0 m - 7.5 m	1:4	No
>7.5 m	1:2	Yes

Also, see Figure 5J for treatment at bottom of fill slope and for guide rail placement on fill slopes.

7. Cut Slope: These should be as flat as practical, but should not exceed 1:2. Also see the clear zone discussion in Note #3. A uniform rate of slope should be maintained throughout a cut section. Where site conditions dictate a change from one rate of slope to another within a cut section, the length of transition will be as long as practical to effect a natural appearing contour. Figure 5L contains detailed information on earth and rock cuts.
8. Shoulder Superelevation (Low-Side): The slope of the shoulder should be 4% or "e", whichever is greater.
9. Shoulder Superelevation (High-Side): See Figure 5J for treatment of high-side shoulder. For the 2.4-m shoulder (two lanes in one direction), use 2.4 m when reading into the table in Figure 5J.
10. Median Slope: When the axis of rotation is at the centerline of the two roadways, a compensating median slope must be used on a superelevated section, or independent profiles must be used.



NORMAL SECTION



SUPERELEVATED SECTION

TYPICAL RAISED MEDIAN SECTION (Urban Arterials)

Figure 5H

MARCH 2000

TYPICAL RAISED MEDIAN SECTION (Urban Arterials)

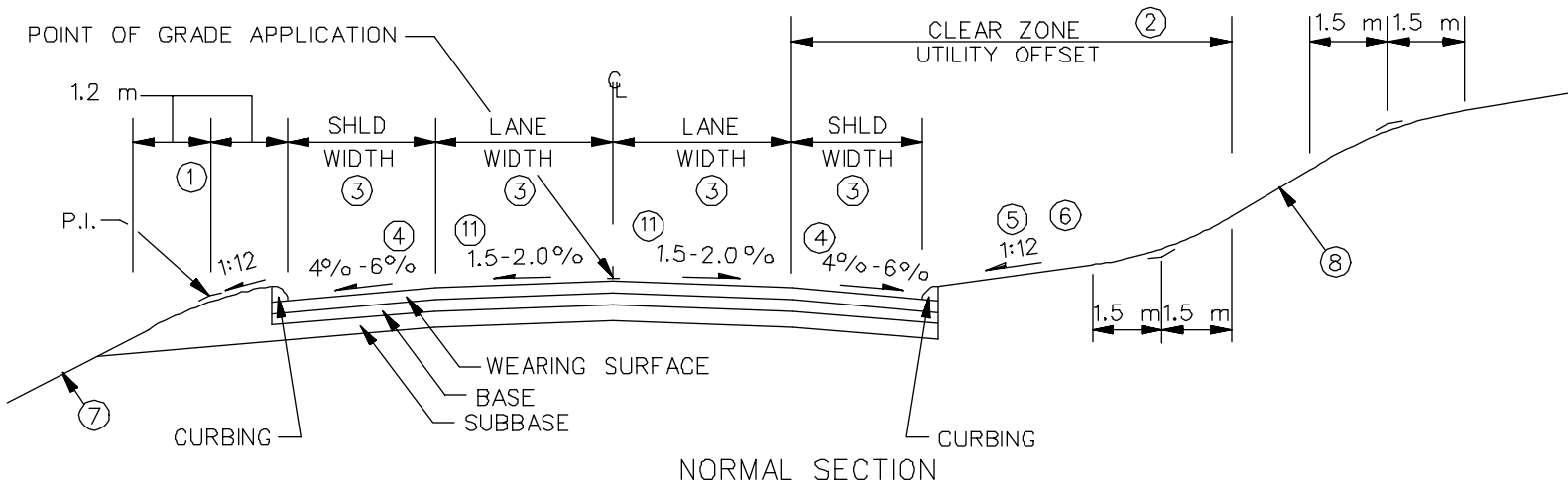
Notes to Figure 5H

1. Median: In addition to a raised median, a flush median may also be used (see Section 10-3.0).
2. Slope Rounding: This is the recommended treatment and, when used, the slope rounding should be 2.4 m. Rounding is not necessary on fill slopes protected by guide rail. See Figure 5J for detail if guide rail is used.
3. Clear Zone: A minimum horizontal, obstruction-free clearance of 500 mm should be provided as measured from the gutter line of the curb. This applies to both barrier and mountable curbs. If practical, the designer should provide obstruction-free clearances beyond the curb greater than 500 mm. See Section 13-2.04 for Department policy on utility offsets.
4. Shoulders: See Figure 5B for criteria on right and left shoulder widths. If on-street parking is provided, see criteria in Figure 5B for parking lane width. Also note that the 4%-6% shoulder cross slope will only apply if the shoulder width is 1.2 m or greater. If less than 1.2 m, the shoulder cross slope will be the same as the travel lane cross slope.
5. Sidewalks: See Figure 5J for typical treatment of sidewalks.
6. Cross Slope: Positive cross slope upward from curb is preferred; however, negative cross slope may be used if site conditions warrant.
7. Fill Slope: These should be as flat as practical. Consider the following criteria:

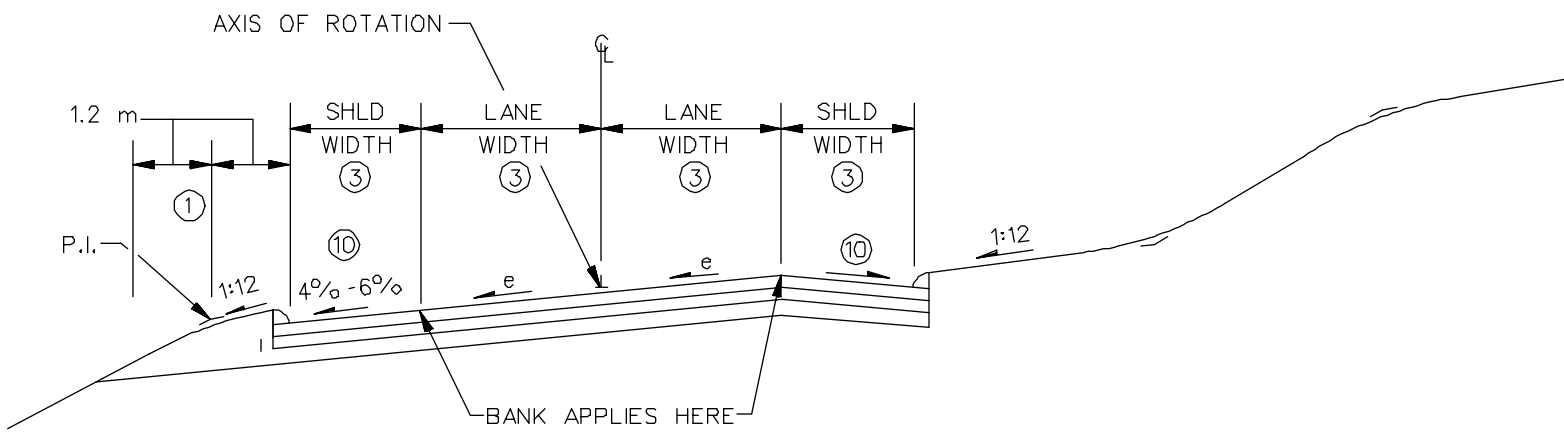
<u>Fill Height</u>	<u>Fill Slope</u>	<u>Guide Rail</u>
3.0 m	1:6	No
3.0 m - 7.5 m	1:4	No
> 7.5 m	1:2	Yes

Also, see Figure 5J for treatment at bottom of fill slope and for guide rail placement on fill slopes.

8. Cut Slope: These should be as flat as practical, but should not exceed 1:2. A uniform rate of slope should be maintained throughout a cut section. Where site conditions dictate a change from one rate of slope to another within a cut section, the length of transition will be as long as practical to effect a natural appearing contour. Figure 5L contains detailed information on earth and rock cuts.
9. Median Width: The raised portion of the median should be wide enough to accommodate the width of any anticipated signs plus 0.3 m on each side of the sign.
10. Superelevated Section: Superelevation in built-up urban areas should be avoided if practical, provided that the maximum side friction factors are not exceeded. See Section 8-3.0. For the example shown on Figure 5H, axes of rotation are at the two median edges. This allows the raised median to remain in a horizontal plane. The axes of rotation may also be at the two roadway centerlines with a compensating slope in the raised median.
11. Shoulder Superelevation: See Figure 5J for treatment of high-side superelevated shoulder. Note that, if the shoulder width is less than 1.2 m, the shoulder will be superelevated at the same rate and in the same direction as the travel lane. This applies to both the high side and the low side.



NORMAL SECTION



SUPERELEVATED SECTION ⑨

**TYPICAL TWO-LANE SECTION
(Urban Arterial/Collector/Local Street)**

Figure 5I

MARCH 2000

TYPICAL TWO-LANE SECTION (Urban Arterial/Collector/Local Street)

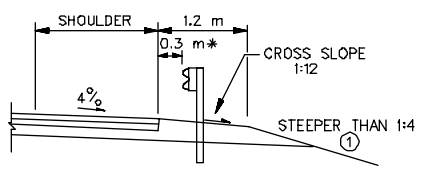
Notes to Figure 5I

1. **Slope Rounding:** This is the recommended treatment and, when used, the slope rounding should be 2.4 m. Rounding is not necessary on fill slopes protected by guide rail. See Figure 5J for detail if guide rail is used.
2. **Clear Zone:** A minimum horizontal, obstruction-free clearance of 500 mm should be provided as measured from the gutter line of the curb. This applies to both barrier and mountable curbs. If practical, the designer should provide obstruction-free clearances beyond the curb greater than 500 mm. See Section 13-2.04 for Department policy on utility offsets.
3. **Lane and Shoulder Width:** See Figures 5C through 5F for criteria on lane and shoulder widths. If on-street parking is provided, see criteria in Figures 5C through 5F for parking lane widths.
4. **Shoulder Cross Slopes:** Note that the 4%-6% shoulder cross slope will only apply if the shoulder is 1.2 m or greater. If less than 1.2 m, the shoulder cross slope will be the same as the travel lane cross slope.
5. **Sidewalks:** See Figure 5J for typical treatment of sidewalks.
6. **Cut Section Cross Slope:** Positive cross slope upward from curb is preferred; however, a negative cross slope may be used if site conditions warrant.
7. **Fill Slope:** These should be as flat as practical. Consider the following criteria:

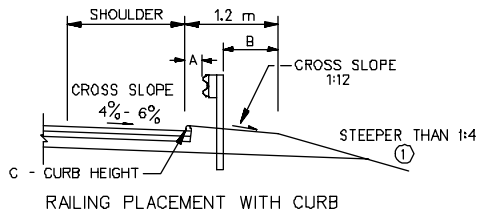
<u>Fill Height</u>	<u>Fill Slope</u>	<u>Guide Rail</u>
0.0 m - 3.0 m	1:6	No
3.0 m - 7.5 m	1:4	No
>7.5 m	1:2	Yes

Also, see Figure 5J for treatment at bottom of fill slope. If a curb is used, see Figure 5J for treatment of guide rail and curb used in combination.

8. **Cut Slope:** These should be as flat as practical, but should not exceed 1:2. A uniform rate of slope should be maintained throughout a cut section. Where site conditions dictate a change from one rate of slope to another within a cut section, the length of transition will be as long as practical to effect a natural appearing contour. Figure 5L contains detailed information on earth and rock cuts.
9. **Superelevated Section:** Superelevation in built-up urban areas should be avoided if practical, provided that the maximum side friction factors are not exceeded. See Section 8-3.0.
10. **Shoulder Superelevation:** See Figure 5J for treatment of high-side superelevated shoulder. Note that, if the shoulder width is less than 1.2 m, the shoulder will be superelevated at the same rate and in the same direction as the travel lane. This applies to both the high side and the low side.
11. **Cross Slope:** On Urban Collector Streets and Urban Local Streets that have curbing, a 1.5-3.0% cross slope may be used on the travel lane.



*TYPICAL OR FLUSH WITH EDGE OF PAVEMENT RAILING PLACEMENT WITHOUT CURB

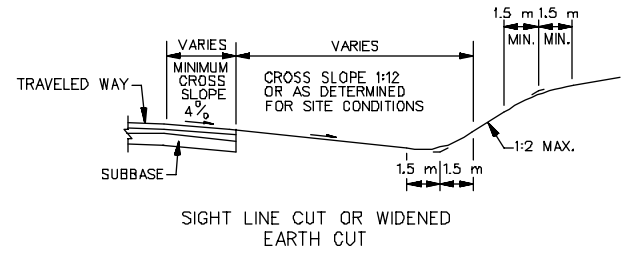


RAILING PLACEMENT WITH CURB

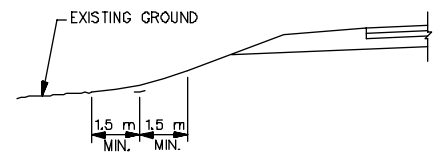
TYPE OF GUIDE RAIL	A	B (MINIMUM)	C (MAXIMUM)
METAL BEAM RAIL (TYPE R-B 350)			
LOW SPEED (V < 80 km/h)	230 mm	610 mm	150 mm.
HIGH SPEED (V ≥ 80 km/h)	0 mm	610 mm	100 mm
THREE-CABLE GUIDE RAILING (I-BEAM POST)	305 mm	610 mm	*

① USE METAL BEAM RAIL (TYPE R-B 350) OR THREE-CABLE GUIDE RAILING (I-BEAM POSTS) ON FILL SLOPES STEEPER THAN 1:4. WITH CURBING, SLOPES 1:4 OR STEEPER USE GUIDE RAIL. GUIDE RAIL MAY ALSO BE REQUIRED WHERE ROADSIDE HAZARDS ARE LOCATED WITHIN ROADSIDE CLEAR ZONE. SEE CHAPTER THIRTEEN.

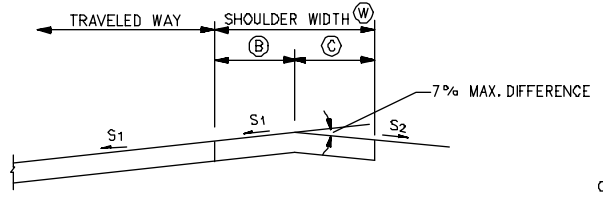
* CURBING, WHERE USED IN CONJUNCTION WITH THREE-CABLE GUIDE RAILING ON HIGH-SPEED ROADWAYS (V ≥ 80 km/h), SHALL BE 100 mm MAX. IN HEIGHT.



SIGHT LINE CUT OR WIDENED EARTH CUT



TREATMENT AT BOTTOM OF FILL SLOPES

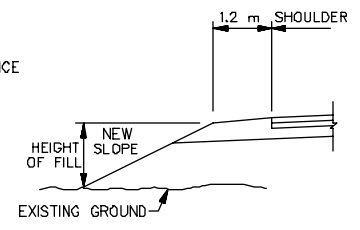


W	B	C
< 1.2 m	0 m TO 1.2 m	0 m
1.2 m TO < 2.4 m	0 m TO 1.2 m	1.2 m
≥ 2.4 m	0 m	≥ 2.4 m

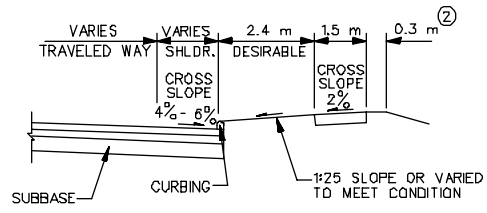
GENERAL NOTES:

- MAY REQUIRE ATTACHABLE EXTENSIONS OR CUT-OFF PLATES ON PAVING EQUIPMENT.
- WHERE S₂ IS FLATTER THAN 2%, THE CONTRACTOR SHALL VERIFY THE CROSS SLOPE AT EACH 10-m INTERVAL (PAYMENT TO BE INCLUDED IN THE COST OF THE BITUMINOUS CONCRETE PAY ITEM - THERE WILL BE NO DIRECT PAYMENT.)
- S₂ SHALL BE 1% MINIMUM.
- DO NOT PROVIDE CURBING ON 1.2-m SHOULDERS WITH SUPERELEVATION >4%.
- ALL OTHER TREATMENTS TO BE USED ONLY WITH PRIOR APPROVAL FROM THE HYDRAULICS AND DRAINAGE, DESIGN DEVELOPMENT TEAM AND PAVEMENT MANAGEMENT UNIT.
- INCLUDE NOTE 1 ON ALL CONTRACT DRAWINGS. INCLUDE NOTE 2 ON ALL CONTRACT DRAWINGS WHERE THE SUPERELEVATION RATES ARE STEEPER THAN 4%.

SHOULDER TREATMENT HIGH SIDE OF BANK



METHOD OF DETERMINING HEIGHT OF FILL AS RELATED TO SIDE SLOPE DESIGN



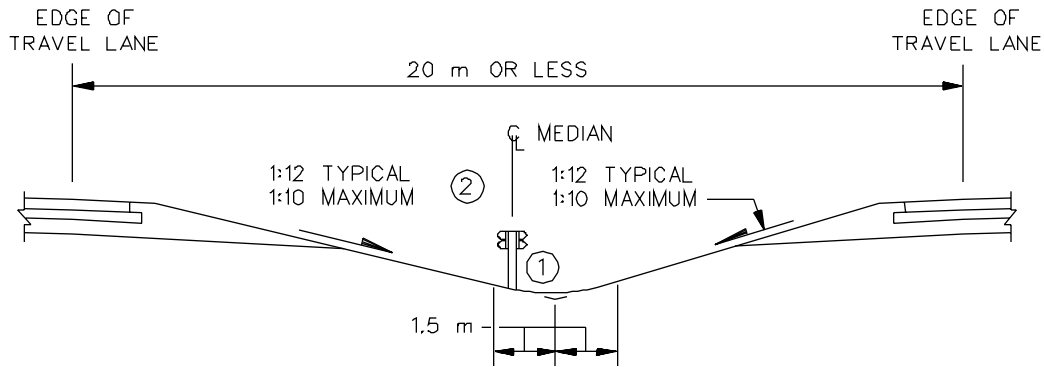
CURB AND WALK AREA

② IF GUIDE RAIL IS REQUIRED, IT WILL BE PLACED BEYOND SIDEWALK. THEREFORE, THIS DIMENSION WILL BE INCREASED AS NECESSARY TO ALLOW FOR PROPER GUIDE RAIL PLACEMENT.

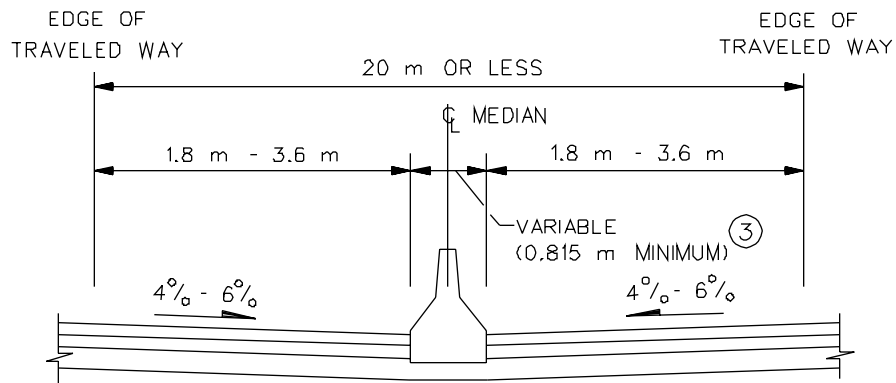
MISCELLANEOUS DETAILS

VARIOUS CLASSES

Figure 5J



TYPICAL DEPRESSED MEDIAN
(With Metal-Beam Barrier)

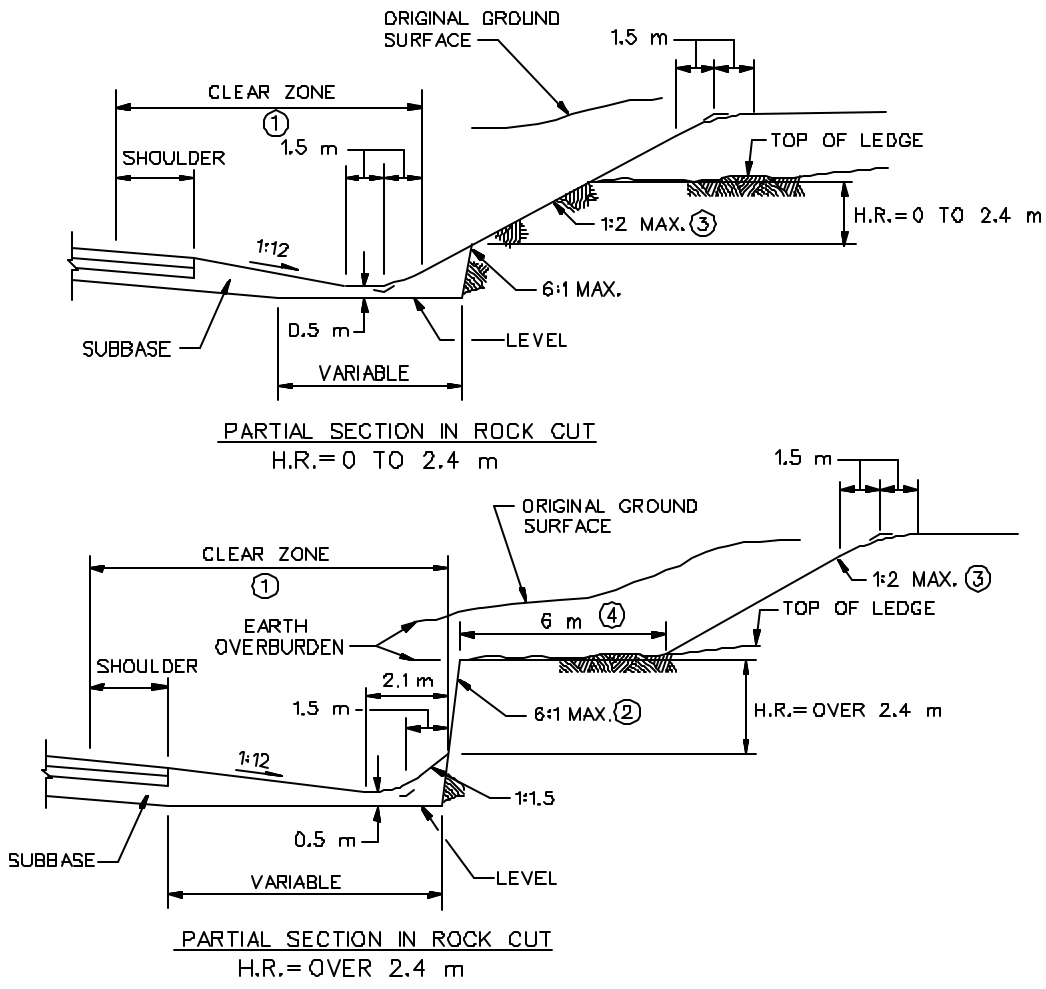


TYPICAL MEDIAN
(With Concrete Median Barrier)

1. **Placement of Median Barrier:** The preferred location of the median barrier is in the center of the median. This will require that the drainage system be offset from the center as indicated in the figure.
2. **Median Slope on Superelevated Sections:** The designer must ensure that the slope leading up to the median barrier does not exceed 1:10. This may require the use of independent profiles for the two roadways. Another option is to place the barrier near the edge of the shoulder; however, this is undesirable and should be avoided.
3. **CMB Width:** Consider providing a 2.54-m wide CMB to accommodate bridge piers for overpassing structures or other appurtenances in the median.

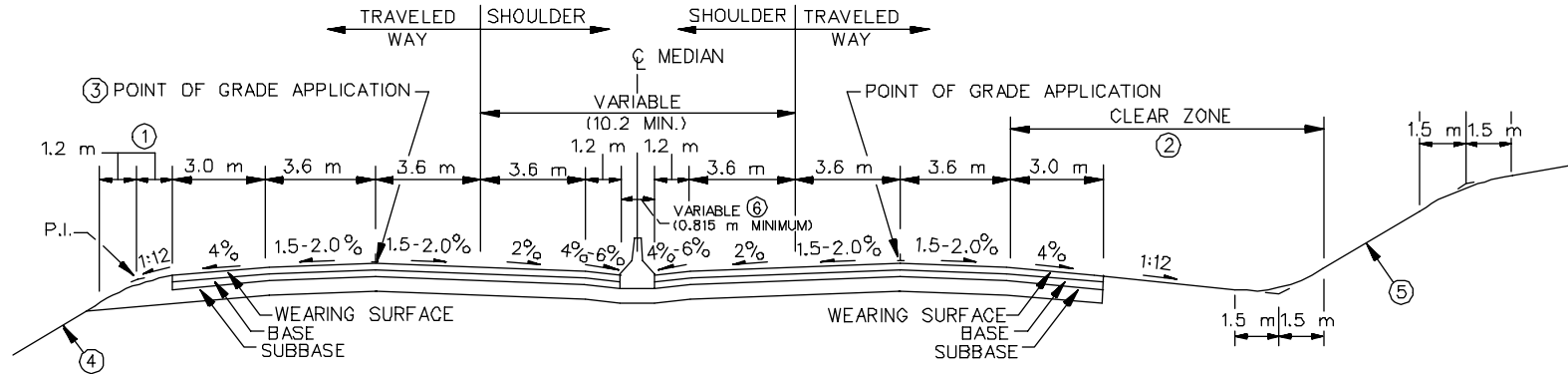
**TYPICAL MEDIAN SECTION FOR FREEWAYS
(20 m or Less)**

Figure 5K

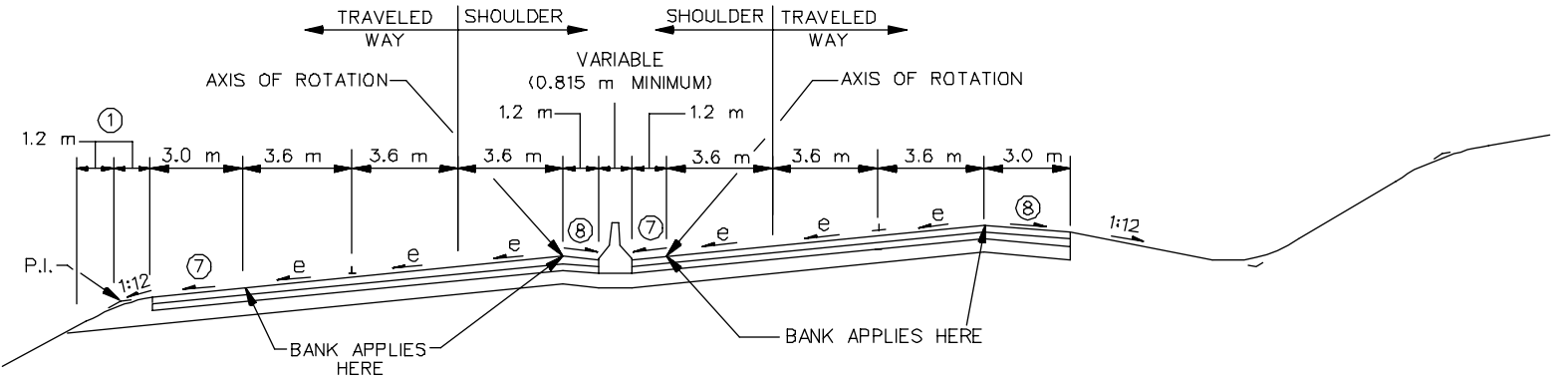


- † To be increased as rock competence decreases or as height of rock cut increases.
- † Rock slopes should be determined by geological investigations and analysis.
- Đ Slopes flatter than the 1:2 maximum are preferred and should be used where site conditions allow. Generally a uniform rate of slope should be held throughout a section. Where site conditions dictate a change from one rate of slope to another within a cut section, the length of transition should be as long as possible to effect a natural appearing contour.
- Ñ The 6-m rock shelf may be reduced to a minimum of 1.5 m when: (a) during construction, the rock elevation is found to be lower than anticipated during design, (b) it is desirable to reduce surplus excavation, and (c) it is desirable to minimize right-of-way needs.

DETAILS OF CUT SECTIONS
Figure 5L



NORMAL SECTION



SUPERELEVATED SECTION

Note: See Section 10-6.0 for a discussion on this typical section.

**TYPICAL SECTION FOR URBAN FREEWAYS
(High-Volume/Incident Management Freeways)**

Figure 5M

MARCH 2000

TYPICAL SECTION FOR URBAN FREEWAYS (High-Volume/Incident Management Freeways)

Notes to Figure 5M

1. **Slope Rounding:** This is the recommended treatment and, when used, the slope rounding should be 2.4 m. This will apply to all conditions, except where the design speed is 110 km/h and where an unprotected 1:4 slope is provided. In this case, the recommended rounding is 3.3 m. Rounding is not necessary on fill slopes protected by guide rail. See Figure 5J for detail if guide rail is used.
2. **Clear Zone:** The outside limit of rounding for the backslope should be outside of the clear zone as determined by Section 13-2.0. If this is within the clear zone, the backslope should be safely traversable (See 13-3D).
3. **Point of Grade Application:** The following criteria will apply:

<u>Pavement Width</u>	<u>Point of Grade Application</u>
Two 3.6-m lanes	3.6 m from inside edge of traveled way
Three 3.6-m lanes	3.6 m from inside edge of traveled way
Four 3.6-m lanes	7.2 m from inside edge of traveled way

4. **Fill Slope:** These should be as flat as practical. Consider the following criteria:

<u>Fill Height</u>	<u>Fill Slope</u>	<u>Guide Rail</u>
0.0 m - 3.0 m	1:6	No
3.0 m - 7.5 m	1:4	No
>7.5 m	1:2	Yes

Also, see Figure 5J for treatment at bottom of fill slope and for guide rail placement on fill slopes.

5. **Cut Slope:** These should be as flat as practical, but should not exceed 1:2. Also see the clear zone discussion in Note #3. A uniform rate of slope should be maintained throughout a cut section. Where site conditions dictate a change from one rate of slope to another within a cut section, the length of transition will be as long as practical to effect a natural appearing contour. Figure 5L contains detailed information on earth and rock cuts.
6. **CMB Width:** Consider providing a 2.4-m wide CMB to accommodate bridge piers for overpassing structures or other appurtenances in the median.
7. **Shoulder Superelevation (Low-Side):** The slope of the shoulder should be the typical shoulder cross slope or "e", whichever is greater.
8. **Shoulder Superelevation (High-Side):** See Figure 5J for treatment of high-side shoulder.
9. **Stage Construction:** When Stage Construction requires excavation for future lanes, the extent and details of grading and drainage will be determined during design of initial construction. Where rock is encountered, it will be removed in the initial construction as necessary to preclude subsequent operational interference.

Chapter Six**DESIGN CONTROLS****Table of Contents**

	<u>Page</u>
6-1.0 HIGHWAY SYSTEMS	6-1(1)
6-1.01 <u>Functional Classification System</u>	6-1(1)
6-1.01.01 Arterials	6-1(1)
6-1.01.02 Collectors	6-1(2)
6-1.01.03 Local Roads and Streets	6-1(2)
6-1.02 <u>Federal-Aid System</u>	6-1(2)
6-1.02.01 National Highway System	6-1(3)
6-1.02.02 Surface Transportation System	6-1(3)
6-1.02.03 Bridge Replacement and Rehabilitation Program	6-1(4)
6-1.03 <u>Classification by Type of Area</u>	6-1(4)
6-1.03.01 Rural Highways and Roads	6-1(4)
6-1.03.02 Urban Highways and Streets	6-1(5)
6-2.0 SPEED	6-2(1)
6-2.01 <u>Definitions</u>	6-2(1)
6-2.02 <u>Design Speed</u>	6-2(2)
6-2.03 <u>Posted Speed Limit</u>	6-2(3)
6-3.0 HIGHWAY CAPACITY	6-3(1)
6-3.01 <u>Definitions</u>	6-3(1)
6-3.02 <u>Selection of Design Hourly Volume</u>	6-3(2)
6-3.03 <u>Capacity Analyses</u>	6-3(3)

Table of Contents

(Continued)

	<u>Page</u>
6-4.0 ACCESS CONTROL	6-4(1)
6-5.0 PROJECT SCOPE OF WORK	6-5(1)
6-5.01 <u>Description</u>	6-5(1)
6-5.01.01 New Construction	6-5(1)
6-5.01.02 4R (Freeways)	6-5(2)
6-5.01.03 Major Reconstruction (Non-Freeways)	6-5(3)
6-5.01.04 3R (Non-Freeways)	6-5(5)
6-5.01.05 Spot Improvements	6-5(7)
6-5.02 <u>Procedures</u>	6-5(8)
6-6.0 EXCEPTIONS TO GEOMETRIC DESIGN CRITERIA	6-6(1)
6-6.01 <u>Department Intent</u>	6-6(1)
6-6.02 <u>Controlling Design Criteria</u>	6-6(1)
6-6.03 <u>Application</u>	6-6(3)
6-6.03.01 Project Scope of Work	6-6(3)
6-6.03.02 Highway System/Funding Source	6-6(3)
6-6.04 <u>Procedures for Exceptions</u>	6-6(4)
6-7.0 REFERENCES	6-7(1)

Chapter Six

DESIGN CONTROLS

6-1.0 HIGHWAY SYSTEMS

6-1.01 Functional Classification System

The Department's *Highway Design Manual* is based on the functional classification concept. Chapters Two through Five summarize the Department's design criteria for each functional class for rural and urban highways and streets and for the Project Scope of Work.

The Department has functionally classified all public highways and streets within Connecticut. To design a project, the designer should contact the appropriate Department office to determine the predicted functional class of the highway or street.

6-1.01.01 Arterials

Arterial highways are characterized by a capacity to quickly move relatively large volumes of traffic. They are sometimes deliberately restricted in their service to abutting properties. The arterial functional class is subdivided into principal and minor categories for rural and urban areas:

1. Principal Arterials. In both rural and urban areas, the principal arterials provide the highest traffic volumes and the greatest trip lengths. The designer should review the project scope of work and the environmental documents to determine which of the following principal arterials should be used in design and identify its corresponding criteria:
 - a. Freeways. The freeway is the highest level of principal arterials. These facilities are characterized by full control of access, high design speeds and a high level of driver comfort and safety. For these reasons, freeways are considered a special type of highway within the functional classification system, and separate design criteria have been developed for these facilities.
 - b. Expressways. These are divided-highway facilities which are characterized by full or partial control of access. Expressways with full control of access are actually freeways. Partial control of access is characterized by a few at-grade intersections with other public roads, and there may be an occasional private access.

- c. **Urban/Rural Arterials.** These facilities are usually 2 or 4 lanes with or without a median. Partial control of access is desirable along these facilities. A high level of geometric design is desirable to move the high traffic volumes quickly and efficiently through an area.
2. **Minor Arterials.** In rural areas, minor arterials will provide a mix of interstate and interregional travel service. In urban areas, minor arterials may carry local bus routes and provide intracommunity connections, but they will not, for example, penetrate neighborhoods. When compared to the principal arterial system, the minor arterials provide lower travel speeds, accommodate shorter trips and distances and lower traffic volumes but provide more access to property.

6-1.01.02 Collectors

Collector routes are characterized by a roughly even distribution of their access and mobility functions. Traffic volumes and speeds will typically be somewhat lower than those of arterials. In rural areas collectors serve intraregional travel needs and provide connections to the arterial system. All cities and towns within a region will be connected. In urban areas collectors act as intermediate links between the arterial system and points of origin and destination. Urban collectors typically penetrate residential neighborhoods and commercial and industrial areas. Local bus routes will often include collector streets.

6-1.01.03 Local Roads and Streets

All public roads and streets not classified as arterials or collectors will have a local classification. Local roads and streets are characterized by their many points of direct access to adjacent properties and their relatively minor value in accommodating mobility. Speeds and volumes are usually low and trip distances short. Through traffic is often deliberately discouraged.

6-1.02 Federal-Aid System

The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 implemented a major realignment of the Federal-aid system. Traditionally, the system had been divided into Interstate, primary, secondary and urban Federal-aid systems. Separate categories of Federal funds were available for eligible Federal-aid projects on each system. The following sections briefly describe the Federal-aid system created by ISTEA.

6-1.02.01 National Highway System

The National Highway System (NHS) is a system of those highways determined to have the greatest national importance to transportation, commerce and defense in the United States. It consists of the Interstate highway system, logical additions to the Interstate system, selected other principal arterials, and other facilities which meet the requirements of one of the subsystems within the NHS. The NHS represents approximately 4%-5% of the total public road kilometers in the United States. Specifically, the NHS includes the following subsystems (note that a specific highway route may be on more than one subsystem):

1. Interstate. The current Interstate system of highways retains its separate identity within the NHS. There are also provisions to add kilometers to the existing Interstate subsystem.
2. Other Principal Arterials. These are highways in rural and urban areas which provide access between an arterial and a major port, airport, public transportation facility or other intermodal transportation facility.
3. Strategic Highway Network. This is a network of highways which are important to the United States' strategic defense policy and which provide defense access, continuity and emergency capabilities for defense purposes.
4. Major Strategic Highway Network Connectors. These are highways which provide access between major military installations and highways which are part of the Strategic Highway Network.

The 1991 ISTEA has mandated that each State highway agency, in cooperation with other jurisdictional agencies, develop and implement several management systems. These include management systems for pavements, bridges, traffic congestion, highway safety, public transportation facilities/equipment and intermodal transportation facilities/systems.

6-1.02.02 Surface Transportation Program

The Surface Transportation Program (STP) is a block grant type program that may be used by the States and localities for any roads (including NHS facilities) that are not functionally classified as local routes or rural minor collectors. These roads are now collectively referred to as Federal-aid roads. Bridge projects using STP funds are not restricted to Federal-aid roads, but may be used on any public road. Transit capital projects are also eligible under the STP program.

6-1.02.03 Bridge Replacement and Rehabilitation Program

The Bridge Replacement and Rehabilitation Program (BRRP) has retained its separate identity within the Federal-aid program. BRRP funds are eligible for work on any bridge on any public road regardless of its functional classification.

6-1.03 Classification by Type of Area

The functional classification system is based on urban or rural designation. For a highly developed State like Connecticut, this is not sufficient to determine the appropriate project design. Therefore, the design criteria in Chapters Two, Four and Five are further divided by the type of area where the project is located. This refinement to the highway design process will allow the designer to better tailor the project to the constraints of the surrounding environment.

The following sections briefly discuss the classifications by type of area for urban and rural locations. The designer is responsible for determining which type of area is most appropriate for the project under design.

6-1.03.01 Rural Highways and Roads

Chapter Four presents the Department's design criteria for new construction or major reconstruction of rural highways and roads; Chapter Two presents the criteria for 3R non-freeway projects. Many highways in Connecticut are classified as rural but frequently pass through relatively built-up areas. Therefore, Chapters Two and Four present design criteria based on the extent of roadside development. The tables in the chapters provide criteria for the average number of access points per kilometer per side. These criteria provide some guidance for the designer, but they should not be considered rigid. In addition, the designer should consider the following narrative descriptions:

1. Open. This fits the traditional concept of a rural area. The driver has almost total freedom of movement and is generally not affected by occasional access points along the highway or road. For the purpose of determining the classification, access points will average less than 10 per kilometer per side. Right-of-way is usually not a problem.
2. Low/Moderate Density. The roadside development has increased to a level where the prudent driver will instinctively reduce his/her speed as compared to an open highway. The driver must be more alert to the possibility of entering and exiting vehicles, but he/she is still able to maintain a relatively high travel speed. The estimated number of access points will average between 10 and 20 per kilometer per side. Right-of-way may be difficult to attain.

3. Moderate/High Density. The roadside development has increased to a level which is comparable to a suburban area within an urbanized boundary. The extent of the development will have a significant impact on the selected travel speed of a prudent driver. Exiting and entering vehicles are frequent, and traffic signals are typical at major intersections. The estimated number of access points will average greater than 20 per kilometer per side. Right-of-way is usually quite difficult to attain.

6-1.03.02 Urban Highways and Streets

Chapter Five presents the Department's design criteria for new construction or major reconstruction of urban highways and streets; Chapter Two presents the criteria for 3R non-freeway projects. Each functional classification table is subdivided by the type of area where the project is located. The designer should consider the following descriptions when selecting the applicable type of area:

1. Suburban. These areas are usually located at the fringes of urbanized and small urban areas. The predominant character of the surrounding environment is usually residential, but it will also include a considerable number of commercial establishments. There may also be a few industrial parks in suburban areas. On suburban roads and streets, drivers usually have a significant degree of freedom but, nonetheless, they must also devote some of their attention to entering and exiting vehicles. Roadside development is characterized by low to moderate density. Pedestrian activity may or may not be a significant design factor. Right-of-way is often available for roadway improvements.

Local and collector streets in suburban areas are typically located in residential areas, but may also serve a commercial area. Posted speed limits typically range between 25 and 40 mph (40 and 70 km/h). The majority of intersections will have stop or yield control, but there will be an occasional traffic signal. A typical suburban arterial will have strip commercial development and perhaps a few residential properties. Posted speed limits usually range between 35 and 50 mph (60 and 80 km/h), and there will usually be a few signalized intersections along the arterial.

2. Intermediate. As its name implies, intermediate areas fall between suburban and built-up areas. The surrounding environment may be either residential, commercial or industrial or some combination of these. On roads and streets in intermediate areas, the extent of roadside development will have a significant impact on the selected speeds of drivers. The increasing frequency of intersections is also a major control on average travel speeds. Pedestrian activity has now become a significant design consideration, and sidewalks and cross walks at intersections are common. The available right-of-way will often restrict the practical extent of roadway improvements.

Local and collector streets in intermediate areas typically have posted speed limits between 25 and 35 mph (40 and 60 km/h). The frequency of signalized intersections has increased substantially when compared to suburban areas. An arterial in an intermediate area will often have intensive commercial development along its roadside. Posted speed limits range between 30 and 40 mph (50 and 70 km/h). These arterials typically have several signalized intersections per kilometer.

3. Built-up. These areas normally refer to the central business district within an urbanized or small urban area. The roadside development has a high density and is often commercial. However, a substantial number of roads and streets in built-up areas pass through a high-density, residential environment (e.g., apartment complexes, row houses). Access to property is the primary function of the road network in built-up areas; the average driver rarely passes through a built-up area for mobility purposes. Pedestrian considerations may be as important as vehicular considerations, especially at intersections. Right-of-way for roadway improvements is usually not available.

Because of the high density of development in built-up areas, the distinction between the functional classes (local, collector or arterial) becomes less important when considering signalization and speeds. The primary distinction among the three functional classes is often the relative traffic volumes and, therefore, the number of lanes. As many as half the intersections may be signalized; posted speed limits typically range between 25 and 35 mph (40 and 60 km/h).

6-2.0 SPEED

6-2.01 Definitions

1. Design Speed. Design speed is the maximum safe speed that can be maintained over a specified section of highway when conditions are so favorable that the design features of the highway govern. A design speed is selected for each project which will establish criteria for several design elements including horizontal and vertical curvature, superelevation and sight distance.
2. Low Speed. For geometric design applications, low speed is defined as 70 km/h or less.
3. High Speed. For geometric design applications, high speed is defined as greater than 70 km/h.
4. Average Running Speed. Running speed is the average speed of a vehicle over a specified section of highway. It is equal to the distance traveled divided by the running time (the time the vehicle is in motion). The average running speed is the distance summation for all vehicles divided by the running time summation for all vehicles.
5. Average Travel Speed. Average travel speed is the distance summation for all vehicles divided by the total time summation for all vehicles. (Note: Average running speed only includes the time the vehicle is in motion. Therefore, on uninterrupted flow facilities which are not congested, average running speed and average travel speed are equal.)
6. Operating Speed. Operating speed, as defined by AASHTO, is the highest overall speed at which a driver can safely travel a given highway under favorable weather conditions and prevailing traffic conditions while at no time exceeding the design speed. Therefore, for low-volume conditions, operating speed equals design speed. The designer should note that this term has little or no usage in geometric design.
7. 85th-Percentile Speed. The 85th-percentile speed is the speed below which 85 percent of vehicles travel on a given highway. The most common application of the value is its use as one of the factors, and usually the most important factor, for determining the posted, regulatory speed limit of a highway section. In most cases, field measurements for the 85th-percentile speed will be conducted during off-peak hours when drivers are free to select their desired speed.

6-2.02 Design Speed

Design speed, perhaps more so than any other design control, will have a major impact on all facets of geometric design. Many design elements, such as horizontal and vertical curvature, superelevation and sight distances, are directly dependent on the design speed; i.e., the selected design speed is used directly in the equations for these geometric design elements. Other features, such as lane and shoulder width and clear zones, logically vary with design speed but are not a direct function of the design speed.

Chapters Four and Five present the minimum design speeds for new construction and major reconstruction. The design speed will vary according to functional classification, urban/rural location and type of area. Chapter Two presents the Department's policy for determining the design speed on 3R non-freeway projects. Design speeds are selected at 10-km/h increments.

The following should be evaluated when determining the project design speed:

1. Balance. The selected design speed should be a reasonable balance between topography, urban or rural character, and the functional use of the highway. The designer must weigh the benefits of a desired degree of safety, mobility and efficiency against the environmental, right-of-way and cost impacts.
2. Driver Expectancy. The element of driver expectancy should be considered when selecting the design speed. The driver expects to be able to drive at certain maximum speeds based on the functional and rural or urban character of the highway. Therefore, the design speed should fit the travel desires and habits of the great majority of drivers. Driver expectancy should also be considered where design speed transitions are introduced. If a difficult condition is obvious, drivers are more likely to accept a lower speed than if there is no apparent reason for it.
3. Traffic Volumes. This may also impact the selection of design speed. With all other factors equal, a higher volume highway may justify a higher design speed because of the increased capacity and savings in vehicular operating costs. However, the designer should consider that at low volumes drivers are likely to travel at higher speeds. Therefore, the values in Chapters Four and Five are applicable to a wide range of traffic volumes.
4. Consistency. When a substantial length of highway is under design, the designer should assume a constant design speed. Where restrictive conditions dictate a lower design speed, it should be introduced gradually over a sufficient distance to transition drivers down to the lower speed.

5. Design Speed as Minimum Control. Although the selected design speed establishes the minimum criteria for highway alignment, the designer should consider providing flatter horizontal curves and longer sight distances if compatible with community objectives. Even in difficult terrain, an occasional tangent or flat curve may be appropriate. The designer should also be especially careful when providing a long tangent on any highway and then minimum radii at the end of the tangent. A lengthy tangent section may encourage a driver to exceed the design speed of the horizontal curve.
6. Posted Speed Limit. For all new construction/major reconstruction projects, the selected design speed should equal or exceed the anticipated posted or regulatory speed limit of the completed facility. This requirement recognizes the important relationship between likely travel speeds and the highway design. It also recognizes that a posted speed limit creates a definite driver expectation of safe operating speed. The design speeds in Chapters Four and Five and the procedure in Chapter Two for 3R non-freeway projects are intended to achieve this objective. Section 6-2.03 discusses the Department's policy on determining the posted speed limit.

6-2.03 Posted Speed Limit

The Office of Traffic Engineering is responsible for recommending to the State Traffic Commission the posted speed limit on all State highways. It also typically assists or advises municipalities in determining the posted speed on other public roads and streets. The Office of Traffic Engineering conducts an engineering evaluation of each site. The following factors are evaluated:

1. the 85th percentile speed,
2. roadway geometrics,
3. functional classification and type of area,
4. type and density of roadside development,
5. accident experience, and
6. pedestrian activity.

6-3.0 HIGHWAY CAPACITY

6-3.01 Definitions

1. Capacity. The maximum number of vehicles which can reasonably be expected to traverse a point or uniform section of a road during a given time period under prevailing roadway, traffic and control conditions. The time period most often used for analysis is 15 minutes.
2. Level of Service. A qualitative concept which has been developed to characterize acceptable degrees of congestion. In the *Highway Capacity Manual*, the qualitative descriptions of each level of service (A to E) have been converted into quantitative measures for the capacity analysis for each highway element (freeway, signalized intersection, etc.). Chapters Four and Five present guidelines for selecting the level of service for highway design. These apply to all highway elements (mainline, intersections, weaving areas, etc.)
3. Average Annual Daily Traffic (AADT). The total yearly volume in both directions of travel divided by the number of days in the year.
4. Average Daily Traffic (ADT). The calculation of average traffic volumes in both directions of travel during a specified time period and divided by the number of days in that time period.
5. Hourly Volume. The total number of vehicles that pass over a given point or section of a lane or roadway during a hour.
6. Peak-Rate of Flow. The highest equivalent hourly rate at which vehicles pass over a given point or section of a lane or roadway during a given time interval less than one hour, usually 15 min.
7. Peak-Hour Factor (PHF). A ratio of the total hourly volume to the maximum 15-min rate of flow within the hour.
8. Design Hourly Volume (DHV). The 1-hr volume in both directions of travel in the design year selected for determining the highway design. Section 6-3.02 discusses the Department's policy for selecting the DHV for highway design. The 30th highest hourly volume is normally used for design.
9. Directional Design Hourly Volume (DDHV). The 1-hr volume in one direction of travel in the selected design year.

10. Design Service Volume or Flow Rate. The maximum hourly vehicular volume which can pass through a highway element at the selected level of service. The basic intent of a highway capacity analysis is to ensure that the DHV does not exceed the calculated design service volume of the highway element when considering the prevailing roadway, traffic and control conditions.
11. Density. The number of vehicles occupying a given length of lane, averaged over time. It is usually expressed as vehicles per kilometer (vpk).
12. Delay. A critical performance measure on interrupted flow facilities, especially at signalized intersections. For this element, average stopped-time delay is measured, which is expressed in seconds per vehicle.
13. Directional Distribution. The division, by percent, of the traffic in each direction of travel during the design hour.
14. Traffic Composition. A factor which reflects the percentage of heavy vehicles (trucks, buses and recreational vehicles) in the traffic stream during the DHV. The poorer operating capabilities and larger size of heavy vehicles must be reflected in the capacity analysis.

6-3.02 Selection of Design Hourly Volume

For most geometric design elements which are impacted by traffic volumes, the peaking characteristics are most significant. The highway facility should be able to accommodate the predicted traffic volumes for the great majority of time at the selected level of service. An analysis of peaking trends has led to the conclusion that the 30th highest hourly volume (30 HV) in the selected design year is a reasonable design control. This design hourly volume (DHV) will affect many design elements including the number of travel lanes, lane and shoulder width, and intersection geometrics.

A highway should be designed to accommodate the traffic that might occur within the life of the facility under reasonable maintenance. This involves projecting the traffic conditions for a selected future year. For new construction and major reconstruction, traffic volume projections are usually based on 20 years from the expected construction completion date. This is a reasonable compromise between a facility's useful life, the uncertainties of long-range projections, and the consequences of inaccurate projections.

For 3R non-freeway projects, the designer should provide a highway facility which, desirably, will accommodate the DHV for ten years in the future at the selected level of service. At a minimum, the highway facility should accommodate current traffic volumes at the selected level of service. Chapter Two discusses the geometric design of 3R non-freeway projects in detail.

Bridge design life is considered to be approximately 50 years. This should be considered in the geometric design of bridges and in the design of roadways which pass beneath a bridge.

The designer should analyze the proposed design using the a.m. and p.m. DHV's separately. This could have an impact on the geometric design of the highway.

The Office of Inventory and Forecasting in the Bureau of Planning prepares traffic forecasts for DHV, AADT, directional distribution and percentage of heavy vehicles. A simple traffic analysis would be predicting the 30th highest hourly volume in 20 years by applying the traffic growth factors to present volumes. The forecaster must also incorporate the impact of any anticipated land development or traffic diversions onto or away from the facility. In addition, the forecaster must determine the traffic characteristics of directional distribution and composition specifically during the DHV. For intersections and interchanges, DHV forecasts must be made for every possible through and turning movement.

6-3.03 Capacity Analyses

The highway mainline, intersection or interchange should be designed to accommodate the selected design hourly volume (DHV) at the selected level of service. This may involve adjusting the various highway factors which affect capacity until a design is developed that will accommodate the DHV. The detailed calculation factors and methodologies are in the *Highway Capacity Manual* (HCM). In reality the design service volume of the facility should be calculated. Capacity assumes a level of service E; design service volume is the maximum volume of traffic that a projected highway of designed dimensions is able to serve without the degree of congestion falling below a preselected level.

6-4.0 ACCESS CONTROL

Access control is defined as the condition where the public authority fully or partially controls the right of abutting owners to have access to and from the public highway. The functional classification of a highway (Section 6-1.0) is partially determined by the degree of access it allows. Access control may be exercised by statute, zoning, right-of-way purchases, driveway controls, turning and parking regulations, or geometric design (e.g., grade separations and frontage roads).

Chapters Two, Three and Four provide the typical degree of access control for the various functional classes and for the type of area. The following provides definitions for the three basic types of access control:

1. Full Control. Full control of access is achieved by giving priority to through traffic by providing access only at grade separation interchanges with selected public roads. No at-grade crossings or private driveway connections are allowed. The freeway is the common term used for this type of highway. Full control of access maximizes the capacity, safety and vehicular speeds on the freeway.
2. Partial Control. Partial control of access is an intermediate level between full control and regulatory restriction. Priority is given to through traffic, but a few at-grade intersections and private driveway connections may be allowed. The proper selection and spacing of at-grade intersections and service connections will provide a balance between the mobility and access service of the highway.
3. Control by Regulation. All highways warrant some degree of access control. If access points are properly spaced and designed, the adverse effects on highway capacity and safety will be minimized. These points should be located where they can best suit the traffic and land-use characteristics of the highway under design. Their design should enable vehicles to enter and exit safely with a minimum of interference to through traffic.

Control by regulation is exercised by the Department and all Connecticut municipalities to determine where private interests may have access to and from the public road system. Occasionally, statutory control is used on arterials to restrict access to only public roads and major traffic generators. Zoning may be used to effectively control the adjacent property development so that major generators of traffic will not develop. However, zoning restrictions are at the discretion of the local government. Driveway regulations and permits are used to control the geometric design of an entrance, driveway spacing, and driveway proximity to public road intersections. Section 11-8.0 discusses the applicable criteria for driveway design. The Department's *Highway Encroachment Permit Regulations* discusses the procedures and design criteria for obtaining driveway permits onto State highways.

6-5.0 PROJECT SCOPE OF WORK

6-5.01 Description

The scope of work for the proposed highway project is a major control in highway design. The project scope of work will reflect the basic intent of the highway project and will determine the overall level of highway improvement. New construction and reconstruction projects will often have significant impacts (e.g., considerable right-of-way involvement). In contrast, 3R non-freeway projects typically restrict improvements to the existing right-of-way. The decision on the project scope of work will determine the use of the Department's *Highway Design Manual*.

The following descriptions are intended to provide guidance for the determination of the project scope of work.

6-5.01.01 New Construction

New construction is defined as the following for the various highway elements:

1. Highway Mainline. New horizontal and vertical alignment on new location is considered new construction of a highway mainline. Chapters Four and Five present the Department's criteria for new construction.
2. Intersections At-Grade. Any intersection which falls within the project limits of a new highway mainline is considered new construction. Likewise, any existing intersection which is relocated to a new point of intersection is considered new construction. Chapter Eleven presents the Department's criteria for the new construction of intersections; Chapters Four and Five present the Department's criteria for the width of cross-section elements within the intersection (e.g., auxiliary lane width).
3. Interchanges. Any construction of an interchange on a new highway mainline is considered new construction. In addition, the construction of a new interchange on an existing highway is considered new construction. Chapter Twelve presents the Department's criteria for the new construction of interchanges. Chapters Four and Five present the Department's criteria for the width of cross-section elements for the highway mainline within the interchange.
4. Bridges. Bridges on a new highway mainline are considered new construction for bridges. Chapters Four and Five present the Department's criteria for the width of bridges which are new construction.

6-5.01.02 4R (Freeways)

4R (resurfacing, restoration, rehabilitation and reconstruction) is used to describe any project on an existing freeway. These may or may not involve significant right-of-way acquisitions. 4R freeway projects are defined as the following for the various highway elements:

1. Highway Mainline. 4R work on an existing freeway mainline may include:
 - a. lane and shoulder pavement resurfacing;
 - b. lane and shoulder pavement reconstruction;
 - c. lane and shoulder widening;
 - d. addition of through and/or auxiliary lanes;
 - e. flattening a selected horizontal or vertical curve;
 - f. major reconstruction of the existing alignment;
 - g. widening the roadside clear zone;
 - h. upgrading the safety appurtenances to meet current criteria;
 - i. flattening side slopes;
 - j. structural, geometric and/or safety improvements to existing bridges within the project limits;
 - k. upgrading the existing drainage system; and/or
 - l. traffic management, TSM and upgrading of signing.

Section 3-1.0 presents the Department's criteria for the design of 4R freeway projects on highway mainline.

2. Interchanges. An existing interchange may be within the project limits of a 4R project, or a 4R project may be initiated solely to improve an existing interchange. The scope of work may range from a total reconstruction of the existing interchange to selected design improvements. Most often, the level of improvement to an existing interchange within larger project limits will be commensurate

with the level of improvement to the highway mainline. Therefore, 4R work on an existing interchange might include:

- a. upgrading the interchange type (e.g., converting a cloverleaf to a directional interchange);
- b. adding new connections for movements;
- c. adding collector-distributor roads;
- d. lengthening an existing acceleration or deceleration lane;
- e. improving roadside safety within the interchange limits;
- f. realigning an existing ramp; and/or
- g. widening an existing ramp.

Chapter Twelve discusses the Department's criteria for the design of the interchange elements.

3. Bridges. Any work on an existing freeway bridge is considered a 4R project. In addition, a bridge may be within the limits of a 4R project, but no improvement may be proposed. Therefore, the scope of work for a freeway bridge may be one of the following:
 - a. bridge replacement, either as an independent project or within the limits of a mainline/interchange 4R project;
 - b. bridge rehabilitation/reconstruction, either as an independent project or within the limits of a mainline/interchange 4R project; or
 - c. bridge will remain in place within the limits of a mainline/interchange 4R project.

Section 3-1.0 presents the Department's criteria for 4R freeway bridge projects.

6-5.01.03 Major Reconstruction (Non-Freeway)

Major reconstruction on a non-freeway will usually require significant right-of-way purchases and will often have a major impact on the surrounding area. Major reconstruction is defined as the following for the various highway elements:

1. Highway Mainline. Major reconstruction of an existing highway mainline will typically include reconstruction of the existing horizontal and vertical alignment but will be essentially within the existing highway corridor. The primary reason to perform major reconstruction is because the existing facility cannot accommodate its current or future demands and requires an extensive improvement to provide an acceptable level of service. Any project which increases the basic number of through traffic lanes on an existing road is considered Major Reconstruction. Because of the significant level of work, the geometric design of the project should be determined by the criteria for new construction. Therefore, the values in Chapters Four and Five will be used to design major reconstruction projects.

2. Intersections At-Grade. Any intersection which falls within the limits of a major reconstruction project will also be evaluated for major reconstruction. The scope of work for a project strictly to improve an existing intersection may also be considered major reconstruction if the proposed work is extensive. This could include the:
 - a. addition of through and/or auxiliary lanes for all approaches;
 - b. relocation and flattening of turning radii;
 - c. addition of turning roadways;
 - d. flattening the approach and intersection gradients;
 - e. realigning the angle of intersection; and/or
 - f. rechannelizing the intersection.

Because of the extensive level of work for major reconstruction, the criteria in Chapter Eleven will apply to the design of the intersection. The criteria in Chapters Four and Five apply for the width of the cross-section elements.

3. Interchanges. An existing interchange may be within the project limits of a non-freeway facility which is being redesigned as a major reconstruction project. The interchange should also be evaluated for major reconstruction. This may only apply to those interchange elements which directly impact the safety and operations of the non-freeway facility not the entire interchange. In addition, the scope of work for a project strictly to improve an existing interchange may be considered major reconstruction if the proposed work is extensive. This would apply to an interchange between two non-freeway facilities; if a freeway is one of the intersecting facilities, this will be a 4R project. The major reconstruction of an existing interchange may be characterized by:
 - a. upgrading the interchange type (e.g., converting a cloverleaf to a directional interchange);
 - b. adding new connections for movements which are currently not provided; and/or

- c. adding collector-distributor roads.

When major reconstruction is being performed on an existing interchange, the entire interchange should be evaluated according to the criteria in Chapters Four, Five and Twelve.

4. Bridges. "Major reconstruction" on a non-freeway bridge refers to a bridge within the limits of a major reconstruction project. An independent project to perform work solely on a bridge and its approaches is a spot improvement (Section 6-5.01.05). Therefore, the scope of work as it applies to non-freeway bridges and major reconstruction projects may be one of the following:
 - a. bridge replacement, either as a spot improvement (Section 3-2.0) or as part of the major reconstruction of a highway mainline (Section 10-4.0);
 - b. bridge rehabilitation/reconstruction, either as a spot improvement (Section 3-2.0) or as part of the major reconstruction of a highway mainline (Section 10-4.0); or
 - c. bridge will remain in place within the limits of the major reconstruction of a highway mainline (Section 10-4.0).

6-5.01.04 3R (Non-Freeways)

3R (resurfacing, restoration and/or rehabilitation) on non-freeways will typically involve either no or minor right-of-way acquisition (e.g., slivers, an occasional building). A 3R non-freeway project is defined as the following for the various highway elements:

1. Highway Mainline. 3R work on an existing highway mainline is work essentially on the existing highway alignment, but which frequently includes selected improvements to the highway geometrics. The basic number of through traffic lanes must be the same before and after the project. Typical improvements for 3R projects include:
 - a. lane and shoulder pavement resurfacing,
 - b. full-depth reconstruction of the travel lanes up to **a** of the project length (total project length may be full-depth reconstruction with approval from the appropriate Division Manager),
 - c. shoulder pavement reconstruction (for all or part of the project length),
 - d. lane and shoulder widening,

- e. addition of auxiliary lanes,
- f. flattening a selected horizontal or vertical curve,
- g. widening the roadside clear zone,
- h. converting an existing median to include left-turn lanes,
- i. revising the location, spacing or design of existing driveways along the mainline,
- j. adding or removing parking lanes,
- k. adding curbs or sidewalks,
- l. structural, geometric or safety improvements to existing bridges within the project limits,
- m. relocating utility poles,
- n. upgrading safety appurtenances to meet current criteria,
- o. upgrading of the existing drainage system, and/or
- p. upgrading of signing, pavement markings, traffic signals, etc.

Chapter Two presents the Department's criteria for the design of 3R non-freeway projects.

2. Intersections At-Grade. Any intersection which is within the limits of a 3R project will be evaluated for 3R-type improvements. In addition, an existing intersection may also be improved as an independent project. This may be considered as either a 3R project or a spot improvement (Section 6-5.01.05).

A 3R project at an existing intersection may include improvements such as:

- a. widening the approach roadway width,
- b. adding an auxiliary lane,
- c. lengthening an existing auxiliary lane,
- d. improving the intersection sight distance,
- e. flattening the existing turning radii,
- f. minor realignment of the intersection angle,
- g. adding a turning roadway,

- h. widening an existing turning roadway,
- i. minor rechannelization,
- j. upgrading the existing signal system, and/or
- k. upgrading the existing drainage system.

Chapter Two discusses the Department's design criteria for 3R work to an existing intersection. This is primarily a reference to the criteria in Chapter Eleven.

3. Interchanges. An interchange may be within the project limits of a 3R project on a non-freeway facility. The project should also include an evaluation of those interchange elements which directly impact the safety and operations of the non-freeway. 3R-type work to an existing interchange within a 3R project might include:
- a. lengthening an existing acceleration or deceleration lane,
 - b. improving roadside safety within the interchange limits,
 - c. realigning an existing ramp,
 - d. widening an existing ramp, and/or
 - e. improvements to the ramp/non-freeway intersection.

Chapter Twelve discusses the Department's design criteria for interchanges.

4. Bridges. "3R" work on a non-freeway bridge refers to a bridge within the limits of a 3R project. An independent project to perform work solely on a bridge and its approaches is a spot improvement (Section 6-5.01.05). Therefore, the scope of work as it applies to non-freeway bridges and 3R projects may be one of the following:
- a. bridge replacement, either as a spot improvement (Section 3-2.0) or as part of a 3R project (Section 2-7.0);
 - b. bridge rehabilitation/reconstruction, either as a spot improvement (Section 3-2.0) or as part of a 3R project (Section 2-7.0); or
 - c. bridge will remain in place within the limits of a 3R project (Section 2-7.0).

6-5.01.05 Spot Improvements

These projects are intended to correct a deficiency at an isolated location. This may be an intersection, a horizontal curve, a bridge or a limited roadside section. Many spot improvement projects are safety

projects and projects identified by the Highway Bridge Replacement and Rehabilitation Program. Section 3-2.0 discusses the Department's criteria for the design of spot improvement projects.

6-5.02 Procedures

The procedures for selecting and revising the project scope of work are integrated into the Department's Project Initiation and Project Modification process. These overall procedures are outlined in the *Pre-Construction Management System's (PCMS) User Manual* and Appendix. The following provides additional details specifically for the project scope of work:

1. Projects may be initiated by Planning, Project Concept, Traffic, Maintenance, Design or other groups. When the RPM is prepared, the initiating unit will select the project scope of work.
2. The Project Initiation is prepared based on the approved project scope of work.
3. When the project is initiated, the designer will begin work on the project. At any time during design, the designer may recommend to revise the project scope of work based on an evaluation of actual field conditions. The revised scope must then be approved by the Scoping Committee. Once approved, the designer must prepare a Recommended Project Modification to document and justify the revised project scope of work. The modification is then submitted to the appropriate office director for approval. From this point, the processing of the modification is similar to that of the RPM.

6-6.0 EXCEPTIONS TO GEOMETRIC DESIGN CRITERIA

This section discusses the Department's procedures for identifying, justifying and processing exceptions to the geometric design criteria in the *Highway Design Manual*.

6-6.01 Department Intent

The general intent of the Connecticut Department of Transportation is that all design criteria in this *Manual* should be met. Where a range of values is presented, the designer should use the upper values within the range where the cost, social, economic, community, and environmental impacts are not critical. This is intended to ensure that the Department will provide a highway system which meets the transportation needs of the State and provides a reasonable level of safety, comfort and convenience for the traveling public. However, recognizing that this will not always be practical, the Department has established a process to evaluate and approve exceptions to geometric design criteria.

6-6.02 Controlling Design Criteria

Controlling design criteria are those highway design elements which are judged to be the most critical indicators of a highway's safety and its overall serviceability. Obviously, not all design criteria in the Department's *Highway Design Manual* are equally important. Therefore, the Department and FHWA have identified those design elements which qualify as controlling criteria and, therefore, must complete the formal documentation and approval process when not met.

The designer is also responsible for meeting the other design criteria in the *Manual*, if practical. These criteria represent good engineering practice, and the designer should make every reasonable effort to meet these criteria on all projects.

The following establishes the controlling criteria for the design exception process:

1. design speed;
2. travel lane and shoulder widths;
3. auxiliary lane and shoulder widths;
4. bridge widths;
5. structural capacity;

6. horizontal alignment:
 - a. minimum radii, and
 - b. compound curves which do not meet the 1.5:1 ratio;
7. vertical curvature based on:
 - a. level SSD at crests, and
 - b. level SSD at sags;
8. maximum grades;
9. stopping sight distance (based on level grades);
10. cross slopes;
11. superelevation:
 - a. rate based on $e_{\max} = 6.0\%$, and
 - b. transition lengths;
12. vertical clearances;
13. accessibility requirements for handicapped individuals; *
14. roadside clear zones; and **
15. intersection sight distance at unsignalized intersections, excluding residential and minor commercial driveways.**

* *No design exceptions are permitted which do not meet CGS Sections 7-118A and 14-235a or which do not meet the Americans with Disabilities Act (Public Law 101-336).*

** *Not FHWA controlling design criteria. Not controlling design criteria for projects designed by municipalities (or their consultants) on facilities owned and maintained by the municipality.*

The designer is encouraged to use the Department's recommended design speed and then seek design exceptions for individual elements which do not meet the applicable criteria for that design speed (e.g., minimum radius, SSD at crest vertical curve).

6-6.03 Application

6-6.03.01 Project Scope of Work

This design exception process will apply to:

1. all new construction projects,
2. all major reconstruction projects,
3. all 3R projects, and
4. bridge widths, underpass widths and vertical clearances on spot improvement projects which involve work on a bridge. For other design elements, the design exception process will apply to spot improvements as discussed in Section 3-2.02.

6-6.03.02 Highway System/Funding Source

The design exception process will apply as follows:

1. NHS. The process will apply to all projects on the National Highway System regardless of the source of funding.
2. Non-NHS/State Highway System. The process will apply to all projects on State highways not on the NHS regardless of the source of funding.
3. Off State Highway System. The process will apply to all projects off the State highway system which include Federal and/or State funds. It will not apply to projects off the State highway system with 100% local funds.

6-6.04 Procedures for Exceptions

The designer will not request an exception to controlling design criteria until he/she has evaluated the impacts of providing the minimum or better design values. If these impacts are judged to be unacceptable, then the designer can initiate the exception process. The designer's goal will be to identify and seek approval of design exceptions as early in the final design phase as practical.

The following establishes the procedures the highway designer should follow for all proposed exceptions to design criteria:

1. The designer should present information to demonstrate the impacts of meeting the minimum or lower design criteria. This can include but is not limited to:
 - a. construction costs,
 - b. environmental consequences,
 - c. right-of-way impacts, and
 - d. community involvement/concerns.
2. The designer should provide sufficient information to demonstrate the consequences of using a design value which does not meet the minimum criteria. Where appropriate, this may include but is not limited to:
 - a. impacts on traffic serviceability (i.e., level of service);
 - b. impacts on safety (i.e., accident history);
 - c. impacts on traffic operations; and
 - d. impacts on future maintenance.
3. The designer should prepare a written summary of the information and submit it to the appropriate Division Manager for review.
4. The designer will then arrange a meeting through the office of the Engineering Administrator to discuss all proposed design exceptions. The meeting will usually be attended by the Engineering Administrator, Division Manager and the Project Manager and/or Engineer. The FHWA will also be represented for projects that require full FHWA oversight.

6-7.0 REFERENCES

1. *A Policy on Geometric Design of Highway and Streets*, AASHTO, 1994.
2. *Highway Capacity Manual*, TRB, 1994.
3. *Code of Federal Regulations 23*, Office of the Federal Register, published April 1 of every year.

Chapter Seven**SIGHT DISTANCE****Table of Contents**

	<u>Page</u>
7-1.0 STOPPING SIGHT DISTANCE	7-1(1)
7-2.0 DECISION SIGHT DISTANCE	7-2(1)
7-2.01 <u>Application</u>	7-2(1)
7-2.02 <u>Examples</u>	7-2(2)
7-3.0 INTERSECTION SIGHT DISTANCE	7-3(1)

Chapter Seven

SIGHT DISTANCE

7-1.0 STOPPING SIGHT DISTANCE

Stopping sight distance (SSD) is the sum of the distance traveled during a driver's perception/ reaction or brake reaction time and the distance traveled while braking to a stop. Figure 7-1A presents the range of SSD values used in design. The designer is referred to AASHTO *A Policy on Geometric Design of Highways and Streets* for the criteria and assumptions used to develop the SSD. The designer should always try to meet the upper values for SSD. The designer should also consider the following:

1. Height of Eye. When applying the SSD values, the height of eye is assumed to be 1070 mm.
2. Height of Object. The height of object is assumed to be 150 mm.
3. Rounding. The SSD values, as determined from the AASHTO equations, have been rounded up to the next highest 5-m increment.
4. Grade Adjustments. Because of gravitational forces, downgrades require greater distances for braking and upgrades require lesser distances. Figure 7-1A provides adjusted SSD values for grades. Selection of the appropriate gradient and SSD will be based on the longitudinal gradient at the site of the brake application. Note that for design exception purposes, only those values which do not meet or exceed the "Level" SSD criteria will require a design exception as discussed in Section 6-6.0.

Design Speed (km/h)	Average Running Speed (km/h)	f	Downgrades			Level	Upgrades		
			-9% (m)	-6% (m)	-3% (m)		0% (m)	+3% (m)	+6% (m)
30	30	0.40	35	35	35	30 - 30	30	30	30
40	40	0.38	50	50	50	45 - 45	45	45	45
50	47	0.35	75	70	70	65 - 60	65	60	60
60	55	0.33	105	95	90	85 - 75	85	80	80
70	63	0.31	140	130	120	115 - 95	110	105	100
80	70	0.30	180	165	150	140 - 115	135	130	125
90	77	0.30	215	200	185	170 - 135	165	160	155
100	85	0.29	260	245	225	205 - 160	200	190	185
110	91	0.28	330	295	270	250 - 180	240	230	220
120	98	0.28	385	345	315	290 - 205	275	265	255

Notes: 1. For grades intermediate between columns, use a straight-line interpolation to calculate SSD. For example:

$$V = 90 \text{ km/h}$$

$$G = -4.3\%$$

$$\text{Lower } \text{SSD} = 185 + \left(\frac{43 - 3}{6 - 3} \right) (200 - 185)$$

$$= 185 + 6.5$$

$$= 191.5 \text{ m}$$

2. See Section 9-3.0 for application of SSD to crest and sag vertical curves.

STOPPING SIGHT DISTANCE

Figure 7-1A

7-2.0 DECISION SIGHT DISTANCE

7-2.01 Application

At some sites, drivers may be required to make decisions where the highway environment is difficult to perceive or where unexpected maneuvers are required. These are areas of concentrated demand where the roadway elements, traffic volumes and traffic control devices may all compete for the driver's attention. This relatively complex environment may increase the required driver reaction time beyond that provided by the SSD values (2.5 seconds). At these locations, the designer should consider providing decision sight distance to provide an additional margin of safety. Decision sight distance reaction times range from 3 to 10 seconds depending on the location and expected maneuver. The various avoidance maneuvers used to develop Figure 7-2A are as follows:

1. Avoidance Maneuver A: Stop on rural road.
2. Avoidance Maneuver B: Stop on urban road.
3. Avoidance Maneuver C: Speed/path/direction change on rural road.
4. Avoidance Maneuver D: Speed/path/direction change on suburban road.
5. Avoidance Maneuver E: Speed/path/direction change on urban road.

Design Speed (km/h)	Decision Sight Distance for Avoidance Maneuver (m)				
	A	B	C	D	E
50	75	160	145	160	200
60	95	205	175	205	235
70	125	250	200	240	275
80	155	300	230	275	315
90	185	360	275	320	360
100	225	415	315	365	405
110	265	455	335	390	435
120	305	505	375	415	470

DECISION SIGHT DISTANCE

Figure 7-2A

In general, the designer should consider using decision sight distance at any relatively complex location where the driver reaction time may exceed 2.5 seconds. Example locations where decision sight distance may be appropriate include:

1. freeway exits;
2. freeway lane drops;
3. left-side entrances or exits;
4. at-grade intersections near a horizontal curve;
5. railroad/highway grade crossings;
6. detours;
7. along high-speed, high-volume urban arterials with considerable roadside friction; or
8. traffic signals on high-speed rural highways.

As with SSD, the height of eye is 1070 mm and the height of object is typically 150 mm. However, candidate sites for decision sight distance may also be candidate sites for assuming that the "object" is the pavement surface (e.g., freeway exits). Therefore, the designer should consider a 0.0-mm height of object for application at some sites.

7-2.02 Examples

* * * * *

Example 7-2.1

Given:

An exit on a suburban freeway under design (design speed = 100 km/h) is located just beyond a bridge. The freeway passes over. The grade on each side of the overpass is 3%. The freeway will carry high traffic volumes.

Problem: Determine the needed sight distance to the exit gore.

Solution:

A freeway exit is a major decision point for the driver, and the highway design should provide decision sight distance to the exit gore. The avoidance maneuver is a speed/path/direction change (i.e., Avoidance Maneuver D).

1. From Figure 7-2A, the decision sight distance = 365 m.
2. Calculate the length of the crest vertical curve for the freeway overpass. The algebraic difference in grade change is 6%. A height of object of 0.0 mm to the exit gore will be used. Section 9-3.0 provides the following equations for vertical curve lengths:

$$L = \frac{AS^2}{200 (\sqrt{h_1} + \sqrt{h_2})^2}$$

$$L = \frac{(6) (365)^2}{200 (\sqrt{1.07} + \sqrt{0.0})^2}$$

$$L = 3,735 \text{ m}$$

3. The calculated length of vertical curve is obviously unrealistic for normal design. Therefore, to meet the decision sight distance value, the designer should attempt to flatten the upgrade and downgrade of the crest vertical curve.

Example 7-2.2

Given:

An at-grade intersection is located just beyond a horizontal curve on an urban 2-lane highway. Both the highway and the intersection carry heavy traffic volumes. Frequent driveway entrances exist on the highway. The design speed is 70 km/h. The intersection has experienced a disproportionate number of rear-end accidents on the mainline. The existing conditions are:

$$R = 450 \text{ m}$$

$$\text{Middle ordinate} = 10 \text{ m}$$

$$\text{SSD} = 150 \text{ m}$$

Problem: Determine the need for any sight distance improvements.

Solution:

The combination of a horizontal curve, an intersection, high traffic volumes and frequent driveways presents a relatively complex situation for the driver. The high accident rate at the intersection indicates that the existing sight distance around the horizontal curve may be inadequate. This is true even though the existing sight distance exceeds the criteria for stopping sight distance at 70 km/h. Therefore, improvements should be considered to provide decision sight distance for a stop condition (i.e., Avoidance Maneuver B):

1. From Figure 7-2A, the decision sight distance = 250 m.
2. Calculate the middle ordinate needed for the horizontal curve (see Chapter Eight):

$$M = R \left(1 - \cos \frac{28.65S}{R} \right)$$

$$M = 450 \left(1 - \cos \frac{(28.65)(250)}{450} \right)$$

$$M = 17 \text{ m}$$

3. Therefore, the roadside obstructions along the horizontal curve should be cleared approximately an additional 7 m to provide the extra sight distance. If this is impractical, warning signs should be provided to give the driver advance warning of the situation consistent with the values for decision sight distance.

* * * * *

7-3.0 INTERSECTION SIGHT DISTANCE

Section 11-2.0 discusses the design requirements of sight distance for intersections at-grade.

Chapter Eight

HORIZONTAL ALIGNMENT

Table of Contents

<u>Section</u>		<u>Page</u>
8-1.0	DEFINITIONS	8-1(1)
8-2.0	RURAL HIGHWAYS/HIGH-SPEED URBAN HIGHWAYS	8-2(1)
8-2.01	<u>General Controls</u>	8-2(1)
8-2.02	<u>Horizontal Curvature</u>	8-2(2)
	8-2.02.01 Theoretical Discussion	8-2(2)
	8-2.02.02 Application	8-2(2)
	8-2.02.03 Types of Curvature	8-2(3)
8-2.03	<u>Superelevation Development</u>	8-2(5)
	8-2.03.01 Axis of Rotation	8-2(5)
	8-2.03.02 Transition Length (Two-Lane Roadways)	8-2(8)
	8-2.03.03 Transition Length (Multilane Highways)	8-2(8)
	8-2.03.04 Application of Transition Length	8-2(10)
	8-2.03.05 Effects of Curvature Type	8-2(10)
	8-2.03.06 Shoulder Superelevation	8-2(14)
	8-2.03.07 Typical Figures	8-2(14)
8-2.04	<u>Horizontal Sight Distance</u>	8-2(20)
	8-2.04.01 Sight Obstruction (Definition)	8-2(20)
	8-2.04.02 Length of Curve > Sight Distance	8-2(20)
	8-2.04.03 Length of Curve < Sight Distance	8-2(25)
	8-2.04.04 Application	8-2(25)
	8-2.04.05 Longitudinal Barriers	8-2(27)
8-2.05	<u>Crossover Line</u>	8-2(27)
8-3.0	LOW-SPEED URBAN STREETS	8-3(1)
8-3.01	<u>General Controls</u>	8-3(1)
8-3.02	<u>Horizontal Curvature</u>	8-3(1)

Table of Contents
(Continued)

		<u>Page</u>
8-3.02.01	Theoretical Discussion	8-3(1)
8-3.02.02	Application	8-3(1)
8-3.02.03	Types of Curvature	8-3(5)
8-3.03	<u>Superelevation Development</u>	8-3(5)
8-3.04	<u>Horizontal Sight Distance</u>	8-3(5)

Chapter Eight

HORIZONTAL ALIGNMENT

8-1.0 DEFINITIONS

1. Simple Curves. These are continuous arcs of constant radius which achieve the necessary highway deflection without an entering or exiting transition.
2. Compound Curves. These are a series of two or more simple curves with deflections in the same direction immediately adjacent to each other.
3. Reverse Curves. These are two simple curves with deflections in opposite directions which are joined by a relatively short tangent distance.
4. Broken-Back Curves. These are closely spaced horizontal curves with deflection angles in the same direction with an intervening, short tangent section.
5. Spiral Curves. A curve of continuously varying radius.
6. Superelevation (e). Superelevation is the amount of cross slope or "bank" provided on a horizontal curve to counterbalance, in combination with side friction, the centrifugal force of a vehicle traversing the curve.
7. Maximum Superelevation (e_{\max}). The maximum rate of superelevation (e_{\max}) is an overall superelevation control used on a specific facility. Its selection depends on several factors including climatic conditions, terrain conditions, type of area (rural or urban) and highway functional classification.
8. Side Friction (f). The interaction between the tire and the pavement surface to counterbalance, in combination with the superelevation, the centrifugal force of a vehicle traversing a horizontal curve.
9. Maximum Side Friction (f_{\max}). Limiting values selected by AASHTO for use in the design of horizontal curves. The designated f_{\max} values represent a threshold of driver discomfort and not the point of impending skid.
10. Superelevation Transition Length. The superelevation transition length is the distance required to transition the roadway from a normal crown section to full superelevation.

The superelevation transition length is the sum of the tangent runout (TR) and superelevation runoff (L) distances:

- a. Tangent Runout (TR). Tangent runout is the distance needed to change from a normal crown section to a point where the adverse cross slope of the outside lane or lanes is removed (i.e., the outside lane(s) is level).
 - b. Superelevation Runoff (L). Superelevation runoff is the distance needed to change the cross slope from the end of the tangent runout (adverse cross slope removed) to a section that is sloped at the design superelevation rate.
11. Axis of Rotation. The superelevation axis of rotation is the line about which the pavement is revolved to superelevate the roadway. This line will maintain the normal highway profile throughout the curve. The axis of rotation is generally located at the point of application of grade.
 12. Crossover Line. The lane line between any two adjacent lanes of traffic.
 13. Superelevation Rollover. Superelevation rollover is the algebraic difference (A) between the superelevated travel lane slope and shoulder slope on the outside of a horizontal curve.
 14. Normal Crown (NC). The typical cross section on a tangent section of roadway (i.e., no superelevation).
 15. Remove Adverse Crown (RC). A superelevated roadway section which is sloped across the entire traveled way in the same direction and at a rate equal to the cross slope on the tangent section.
 16. Relative Longitudinal Slope. In superelevation transition sections on two-lane facilities, the relative gradient between the profile grade and edge of traveled way.
 17. Open Roadways. All urban facilities with a design speed greater than 70 km/h and all rural facilities for all design speeds.
 18. Low-Speed Urban Streets. All streets within an urbanized or small urban area with a design speed of 70 km/h or less.
 19. Point of Application of Grade. The point on the cross section where the elevation of the calculated profile grade list is located.

8-2.0 RURAL HIGHWAYS/HIGH-SPEED URBAN HIGHWAYS

This section presents horizontal alignment criteria for all rural highways and for high-speed urban highways ($V \geq 80$ km/h). See Section 8-3.0 for horizontal alignment criteria for low-speed urban streets ($V \leq 70$ km/h).

8-2.01 General Controls

Much of the criteria for horizontal alignment seeks to establish minimum design values which are based on specific limiting factors. These include side-friction factors, superelevation, longitudinal gradients for superelevation transition, and middle ordinate values for sight distance. In addition, the designer should adhere to several general controls for horizontal alignment. These are based on aesthetic and safety considerations. They include:

1. Horizontal alignment should be as directional as possible. Where feasible, minimum radii should be avoided. Flatter curvature with shorter tangents is generally preferable to sharp curves connected by long tangents.
2. Curves with small deflection angles should be long enough to avoid the appearance of a kink. For a central angle of 5° or less, the curve should be at least 150-m long. On freeways, the designer should try to provide a curve length, in meters, of at least 6 times the design speed in km/h. On other major highways, try to provide a curve length 3 times the design speed.
3. Very small deflection angles may not require a horizontal curve; i.e., the roadway may be designed with an angular break. As a general guide, the designer may consider using an angle point when the deflection angle is less than 1° . The evaluation on the use of an angle point will be based on urban/rural location, aesthetics, construction costs and the visibility of the kink.
4. Broken back curvature should be avoided.
5. Sharp horizontal curves should not be introduced near crest or sag vertical curves. The combination of horizontal and vertical curves can greatly reduce sight distance, and the likelihood of accidents is increased.
6. Horizontal curves and superelevation transitions should be avoided on bridges. These cause design, construction and operational problems when snow and ice are present. The designer should not, however, avoid placing a curve on a bridge if this results in sharp horizontal curves on the approaching roadway. Where a curve is necessary on a bridge, a simple curve

should be used on the bridge, and any superelevation development should be placed on the approaching roadway.

7. Normally, simple circular curves will be used in design. However, spiral curves may be considered throughout the length of a curve to fit the roadway into a restricted roadside. Spiral transition curves should be considered in areas where high speeds are anticipated in combination with tight curvature. For additional information, refer to any available survey manual.
8. The crossover line will often be a control for setting the rates of superelevation and radius and profile where two roadways converge. Freeway gores are an example.
9. The radius of a ramp curve ending parallel to a freeway should be within 300 meters of the radius of the freeway.

8-2.02 Horizontal Curvature

8-2.02.01 Theoretical Discussion

From the laws of mechanics, the point mass formula for vehicular operation on a curve is used to define the curvature radius. The basic equation is:

$$R = \frac{V^2}{127(e+f)}$$

where: R = radius of curve, m
 e = superelevation rate (expressed as a decimal)
 f = side-friction factor
 V = vehicle speed, km/h

A number of assumptions are reflected in the values used in highway design for rural highways and high-speed urban highways. These apply both to the limiting values for curvature and to the method of determining superelevation for radii greater than the minimum. The designer should reference *A Policy on Geometric Design of Highways and Streets* for more information.

8-2.02.02 Application

Figure 8-2A provides design superelevation rates for combinations of radii and design speeds. The figure also provides the design lengths for superelevation runoff (from the end of the tangent runout

to full superelevation). This is discussed in detail in Section 8-2.03. Note that Figure 8-2A is based on $e_{\max} = 6.0\%$. In built-up areas where attaining the superelevation rates in Figure 8-2A is impractical, it is acceptable to use $e_{\max} = 4.0\%$. Refer to *A Policy on Geometric Design of Highways and Streets* for superelevation rates based on $e_{\max} = 4.0\%$.

Figure 8-2B presents the minimum radii for which the normal crown (NC) section can be maintained around the curve. Figure 8-2B also presents the radii for which remove (adverse) crown (RC) applies. In this range, it is considered sufficient to remove the crown and superelevate the pavement at a rate of 1.5%. These combinations of radii and design speed are also noted as "RC" in Figure 8-2A.

Design Speed (km/h)	Radius (m)		
	Normal Crown	Remove (Adverse) Crown	See Figure 8-2A
40	$R \geq 755$ m	$755 \text{ m} > R \geq 540$ m	$R < 540$ m
50	$R \geq 1050$ m	$1050 \text{ m} > R \geq 755$ m	$R < 755$ m
60	$R \geq 1445$ m	$1445 \text{ m} > R \geq 1040$ m	$R < 1040$ m
70	$R \geq 1905$ m	$1905 \text{ m} > R \geq 1375$ m	$R < 1375$ m
80	$R \geq 2360$ m	$2360 \text{ m} > R \geq 1710$ m	$R < 1710$ m
90	$R \geq 2870$ m	$2870 \text{ m} > R \geq 2085$ m	$R < 2085$ m
100	$R \geq 3515$ m	$3515 \text{ m} > R \geq 2560$ m	$R < 2560$ m
110	$R \geq 4065$ m	$4065 \text{ m} > R \geq 2970$ m	$R < 2970$ m
120	$R \geq 4770$ m	$4770 \text{ m} > R \geq 3510$ m	$R < 3510$ m

*Note: Flatter radius is based on a theoretical superelevation rate of +.015.
 Sharper radius is based on a theoretical superelevation rate of +.020.*

RANGE OF RADII FOR NORMAL CROWN SLOPE AND REMOVE CROWN SLOPE

Figure 8-2B

8-2.02.03 Types of Curvature

Horizontal curves are necessary to achieve deflectional changes in alignment on the roadway. This may be accomplished by one of two methods — a simple curve or a compound curve. The following discusses each of the horizontal curvature types:

R* (m)	V = 40 km/h			V = 50 km/h			V = 60 km/h			V = 70 km/h			V = 80 km/h			V = 90 km/h			V = 100 km/h			V = 110 km/h			V = 120 km/h		
	e (%)	L (m)		e (%)	L (m)		e (%)	L (m)		e (%)	L (m)		e (%)	L (m)		e (%)	L (m)		e (%)	L (m)		e (%)	L (m)		e (%)	L (m)	
		A	B		A	B		A	B		A	B		A	B		A	B		A	B		A	B		A	B
7000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
5000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
3000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	56	84	RC	61	92	RC	61	92	2.3	67	101
2500	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	50	75	2.1	56	84	2.3	61	92	2.7	67	101
2000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	44	66	2.1	50	75	2.5	56	84	2.8	61	92	3.3	67	101
1500	NC	0	0	NC	0	0	NC	0	0	RC	39	59	2.2	44	66	2.7	50	75	3.1	56	84	3.6	61	92	4.2	67	101
1400	NC	0	0	NC	0	0	NC	0	0	RC	39	59	2.4	44	66	2.8	50	75	3.3	56	84	3.8	61	92	4.4	67	101
1300	NC	0	0	NC	0	0	RC	33	50	2.1	39	59	2.5	44	66	3.0	50	75	3.5	56	84	4.0	61	92	4.7	67	101
1200	NC	0	0	NC	0	0	RC	33	50	2.2	39	59	2.7	44	66	3.2	50	75	3.7	56	84	4.2	61	92	5.0	67	101
1000	NC	0	0	RC	28	42	2.1	33	50	2.6	39	59	3.1	44	66	3.6	50	75	4.2	56	84	4.8	61	92	5.5	67	101
900	NC	0	0	RC	28	42	2.3	33	50	2.8	39	59	3.4	44	66	3.9	50	75	4.5	56	84	5.1	61	92	5.8	67	101
800	NC	0	0	RC	28	42	2.5	33	50	3.1	39	59	3.6	44	66	4.2	50	75	4.9	56	84	5.4	61	92	6.0	67	101
700	RC	22	33	2.1	28	42	2.8	33	50	3.4	39	59	4.0	44	66	4.6	50	75	5.2	56	84	5.7	61	92	R _{min} = 760		
600	RC	22	33	2.4	28	42	3.1	33	50	3.8	39	59	4.3	44	66	5.0	50	75	5.6	56	84	6.0	61	92	R _{min} = 565		
500	2.1	22	33	2.8	28	42	3.5	33	50	4.2	39	59	4.8	44	66	5.4	50	75	5.9	56	84	R _{min} = 440					
400	2.5	22	33	3.3	28	42	4.0	33	50	4.7	39	59	5.3	44	66	5.9	50	75	R _{min} = 340								
300	3.1	22	33	3.9	28	42	4.6	33	50	5.4	39	59	5.9	44	66	R _{min} = 255											
250	3.5	22	33	4.2	28	42	5.0	33	50	5.7	39	59	6.0	44	66	R _{min} = 195											
200	3.9	22	33	4.7	28	42	5.5	33	50	6.0	39	59	R _{min} = 135														
175	4.1	22	33	5.0	28	42	5.8	35	52	R _{min} = 90																	
150	4.4	23	34	5.3	29	43	5.9	35	53	R _{min} = 55																	
140	4.5	23	35	5.4	29	44	6.0	36	54	R _{min} = 55																	
130	4.6	24	36	5.6	30	45	R _{min} = 55																				
120	4.8	25	37	5.7	31	46	R _{min} = 55																				
110	5.0	26	39	5.8	31	47	R _{min} = 55																				
100	5.2	27	40	5.9	32	48	R _{min} = 55																				
90	5.4	28	42	6.0	32	49	R _{min} = 55																				
80	5.6	29	43	R _{min} = 55																							
70	5.8	30	45	R _{min} = 55																							
60	6.0	31	46	R _{min} = 55																							

e_{max} = 6.0%

- Key:
- R = Radius of curve (m)
 - V = Design speed (km/h)
 - e = Superelevation rate
 - L = Minimum length of superelevation runoff (from adverse cross slope removed to full super) (m)
 - A = "L" for 2-lane, 2-way roadway rotated about the centerline
 - B = "L" for 4-lane divided highway rotated about the two median edges
 - NC = Normal crown
 - RC = Remove (adverse) crown

Note: See Figure 8-2E for superelevation runoff lengths for conditions other than "A" and "B."

* For curve radii intermediate between table values, use a straight-line interpolation to determine the superelevation rate.

**RATE OF SUPERELEVATION AND MINIMUM LENGTH OF RUNOFF
(Rural Highways and High-Speed (V ≥ 80 km/h) Urban Highways)**

Figure 8-2A

1. Simple Curves. A simple curve is a constant, circular radius which achieves the desired deflection without using an entering or exiting transition. Considering their simplicity and ease of design, survey and construction, this type of curve is used most often by the Department. Figure 8-2C illustrates a typical simple curve layout.
2. Compound Curves. Compound curves are often used to avoid some control or obstacle which cannot be relocated. Compound curves can be developed with any number of individual simple curves (2-centered, 3-centered, etc.), and they can be symmetrical or asymmetrical. The geometry of each curve within the compound curvature arrangement is identical to that of a simple curve (Figure 8-2C). Figure 8-2D provides the layout of a symmetrical, 3-centered curve. This is only one example of how a compound curve can be designed.

When compound curves are used on mainline, the radius of the flatter circular arc (R_1) should not be more than 50 percent greater than that of the sharper arc (R_2); i.e., $R_1 \leq 1.5R_2$.

8-2.03 Superelevation Development

8-2.03.01 Axis of Rotation

The axis of rotation is the line about which the pavement is revolved to superelevate the roadway. This line will maintain the normal highway profile throughout the horizontal curve.

On 2-lane and undivided multilane highways, the axis of rotation will almost always be the centerline of the roadway (see Figure 8-2G). This method results in the least amount of elevation differential between the edges of the travel lanes and their normal profile. For 2-lane roadways, the designer will use the lengths from Column A in Figure 8-2A. Occasionally, it may be warranted to rotate the pavement about the inside edge of the travel lane. This may be preferable when the lower edge profile is a major control, as for drainage. For 2-lane roadways in this case, the designer will use the lengths from Column B in Figure 8-2A.

Divided highways with medians require special consideration. The basic choices for selecting the axis of rotation are:

1. Rotate about the centerline of the median, which will also be the centerline of the entire roadway section.
2. Rotate about the two median edges and hold the median in a horizontal plane.

CURVE SYMBOLS

- Δ = Deflection Angle, degrees
 T = Tangent Distance = distance from PC to PI = distance from PI to PT
 L = Length of curve in meters = distance from PC to PT along curve
 R = Radius of curve
 E = External Distance (PI to mid-point of curve)
 LC = Length of long chord — PC to PT
 M = Middle Ordinate (mid-point of arc to mid-point of long chord)

CIRCULAR CURVE ABBREVIATIONS

- P.C. = PC = Point of Curvature (Beginning of Curve)
 P.T. = PT = Point of Tangency (End of Curve)
 P.I. = PI = Point of Intersection of Tangents
 P.C.C. = PCC = Point of Compound Curvature

CURVE FORMULA

$$T = R(\tan (\Delta / 2)) = R \frac{\sin (\Delta / 2)}{\cos (\Delta / 2)}$$

$$L = \frac{\Delta}{360} 2\pi R$$

$$E = \frac{R}{\cos (\Delta / 2)} - R$$

$$E = T \tan (\Delta / 4)$$

$$LC = 2R (\sin (\Delta / 2)) = 2T (\cos (\Delta / 2))$$

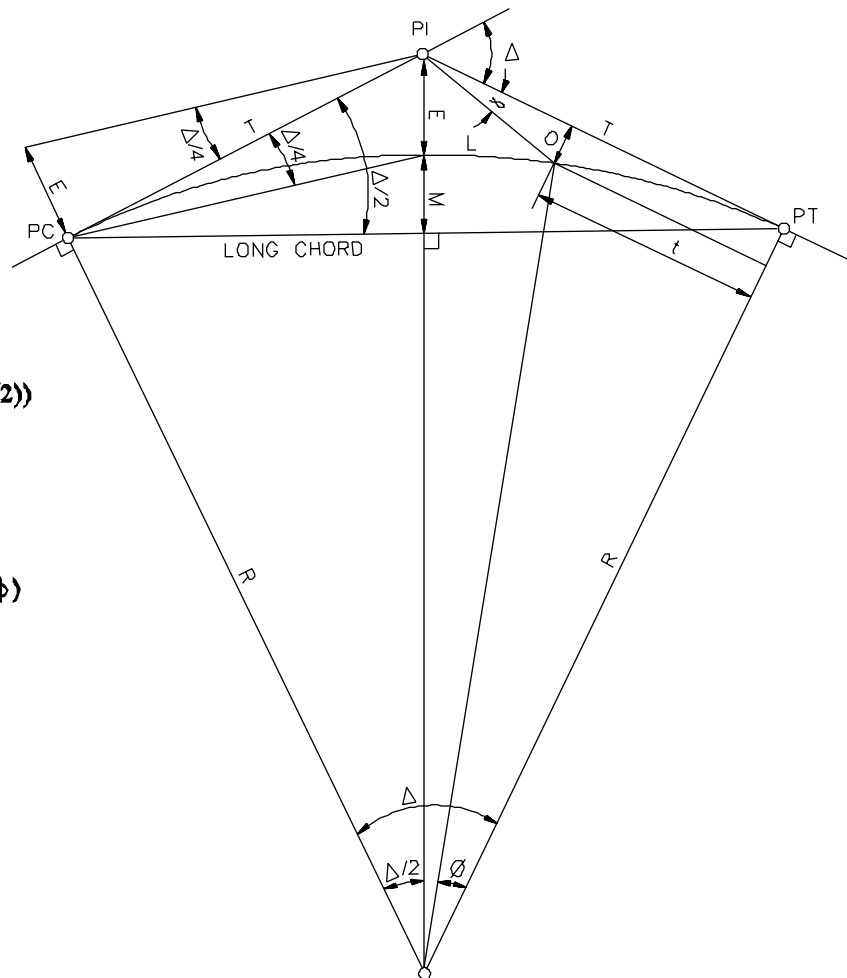
$$M = R(1 - \cos (\Delta / 2))$$

$$M = E \cos (\Delta / 2)$$

$$O = R - \sqrt{R^2 - t^2} = R - R (\cos \phi)$$

$$\tan \alpha = \frac{1 - \cos \phi}{\tan (\Delta / 2) - \sin \phi}$$

$$\pi = 3.141592653$$



LAYOUT OF SIMPLE CURVE

Figure 8-2C

Equations for Any Two-Centered Compound Curves:

$$I = \text{Total Deflection Angle} = \Delta_1 + \Delta_2$$

$$X = R_2 \sin I + (R_1 - R_2) \sin \Delta_1$$

$$Y = R_1 - R_2 \cos I - (R_1 - R_2) \cos \Delta_1$$

$$T_b = \frac{Y}{\sin I}$$

$$T_a = X - T_b \cos I$$

Equations for Any Three-Centered Compound Curves:

$$I = \text{Total Deflection Angle} = \Delta_1 + \Delta_2 + \Delta_3$$

$$X = (R_1 - R_2) \sin \Delta_1 + (R_2 - R_3) \sin (\Delta_1 + \Delta_2) + R_3 \sin I$$

$$Y = R_1 - R_3 \cos I - (R_1 - R_2) \cos \Delta_1 - (R_2 - R_3) \cos (\Delta_1 + \Delta_2)$$

$$T_b = \frac{Y}{\sin I}$$

$$T_a = X - T_b \cos I$$

Equations for Symmetrical Three-Centered Compound Curve ($R_1 = R_3$; $\Delta_1 = \Delta_3$, as shown in Figure):

$$I = \text{Total Deflection Angle} = 2 \Delta_1 + \Delta_2$$

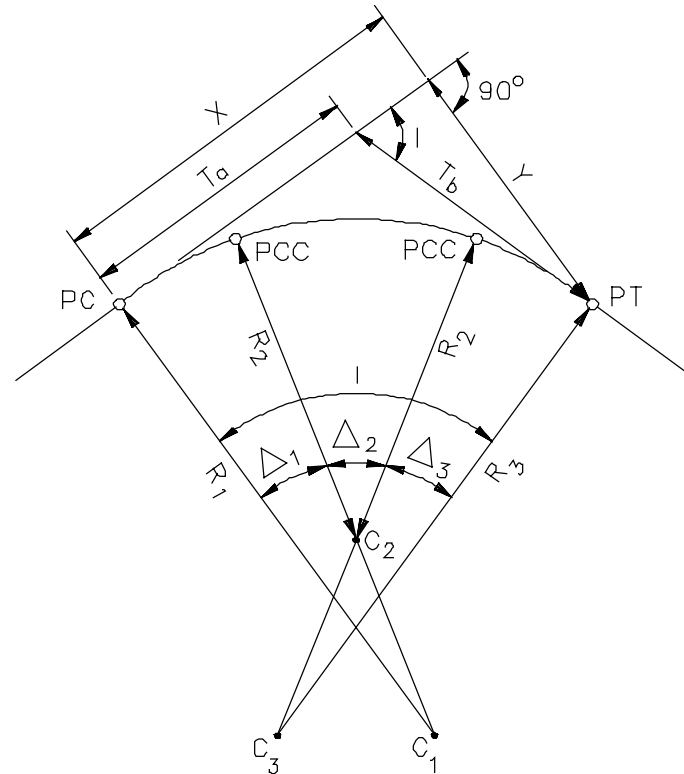
$$X = (R_1 - R_2) \sin \Delta_1 + (R_2 - R_1) \sin (\Delta_1 + \Delta_2) + R_1 \sin I$$

$$Y = R_1 - R_2 \cos I - (R_1 - R_2) \cos \Delta_1 - (R_2 - R_1) \cos (\Delta_1 + \Delta_2)$$

$$T_b = \frac{Y}{\sin I}$$

$$T_a = X - T_b \cos I$$

Note: $R_1 \leq 1.5 R_2$



Note: This is only one example of how a compound curve can be designed.

SYMMETRICAL THREE-CENTERED COMPOUND CURVE

Figure 8-2

3. Rotate each roadway separately and provide a compensating slope in the median.
4. On roadways with independent alignment, rotate each one separately.

Several highway features may significantly influence the superelevation development for divided highways. These include guide rail, median barriers and drainage. The designer should carefully consider the intended function of these features and ensure that the superelevated section does not compromise their operation. Chapters Four and Five provide typical cross section figures for superelevated urban and rural highways for both divided and undivided highways.

8-2.03.02 Transition Length (Two-Lane Roadways)

The superelevation transition length is the distance required to transition the roadway from a normal crown section to the full superelevation needed. The length combines both the tangent runout distance (TR) and the superelevation runoff length (L).

Figure 8-2A presents the lengths of superelevation runoff. The tangent runout length, which is the distance from the normal crown to where the adverse cross slope is removed, is in addition to the superelevation runoff length. Typically, the relative longitudinal gradient for the tangent runout will be set equal to that for the superelevation runoff. The designer may also use graphical methods to determine the tangent runout.

8-2.03.03 Transition Length (Multilane Highways)

The superelevation runoff distance for multilane highways is calculated by:

$$L = C \times L_2$$

where:

L = Superelevation runoff length for multilane highway, m

L₂ = Superelevation runoff length for a 2-lane roadway, m

C = Ratio of runoff length for a multilane highway to runoff length for a 2-lane roadway (see Figure 8-2E)

Number of Lanes Being Rotated*	C
One	1.0
Two	1.5**
Three	2.0
Four	2.5

* *This column refers to the number of lanes being rotated on either side of the axis rotation. Select the higher value. For example, if the axis of rotation for a 3-lane roadway is about the edge of the interior lane, two lanes will be rotated on one side of the axis and one lane will be rotated on the other side. The higher number is two, and C is 1.5.*

Note also that a $C = 1.5$ should be used to determine the superelevation runoff length for a 2-lane, 2-way roadway where the axis of rotation is about either edge of the travelway.

As another example, consider a 5-lane roadway (i.e., four through lanes and a two-way, left-turn lane (TWLTL)) with the axis of rotation in the center of the TWLTL. In this case, the number of lanes being rotated is 2.5; therefore, $C = 1.75$.

** *Column B in Figure 8-2A presents values based on $C = 1.5$.*

C VALUES
(Superelevation Runoff Lengths, Multilane Highways)

Figure 8-2E

8-2.03.04 Application of Transition Length

The location of the transition length may be shifted within the indicated limits to obtain practical beginning and ending points. In most cases, the designer will likely locate the transition termini at the nearest 20-m or 40-m station. In addition, the designer should examine the relationship between the horizontal and vertical alignment to provide a desirable visual impact.

8-2.03.05 Effects of Curvature Type

Horizontal curvature may be a simple curve or a compound curve. Superelevation development will vary for each type. In addition, superelevation development must be carefully addressed at closely spaced reverse curves. Each is discussed:

1. Simple Curves. The typical figures in Section 8-2.03.07 illustrate superelevation development for simple curves. The designer must distribute the placement of the transition length between the tangent section (where no superelevation is needed) and the curve section (where full superelevation is needed). No distribution method can be completely justified. As an approximation, 60% - 80% of the full superelevation should be reached at the PC. If practical, try to provide $0.67e$ at the PC. This superelevation rate will be reached at 0.67 of the superelevation runoff length.
2. Compound Curvature. The typical figure in Section 8-2.03.07 illustrates the superelevation development for compound curvature. These criteria should be met:
 - a. If the distance between the PC and PCC or between two PCC points is less than or equal to 90 m, a uniform longitudinal gradient should be used throughout the transition.
 - b. If the distance between the PC and PCC or between two PCC points is more than 90 m, it may be preferable to consider the two curves separately. Superelevation for the entering curve would be developed by the distribution method used for simple curves. This superelevation rate (e_f) would be maintained until it is necessary to develop the remaining superelevation of the sharper curve.
 - c. The minimum superelevation runoff length in Figure 8-2A applies to the superelevation development for the sharpest or controlling curve; i.e., this length is used from the end of the tangent runout to the PCC of the controlling curve.
 - d. Superelevation should be developed so that, for the first and last curve, two-thirds of the design superelevation rate for those curves will be attained at the PC or PT.

- e. Superelevation should be developed so that, for all interior curves, the design superelevation rate will be available at the PCC.

Example 8-2.1 illustrates how to develop superelevation on compound curves.

* * * * *

Example 8-2.1

Given: $V = 100$ km/h
 $R = 1200$ m
 2-lane roadway
 3.6-m lanes
 1.5% typical cross slope

Problem: Develop the details using a symmetrical compound curve.

Solution:

Compound curvature will be used to enter and exit from the 1200-m controlling curve. Figure 8-2F illustrates the compound curvature. The following outlines the steps necessary for the calculations:

- a. Section 8-2.02.03 states that, when compound curvature is used, the radius of the flatter arc must not be more than 50 percent of the radius of the sharper arc. Therefore, the curves adjacent to the interior curve ($R = 1200$ m) will have radii of $(1.5)(1200) = 1800$ m.
- b. A 3-centered compound curve will be used with radii:

$$R_1 = 1800 \text{ m}$$

$$R_2 = 1200 \text{ m}$$

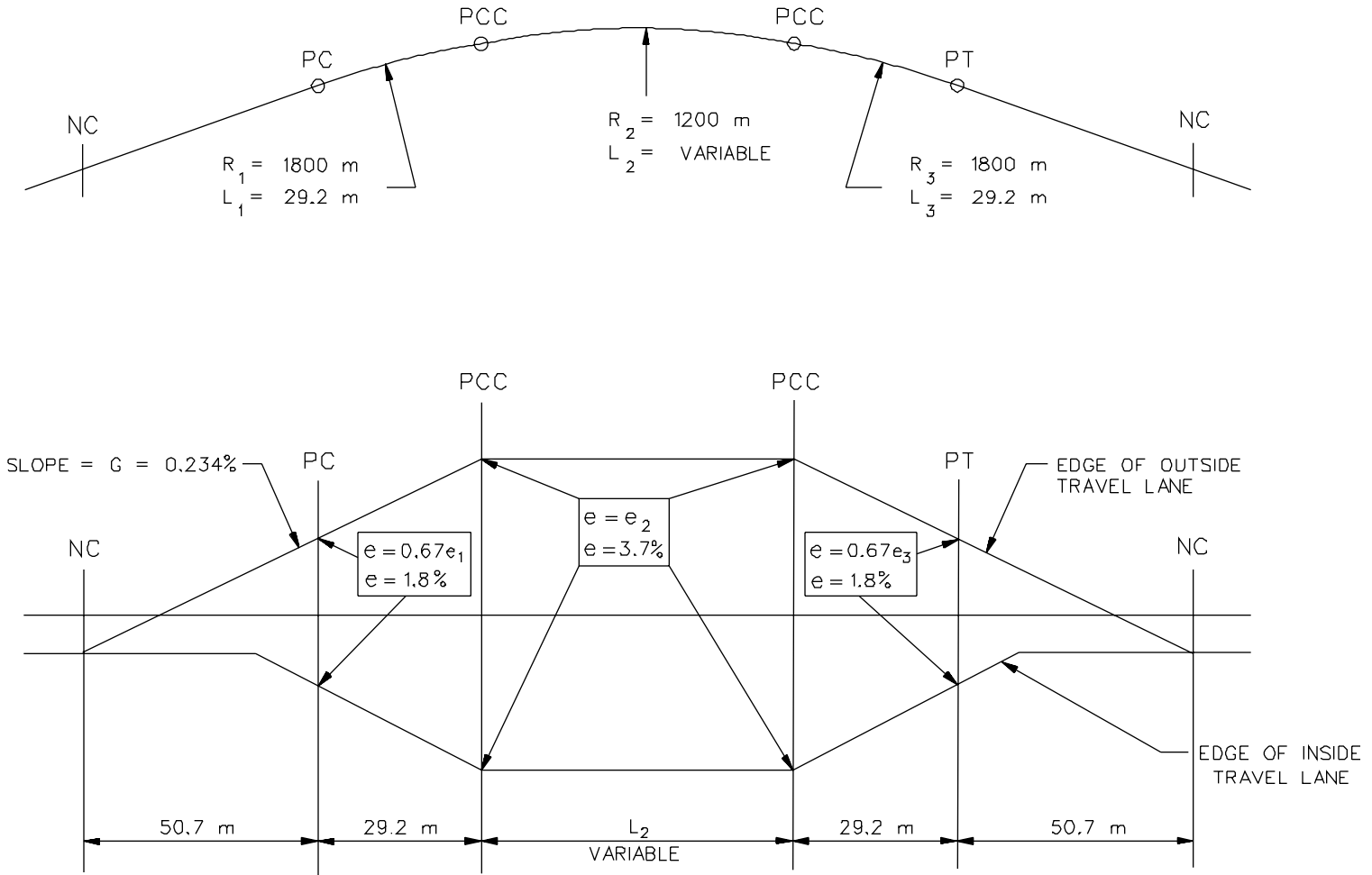
$$R_3 = 1800 \text{ m}$$

- c. The roadway section must be transitioned from its normal crown ($1.5\% = .015$) to the design superelevation for the 1200-m curve. The following approach should be used:

- Figure 8-2A yields:

$$R_1 = R_3 = 1800 \text{ m}, e_1 = e_3 = 2.7\% = .027$$

$$R_2 = 1200 \text{ m}, e_2 = 3.7\% = .037$$



SUPERELEVATION DEVELOPMENT ON A COMPOUND CURVE
(Example 8-2.1)

Figure 8-2F

- ▶ The pavement will be rotated about its centerline. Therefore, the minimum superelevation runoff length (L_2) from Column A in Figure 8-2A is 56 m. Using the relative longitudinal gradient for the superelevation runoff, the tangent runout distance (TR) is 23 m. Therefore, the total transition length from NC to full superelevation is 79 m (use 80 m). This length will apply to reaching e_2 at the PCC for R_2 . This is a practical application of the minimum transition length criteria to compound curvature.
- ▶ One objective is to use a uniform longitudinal gradient (G) to reach e_2 from NC. Therefore:

$$G = \frac{W(e + .015)}{L_2 + TR} = \frac{(3.6)(.037 + .015)}{80} = 0.234\%$$

- ▶ One objective is to reach $0.67e_1$ at the PC for R_1 . This can be accomplished by setting the length of the entering curve (L_1) (from the PC to the PCC) as follows:

$$e @ PC = 0.67 e_1 = (0.67)(.027) = .018$$

$$e @ PCC = e_2 = .037$$

$$L_1 = \frac{(3.6)(.037 - .018)}{0.00234}$$

$$L_1 = 29.2 \text{ m}$$

- d. This approach to developing superelevation on compound curves can result in relatively short lengths of curve segments, especially where there are several curves compounded (e.g., 5 or more). The designer should consider lengthening these curves to a practical minimum. However, it is considered more important to maintain a uniform longitudinal gradient and to achieve the design superelevation at each PCC throughout the curve. The designer may need to try several combinations of curve lengths, longitudinal gradients and superelevation gradients to find the most practical design.

3. Reverse Curves. For closely spaced reverse curves, it is not necessary to achieve an intermediate crowned section between the curves; i.e., a continuously rotating plane may be provided. The designer should adhere to the applicable superelevation development criteria for each curve. For example, assume that each curve is a simple curve and assume

that 0.67 of the full superelevation is provided at the PT and PC. This means that the minimum length of the tangent section between the PT and PC is:

$$L_{\text{tan}} = 0.67L_1 + TR_1 + TR_2 + 0.67L_2$$

where:

L_{tan}	=	Tangent distance between PT and PC, m
L_1	=	Superelevation runoff length for first curve, m
TR_1	=	Tangent runout length for first curve, m
TR_2	=	Tangent runout length for second curve, m
L_2	=	Superelevation runoff length for second curve, m

It is undesirable to have a zero tangent distance between the two curves (i.e., where the PT of the first curve is coincident with the PC of the second curve). This type of alignment requires the driver to shift his steering from a curve in one direction to a curve in the other at exactly the point of reverse curvature if he is to remain within his lane. It is not possible to have a minimum amount of superelevation at the beginning of the curve, and transitions are more difficult. This lowers the effective design speed of the curve within the transition zone. It is preferable to use tighter radii to provide the tangent length required to effect the introduction of superelevation and allow the driver time to react. In general, even under restricted conditions, 2.5 seconds of travel time should be provided on a tangent section.

8-2.03.06 Shoulder Superelevation

Figures 4H and 5J provide the detail for shoulder superelevation on the high side of the roadway. This detail will apply when the shoulder width is 1.2 m or more and will apply to the entire range of superelevation rates (1.5% to 6.0%). When the shoulder width is less than 1.2 m, it will be superelevated at the same rate and in the same direction as the travel lane. In this case, the designer should ensure that the drainage for the area beyond the roadway will not flow into the roadway.

On the low side, the shoulder cross slope will remain equal to its rate on the tangent section until the superelevated rate exceeds that value. Then, the shoulder will be sloped at the same rate as the superelevated travel lanes.

Section 10-1.02.02 contains criteria on shoulders across superelevated bridges.

8-2.03.07 Typical Figures

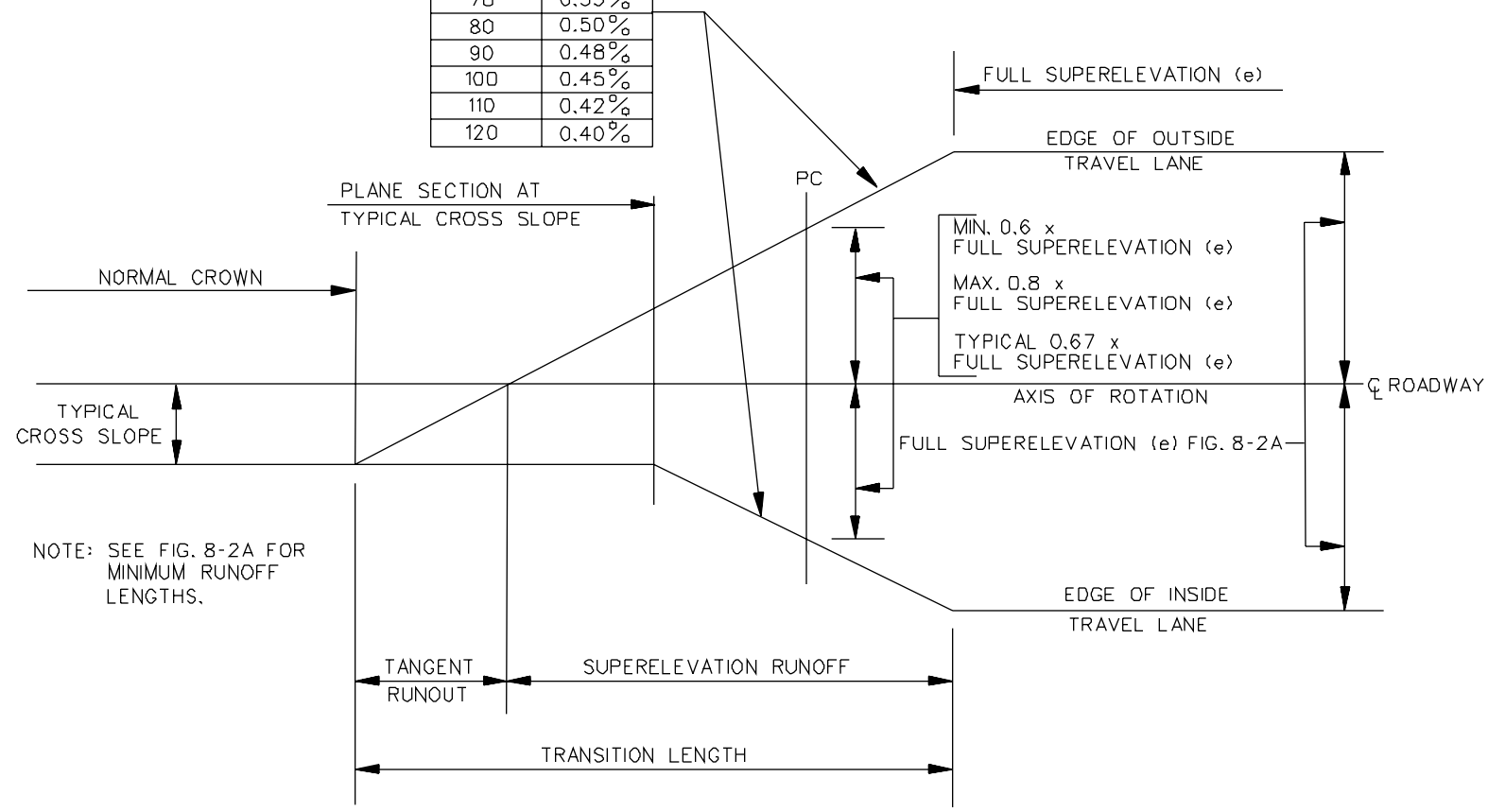
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Based on the discussion in the previous sections, the following figures illustrate the Department's methods for superelevation development:

1. Figure 8-2G is applicable to 2-lane roadways rotated about the centerline where a simple curve is used.
2. Figure 8-2H is applicable to 2-lane roadways rotated about the centerline where compound curvature is provided.
3. Figure 8-2I is applicable to roadways with three or four lanes where a simple curve is used. The axis of rotation is about the centerline (4-lane roadways) or about one inside edge of travel lane (3-lane roadways). If a compound curve is used, the designer will modify the superelevation development as illustrated in Figure 8-2H.
4. Figure 8-2J is applicable to roadways with five or six lanes where a simple curve is used. The axis of rotation is about the centerline (6-lane roadway) or about either edge of the center lane (5-lane roadways). If a compound curve is used, the designer will modify the superelevation development as illustrated in Figure 8-2H.

MAXIMUM RELATIVE LONGITUDINAL SLOPE (G) BETWEEN PROFILES OF OUTSIDE EDGES OF TRAVELED WAY AND AXIS OF ROTATION (C_R ROADWAY)

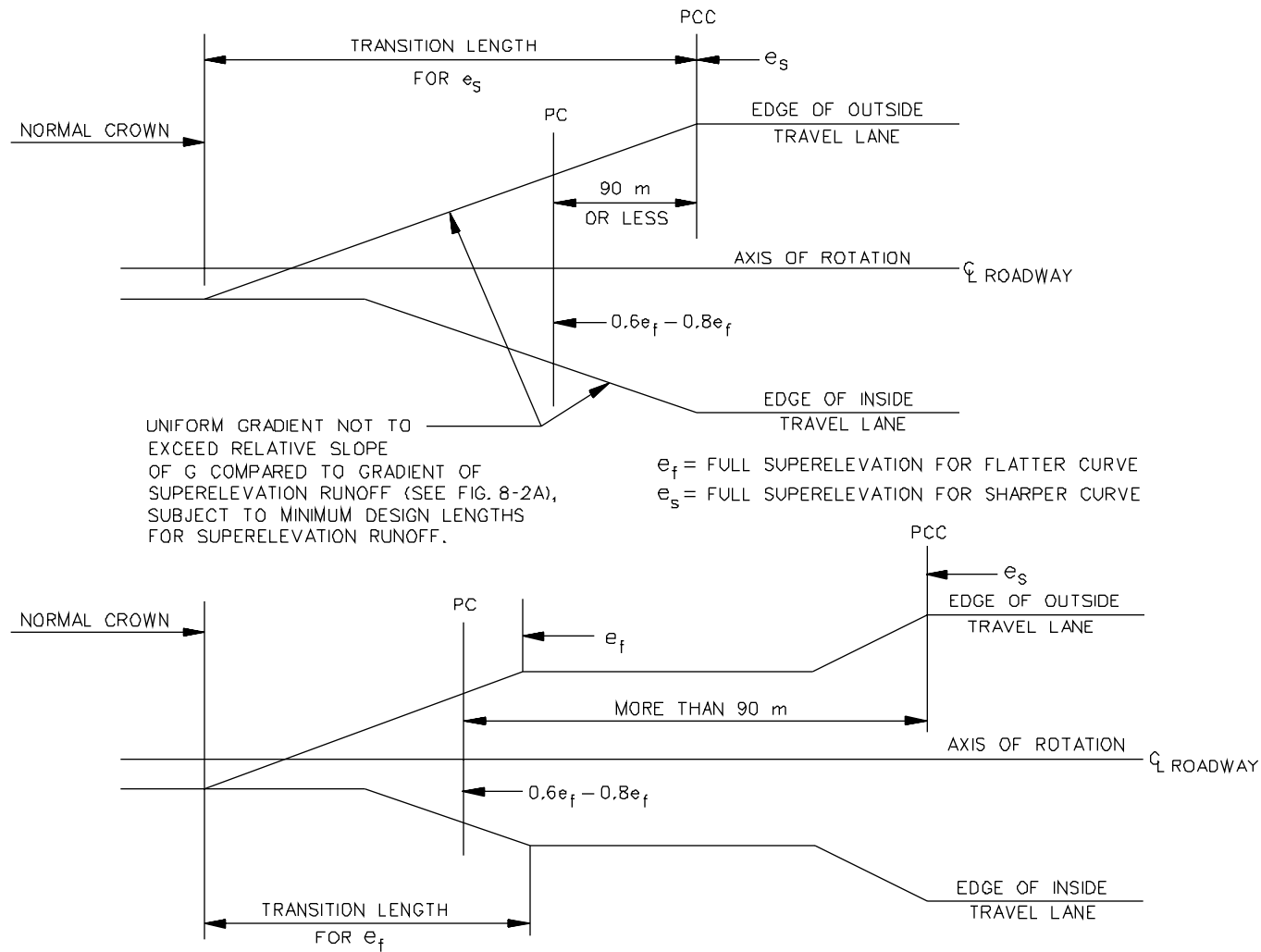
DESIGN SPEED (km/h)	SLOPE (G)
40	0.70%
50	0.65%
60	0.60%
70	0.55%
80	0.50%
90	0.48%
100	0.45%
110	0.42%
120	0.40%



NOTE: SEE FIG. 8-2A FOR MINIMUM RUNOFF LENGTHS.

**SUPERELEVATION DEVELOPMENT ON TWO-LANE ROADWAYS
(Simple Curve)**

Figure 8-2G



**SUPERELEVATION DEVELOPMENT ON TWO-LANE ROADWAYS
(Compound Curves)**

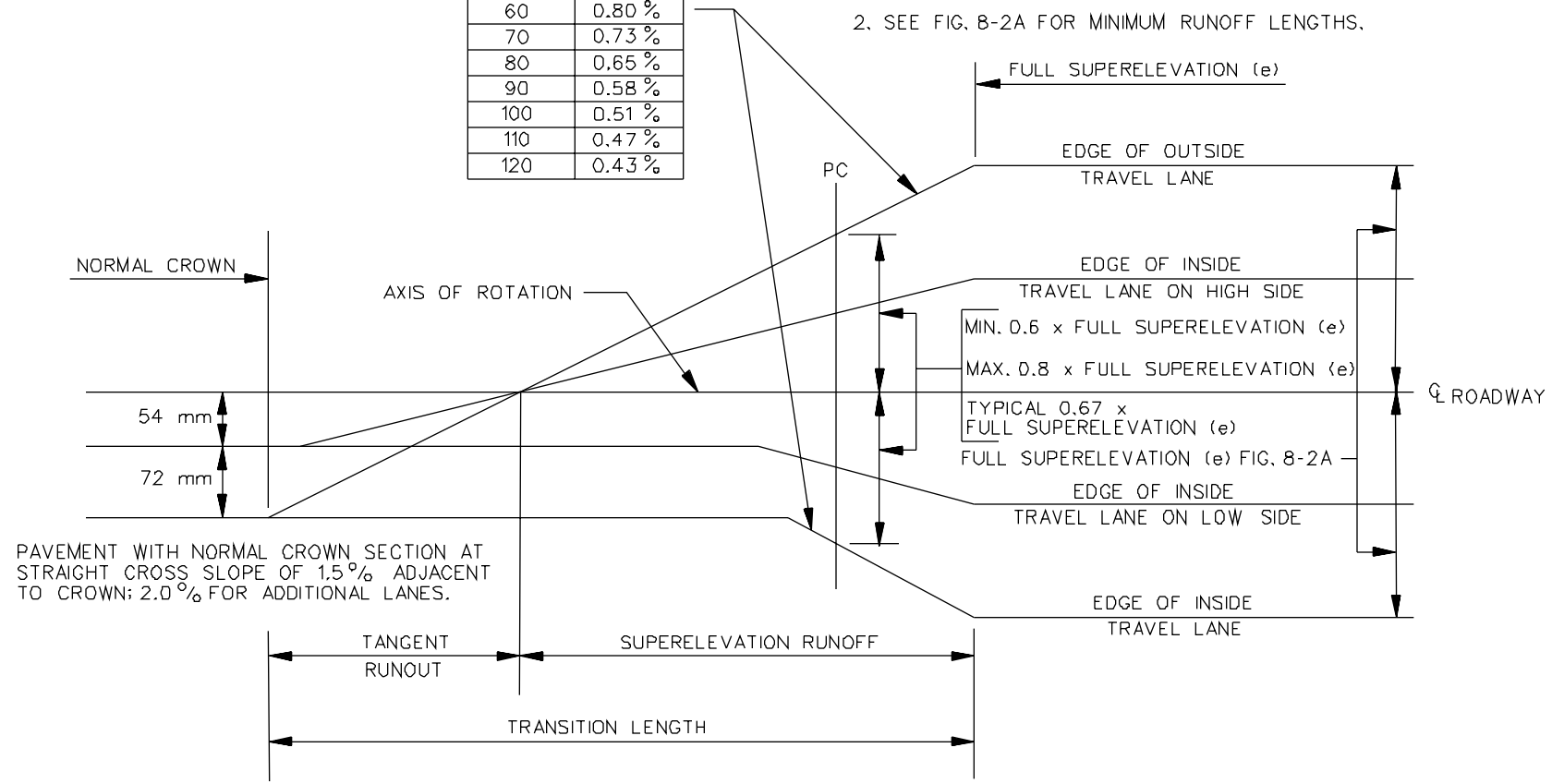
Figure 8-2H

MAXIMUM RELATIVE LONGITUDINAL SLOPE (G) BETWEEN PROFILES OF OUTSIDE EDGES OF TRAVELED WAY AND AXIS OF ROTATION (CL ROADWAY)

DESIGN SPEED (km/h)	SLOPE (G)
40	0.94 %
50	0.88 %
60	0.80 %
70	0.73 %
80	0.65 %
90	0.58 %
100	0.51 %
110	0.47 %
120	0.43 %

NOTES:

1. MODIFY SUPERELEVATION DEVELOPMENT FOR COMPOUND CURVES ACCORDING TO METHODS ILLUSTRATED IN FIG. 8-2H.
2. SEE FIG. 8-2A FOR MINIMUM RUNOFF LENGTHS.



SUPERELEVATION DEVELOPMENT ON THREE-LANE AND FOUR-LANE ROADWAYS (Simple Curve)

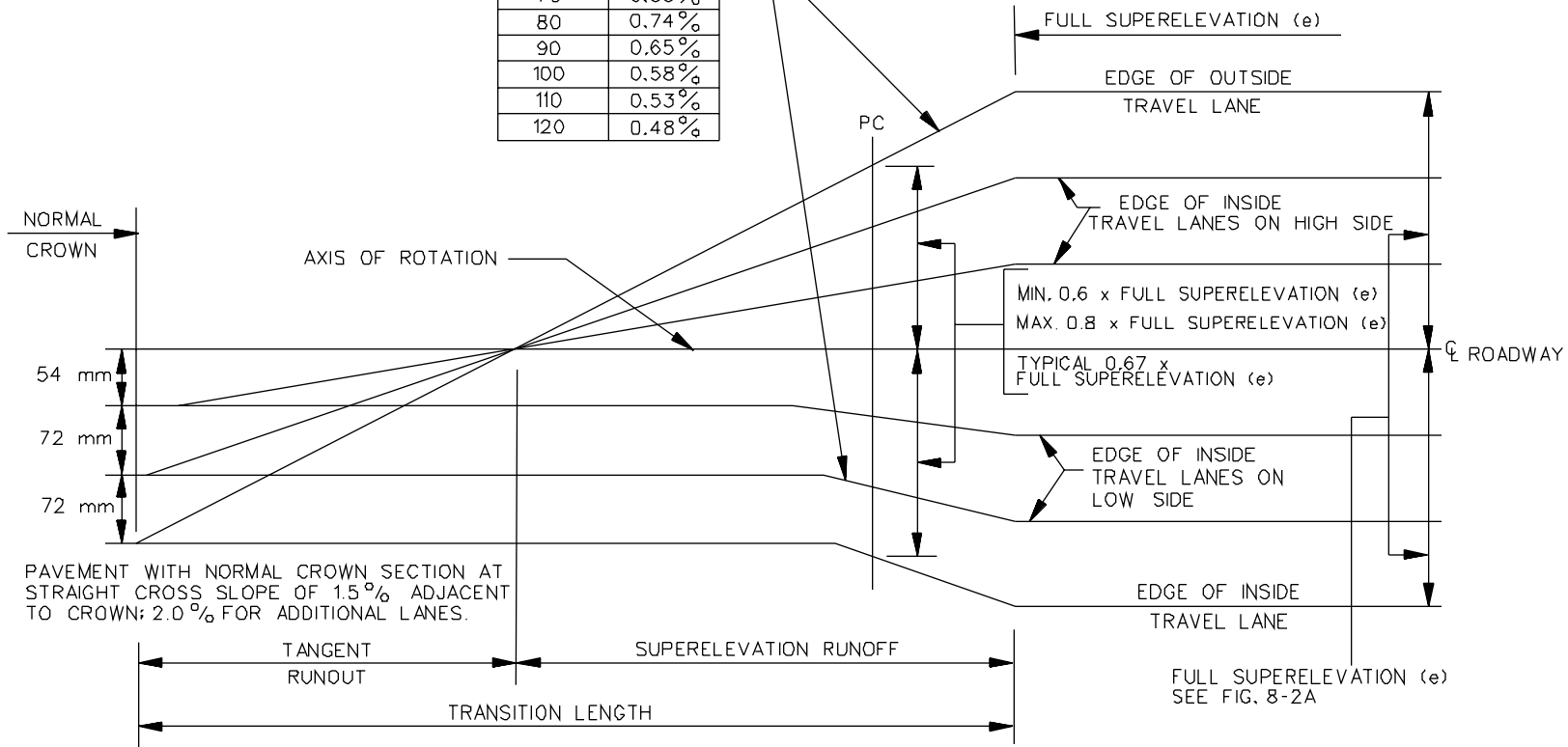
Figure 8-2I

MAXIMUM RELATIVE LONGITUDINAL SLOPE (G) BETWEEN PROFILES OF OUTSIDE EDGES OF TRAVELED WAY AND AXIS OF ROTATION (CL ROADWAY)

DESIGN SPEED (km/h)	SLOPE (G)
40	1.04%
50	1.01%
60	0.90%
70	0.83%
80	0.74%
90	0.65%
100	0.58%
110	0.53%
120	0.48%

NOTES:

1. MODIFY SUPERELEVATION DEVELOPMENT FOR COMPOUND CURVES ACCORDING TO METHODS ILLUSTRATED IN FIG. 8-2H.
2. SEE FIG. 8-2A FOR MINIMUM RUNOFF LENGTHS.



**SUPERELEVATION DEVELOPMENT ON FIVE-LANE AND SIX-LANE ROADWAYS
(Simple Curve)**

Figure 8-2J

8-2.04 Horizontal Sight Distance

The designer must evaluate the impact of sight obstructions which are located laterally on the inside of horizontal curves. These may interfere with the required sight distance and should be removed if practical.

8-2.04.01 **Sight Obstruction (Definition)**

Sight obstructions on the inside of a horizontal curve are defined as obstacles of considerable length which interfere with the line of sight on a continuous basis. These include walls, cut slopes, wooded areas, buildings and high farm crops. In general, point obstacles such as traffic signs and utility poles are not considered sight obstructions on the inside of horizontal curves. The designer must examine each curve individually to determine whether it is necessary to remove an obstruction or adjust the horizontal alignment to obtain the required sight distance.

8-2.04.02 **Length of Curve > Sight Distance**

Where the length of curve (L) is greater than the sight distance (S) used for design, the needed clearance on the inside of the horizontal curve is calculated as follows:

$$M = R \left(1 - \cos \left(\frac{28.65 S}{R} \right) \right) \quad \text{(Equation 8-2.1)}$$

Where:

M = Middle ordinate, or distance from the center of the inside travel lane to the obstruction, m

R = Radius of centerline of inside travel lane, m

S = Sight distance, m

Note: The expression $\left(\frac{28.65 S}{R} \right)$ is in degrees, not radians.

Stopping Sight Distance (SSD)

At a minimum, SSD will be available throughout the horizontal curve. Figure 8-2K and Figure 8-2L provide the horizontal clearance criteria (i.e, middle ordinate) for various combinations of stopping

sight distance and curve radii. For those selections of S which fall outside of the figures (e.g., $M > 16$ m and/or $R < 50$ m), the designer should use Equation 8-2.1 to calculate the needed clearance.

The Example on Figure 8-2M illustrates the determination of clearance requirements at a horizontal curve based on SSD.

Decision Sight Distance (DSD)

At some locations, it may be warranted to provide decision sight distance at the horizontal curve. Chapter Seven discusses candidate sites and provides design values for these sight distance criteria. These "S" values should be used in the basic equation to calculate "M" (Equation 8-2.1).

Entering/Exiting Portions

The M values from Figures 8-2K and 8-2L apply between the PC and PT. In addition, some transition is needed on the entering and exiting portions of the curve. The designer should use the following steps:

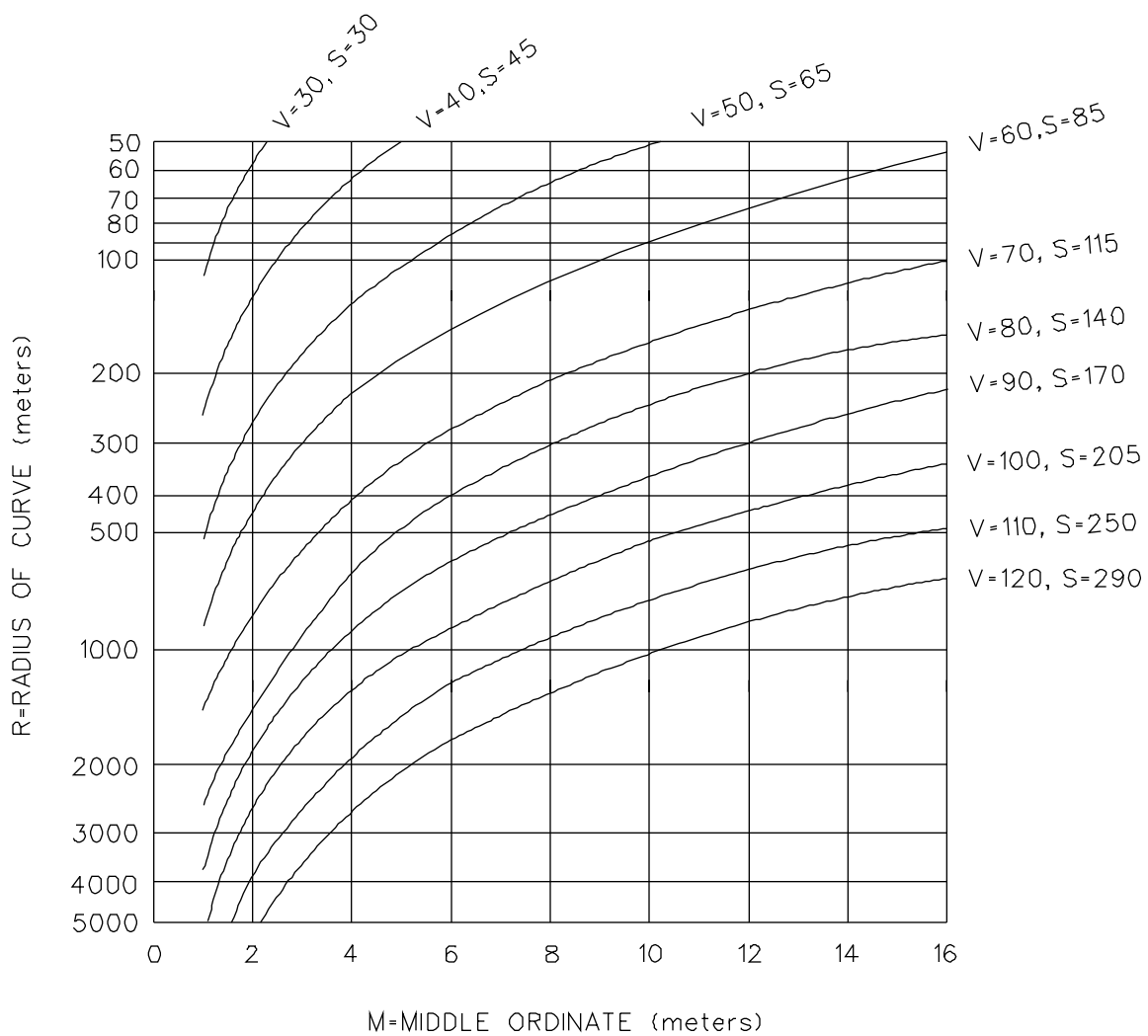
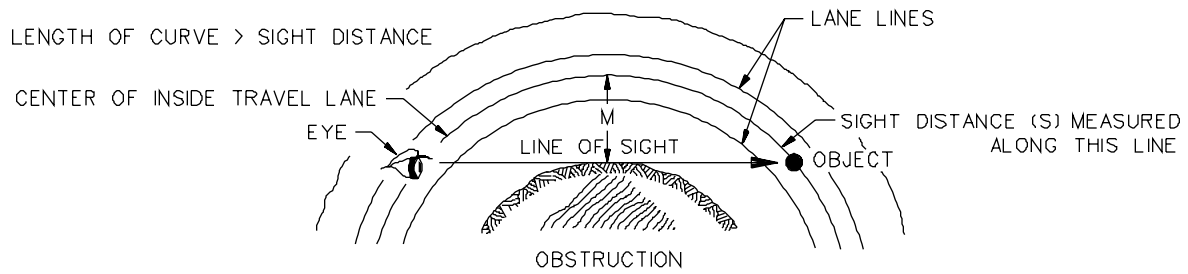
Step 1: Locate the point which is on the outside edge of shoulder and a distance of $S/2$ before the PC.

Step 2: Locate the point which is a distance M measured laterally from the center of the inside travel lane at the PC.

Step 3: Connect the two points located in Step #'s 1 and 2. The area between this line and the roadway should be clear of all continuous obstructions.

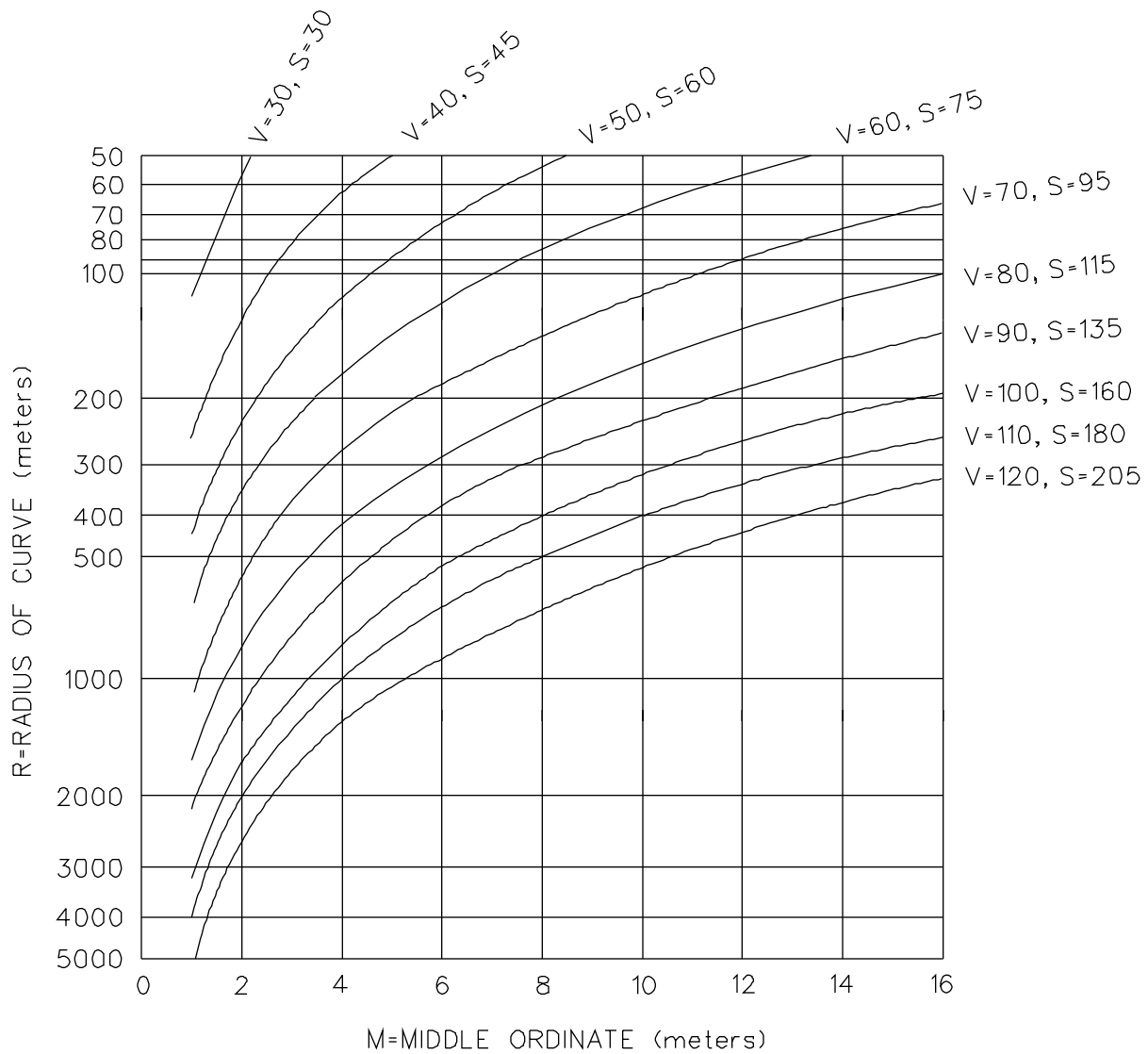
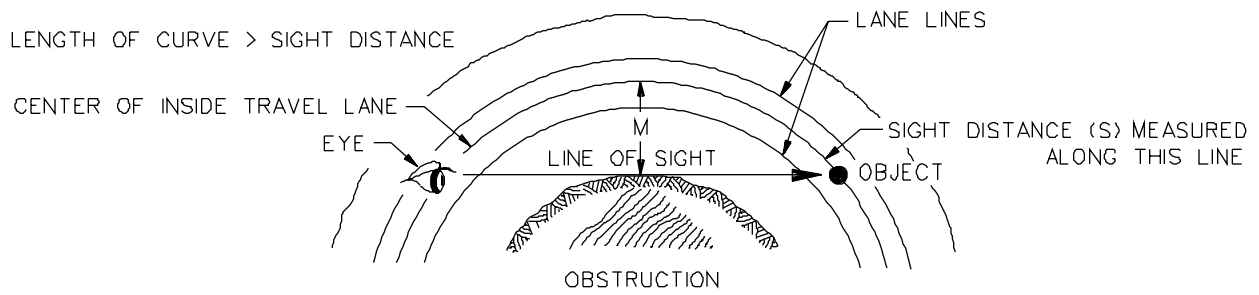
Step 4: A symmetrical application of Step #'s 1 through 3 should be used beyond the PT.

The Example on Figure 8-2M illustrates the determination of clearance requirements entering and exiting from a curve.



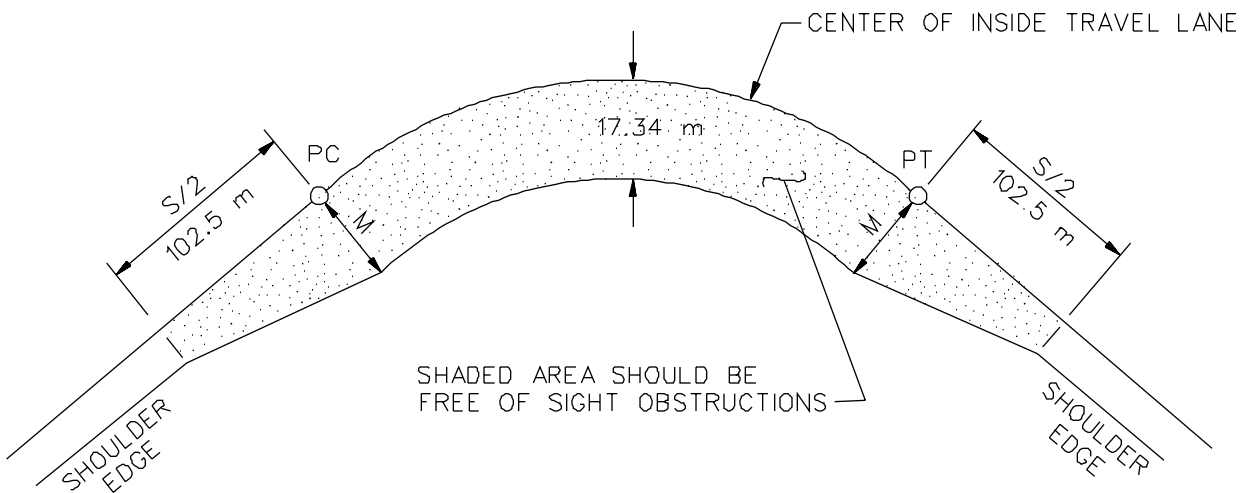
**SIGHT DISTANCE AT HORIZONTAL CURVES
(Upper Range of SSD)**

Figure 8-2K



**SIGHT DISTANCE AT HORIZONTAL CURVES
(Lower Range of SSD)**

Figure 8-2L



Example 8-2.2

Given: Design Speed = 100 km/h
 $R = 300$ m

Problem: Determine the horizontal clearance requirements for the horizontal curve to meet the upper SSD on level grade.

Solution: Figure 7-1A yields a SSD = 205 m. Using the equation for horizontal clearance ($L > S$):

$$M = R \left(1 - \cos \left[\frac{28.65 S}{R} \right] \right)$$

$$M = 300 \left(1 - \cos \left[\frac{(28.65)(205)}{300} \right] \right) = 17.34 \text{ m}$$

The above figure also illustrates the horizontal clearance requirements for the entering and exiting portion of the horizontal curve.

SIGHT CLEARANCE REQUIREMENTS FOR HORIZONTAL CURVES ($L > SSD$)

Figure 8-2M

8-2.04.03 Length of Curve < Sight Distance

Where the length of curve is less than the sight distance used in design, the M value from the basic equation will never be reached. As an approximation, the horizontal clearance for these curves should be determined as follows:

Step 1: For the given R and S, calculate M assuming $L > S$.

Step 2: The maximum M' value will be needed at a point of $L/2$ beyond the PC. M' is calculated from the following proportion:

$$\frac{M'}{M} = \frac{1.2 L}{S}$$

$$M' = \frac{1.2 (L)(M)}{S}, \quad \text{(Equation 8-2.2)}$$

Where:

$$M' \leq M$$

Step 3: Locate the point which is on the outside edge of shoulder and a distance of $S/2$ before the PC.

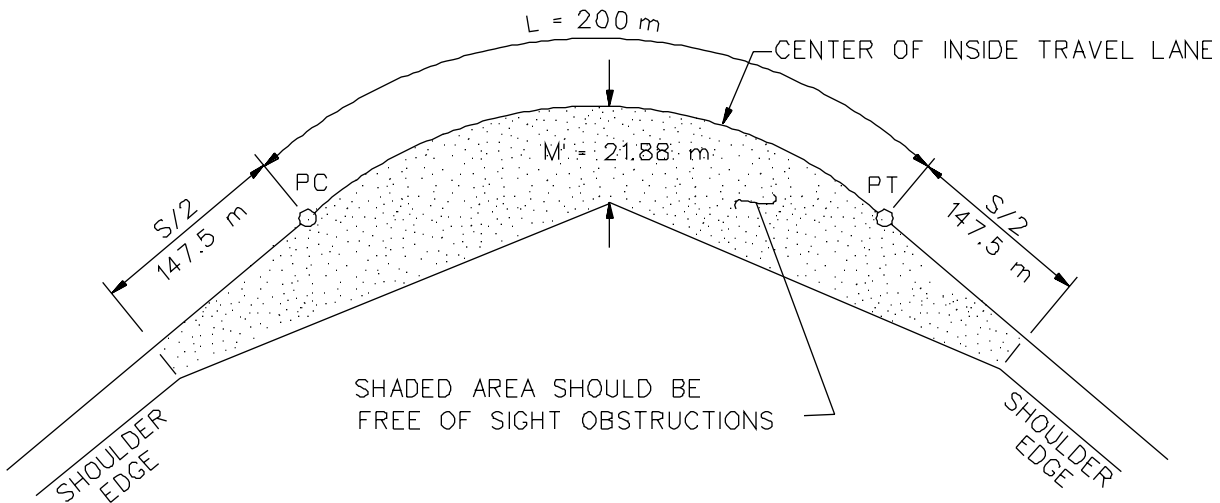
Step 4: Connect the two points located in Step #'s 2 and 3. The area between this line and the roadway should be clear of all continuous obstructions.

Step 5: A symmetrical application of Step #'s 2 through 4 should be used on the exiting portion of curve.

The Example on Figure 8-2N illustrates the determination of the clearance requirements where $L < S$.

8-2.04.04 Application

For application, the height of eye is 1070 mm and the height of object is 150 mm. Both the eye and object are assumed to be in the center of the inside travel lane. The line-of-sight intercept should be unobstructed at least 150 mm above ground level where it is outside of the paved roadway.



Example 8-2.3

Given: Design Speed = 110 km/h
 $R = 400$ m
 $L = 200$ m
 Grade = 6.0% downgrade

Problem: Determine the horizontal clearance requirements for the horizontal curve.

Solution: Because the downgrade is greater than 3.0%, the curve should be designed adjusted for grade. Figure 7-1A yields an upper SSD value of 295 m for 110 km/h and a 6.0% downgrade. Therefore, $L < S$ (200 m < 295 m), and the horizontal clearance is calculated first using Equation 8-2.1:

$$M (L > S) = 400 \left[1 - \cos \frac{(28.65)(295)}{400} \right] = 26.89 \text{ m}$$

Then, using Equation 8-2.2:

$$M' (L < S) = \frac{1.2 (200) (26.89)}{295}$$

$$M' = 21.88 \text{ m}$$

Therefore, a maximum clearance of 21.88 m should be provided at a distance of $L/2 = 100$ m beyond the PC.

SIGHT CLEARANCE REQUIREMENTS FOR HORIZONTAL CURVES ($L < SSD$)

Figure 8-2N

8-2.04.05 Longitudinal Barriers

Longitudinal barriers (e.g., bridge rails, guardrail, CMB) may cause sight distance problems at horizontal curves because barriers are placed relatively close to the travel lane (often, 3 m or less) and because their height is greater than 0.6 m.

The designer should check the line of sight over a barrier along a horizontal curve and attempt, if practical, to locate the barrier such that it does not block the line of sight. The following should be considered:

1. Superelevation. A superelevated roadway will elevate the driver eye and, therefore, improve the line of sight over the barrier.
2. Grades. The line of sight over a barrier may be improved for a driver on an upgrade and lessened on a downgrade.
3. Barrier Height. The higher the barrier, the more obstructive it will be to the line of sight.

Each barrier location on a horizontal curve will require an individual analysis to determine its impacts on the line of sight. The designer must determine the elevation of the driver eye (1070 mm above the pavement surface), the elevation of the object (150 mm above the pavement surface) and the elevation of the barrier where the line of sight intercepts the barrier run. If the barrier does block the line of sight to a 150-mm object, the designer should consider relocating the barrier or revising the horizontal alignment. If the barrier blocks the sight distance needed for minimum SSD on the mainline, it will be necessary to obtain a design exception.

8-2.05 Crossover Line

When adjacent lanes have different cross slopes and the driver moves from one lane to the other, there is a pull on the vehicular steering. This pull can cause erratic behavior when it becomes excessive. To control this, the difference in cross slope on adjacent lanes must be within the limits shown in Figure 8-20. This will limit the radius and superelevation rates which may be used under certain conditions (e.g., when a ramp enters a freeway).

Design Speed (km/h)	Maximum Algebraic Difference in Cross Slope at Crossover Line (%)
30 and under	5.0 to 8.0
40 and 50	5.0 to 6.0
60 and over	4.0 to 5.0

**MAXIMUM ALGEBRAIC DIFFERENCE IN CROSS SLOPE
AT CROSSOVER LINES**

Figure 8-20

8-3.0 LOW-SPEED URBAN STREETS

This section presents horizontal alignment criteria for low-speed urban streets (design speed of 70 km/h or less). The operating conditions on these facilities is significantly different from those on rural highways and high-speed urban highways. Also, urban areas present physical constraints which should be recognized. Therefore, some of the assumptions for horizontal alignment can be legitimately revised for low-speed urban streets. However, much of the criteria in Section 8-2.0 on open highways also applies to low-speed urban streets. Therefore, this section will reference Section 8-2.0 where applicable.

8-3.01 General Controls

The criteria in Section 8-2.01 also applies to low-speed urban streets.

8-3.02 Horizontal Curvature

8-3.02.01 Theoretical Discussion

The point mass formula for curvature is also used for low-speed urban streets. However, the assumptions for the values within the formula differ from those for open highways. See the AASHTO *A Policy on Geometric Design of Highways and Streets* for the theoretical discussion.

For low-speed urban streets, $e_{\max} = 4.0\%$ once the decision is made that a curve requires superelevation. This lower value reflects the problems often encountered when attempting to superelevate in urban areas where roadside development is extensive.

8-3.02.02 Application

Figure 8-3A presents the minimum radii for various design speeds for low-speed urban streets. The designer should wherever practical provide horizontal curvature flatter than the minimum radius.

Figure 8-3B presents the minimum radii for which the normal crown (NC) section can be maintained around a curve. The values assume that the pavement cross slope is 1.5%, which yields a superelevation rate of -1.5% for one direction of travel when the normal crown section is maintained. The figure also presents the range of radii for which remove crown (RC) applies. In this range, the curve must be superelevated at a rate of +1.5% across the entire highway section.

Design Speed (km/h)	e_{\max}	f_{\max}	$e + f$	Minimum Radius (m)
30	4.0%	0.312	0.352	20
40	4.0%	0.252	0.292	45
50	4.0%	0.214	0.254	80
60	4.0%	0.186	0.226	130
70	4.0%	0.163	0.203	190

MINIMUM RADII ON LOW-SPEED URBAN STREETS

Figure 8-3A

Design Speed (km/h)	Radius (m)		
	Normal Crown	Remove Crown	See Figure 8-3C
30	$R > 25$	$25 \geq R \geq 22$	$R < 22$
40	$R > 55$	$55 \geq R \geq 47$	$R < 47$
50	$R > 104$	$104 \geq R \geq 86$	$R < 86$
60	$R > 178$	$178 \geq R \geq 142$	$R < 142$
70	$R > 258$	$258 \geq R \geq 204$	$R < 204$

Note: Flatter radius is based on a theoretical superelevation rate of -1.5%.

Sharper radius is based on a theoretical superelevation rate of +1.5%.

**RANGE OF RADII FOR NORMAL CROWN SLOPE
AND REMOVE CROWN SLOPE
(Cross Slope = 1.5%)**

Figure 8-3B

Figure 8-3C provides the superelevation rates for combinations of curve radius and design speed for those curves when NC or RC is inadequate. The following examples illustrate how to use Figures 8-3B and 8-3C.

* * * * *

Example 8-3.1

Given: Design speed = 60 km/h
Radius = 180 m
Cross slope = 1.5%

Problem: Determine the superelevation rate.

Solution: Figure 8-3C yields a required superelevation rate of -2.6%. If the normal crown is maintained throughout the curve, the superelevation rate is -1.5%. Therefore, the normal crown should be maintained. This is consistent with the NC criteria in Figure 8-3B.

Example 8-3.2

Given: Design speed = 60 km/h
Radius = 150 m
Cross slope = 1.5%

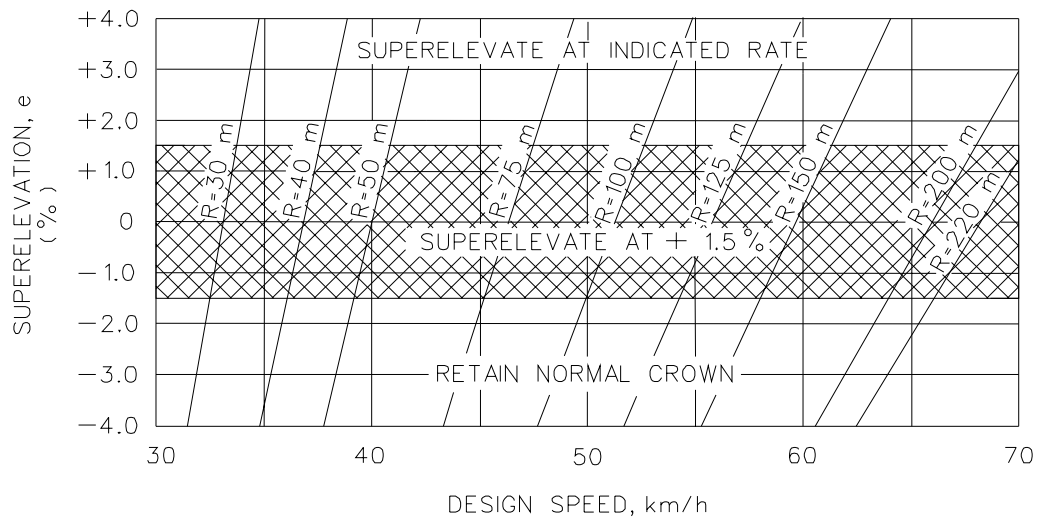
Problem: Determine the superelevation rate.

Solution: Figure 8-3C yields a required superelevation rate of +0.3%. The normal crown would provide a rate of -1.5%, which is unacceptable. Therefore, the pavement should be superelevated at a rate of +1.5% across the entire pavement for ease of design and construction. This is consistent with the RC criteria in Figure 8-3B.

Example 8-3.3

Given: Design speed = 60 km/h
Radius = 135 m
Cross slope = 1.5%

Problem: Determine the superelevation rate.



Notes:

1. $e_{max} = 4.0\%$ (typical)
2. For the rotation of a 1-lane pavement width, the minimum length will always apply. These are:

Design Speed (km/h)	Minimum Runoff Length (m) ^a
30	20
40	25
50	30
60	35
70	40

^a Runoff length is measured from the adverse slope removed to full superelevation. See Section 8-2.03 for calculation of tangent runout length (from normal crown to adverse slope removed).

3. For the rotation of a 2-lane pavement width, see the discussion in Section 8-2.03 to calculate the superelevation transition length.

SUPERELEVATION RATES (Low-Speed Urban Streets)

Figure 8-3C

Solution: Figure 8-3C yields a required rate of +2.4%. Therefore, the entire pavement should be transitioned and superelevated at this rate.

* * * * *

8-3.02.03 Types of Curvature

The discussion and figures in Section 8-2.02.03 also apply to low-speed urban streets.

8-3.03 Superelevation Development

Once the decision is made to provide superelevation on a low-speed urban street, the methods presented in Section 8-2.03 will apply. Section 8-2.03 discusses the length of transition, the effects of the type of curvature (e.g., simple) and the axis of rotation. Note that Figure 8-3C presents the superelevation transition lengths for low-speed urban streets where a 1-lane pavement width is being rotated.

8-3.04 Horizontal Sight Distance

The criteria presented in Section 8-2.04 also apply to horizontal sight distance on low-speed urban streets.

Chapter Nine

VERTICAL ALIGNMENT

Table of Contents

	<u>Page</u>
9-1.0 DESIGN PRINCIPLES AND PROCEDURES	9-1(1)
9-1.01 <u>General Controls for Vertical Alignment</u>	9-1(1)
9-1.02 <u>Coordination of Horizontal and Vertical Alignment</u>	9-1(2)
9-2.0 GRADES	9-2(1)
9-2.01 <u>Terrain (Definitions)</u>	9-2(1)
9-2.02 <u>Critical Length of Grade</u>	9-2(1)
9-2.03 <u>Maximum and Minimum</u>	9-2(2)
9-2.04 <u>Truck-Climbing Lanes</u>	9-2(5)
9-2.04.01 Warrants	9-2(5)
9-2.04.02 Capacity Analysis	9-2(5)
9-2.04.03 Design	9-2(6)
9-3.0 VERTICAL CURVES	9-3(1)
9-3.01 <u>General</u>	9-3(1)
9-3.02 <u>Crest Vertical Curves</u>	9-3(1)
9-3.03 <u>Sag Vertical Curves</u>	9-3(5)
9-4.0 VERTICAL CLEARANCES	9-4(1)
9-5.0 REFERENCES	9-5(1)

Chapter Nine

VERTICAL ALIGNMENT

9-1.0 DESIGN PRINCIPLES AND PROCEDURES

9-1.01 General Controls for Vertical Alignment

As discussed elsewhere in Chapter Nine, the design of vertical alignment involves, to a large extent, complying with specific limiting criteria. These include maximum and minimum grades, sight distance at vertical curves and vertical clearances. In addition, the designer should adhere to certain general design principles and controls which will determine the overall safety of the facility and will enhance the aesthetic appearance of the highway. These design principles for vertical alignment include:

1. Consistency. Use a smooth grade line with gradual changes, consistent with the type of highway and character of terrain, rather than a line with numerous breaks and short lengths of tangent grades.
2. Environmental Impacts. Vertical alignment should be properly coordinated with environmental impacts (e.g., encroachment onto wetlands).
3. Long Grades. On a long ascending grade, it is preferable to place the steepest grade at the bottom and flatten the grade near the top. It is also preferable to break the sustained grade with short intervals of flatter grades.
4. Intersections. Maintain moderate grades through intersections to facilitate turning movements. See Chapter Eleven for specific information on vertical alignment through intersections.
5. Roller Coaster. Avoid using "roller-coaster" type profiles. Roller-coaster profiles are where the horizontal alignment is generally straight and roadway profile closely follows a rolling natural ground line. This type of profile may be proposed in the interest of economy, but it is aesthetically undesirable and may be more difficult to drive.
6. Broken-Back Curvature. Avoid "broken-back" grade lines (two crest or sag vertical curves separated by a short tangent). One long vertical curve is more desirable.

7. Sags. Avoid using sag vertical curves in cut sections unless adequate drainage can be provided.
8. Coordination with Natural/Man-Made Features. The vertical alignment should be properly coordinated with the natural topography, available right-of-way, utilities, roadside development and natural/man-made drainage patterns.

9-1.02 Coordination of Horizontal and Vertical Alignment

Horizontal and vertical alignment should not be designed separately, especially for projects on new alignment. Their importance demands that the designer carefully evaluate the interdependence of the two highway design features. This will enhance highway safety and improve the facility's operation. The following should be considered in the coordination of horizontal and vertical alignment:

1. Balance. Curvature and grades should be in proper balance. Maximum curvature with flat grades or flat curvature with maximum grades does not achieve this desired balance. A compromise between the two extremes produces the best design relative to safety, capacity, ease and uniformity of operations and aesthetics.
2. Coordination. Vertical curvature superimposed upon horizontal curvature (i.e., vertical and horizontal P.I.'s at approximately the same stations) generally results in a more pleasing appearance and reduces the number of sight distance restrictions. Successive changes in profile not in combination with the horizontal curvature may result in a series of humps visible to the driver for some distance, which may produce an unattractive design. However, under some circumstances, superimposing the horizontal and vertical alignment must be tempered somewhat by Comment #'s 3 and 4 as follows.
3. Crest Vertical Curves. Do not introduce sharp horizontal curvature at or near the top of pronounced crest vertical curves. This is undesirable because the driver cannot perceive the horizontal change in alignment, especially at night when headlight beams project straight ahead into space. This problem can be avoided if the horizontal curvature leads the vertical curvature or by using design values which well exceed the minimums.
4. Sag Vertical Curves. Do not introduce sharp horizontal curves at or near the low point of pronounced sag vertical curves or at the bottom of steep vertical grades. Because visibility to the road ahead is foreshortened, only flat horizontal curvature will avoid an undesirable, distorted appearance. At the bottom of long grades, vehicular speeds often are higher, particularly for trucks, and erratic operations may occur, especially at night.

5. Intersections. At intersections, horizontal and vertical alignment should be as flat as practical to provide designs which produce sufficient sight distance and gradients for vehicles to slow or stop. See Chapter Eleven.
6. Divided Highways. On divided facilities with wide medians, it is frequently advantageous to provide independent alignments for the two one-way roadways. Where traffic justify a divided facility, a superior design with minimal additional cost generally can result from the use of independent alignments.
7. Residential Areas. Design the alignment to minimize nuisance factors to neighborhoods. Generally, a depressed facility makes the highway less visible and reduces the noise to adjacent residents. Minor adjustment to the horizontal alignment may increase the buffer zone between the highway and residential areas.
8. Aesthetics. Layout alignment to enhance attractive scenic views of rivers, rock formations, parks, golf courses, etc. The highway should head into rather than away from those views that are considered to be aesthetically pleasing. The highway should fall towards those features of interest at a low elevation and rise toward those features which are best seen from below or in silhouette against the sky.

The designer should coordinate the layout of the horizontal and vertical alignment as early as practical in the design process. Alignment layouts are typically completed after the topography and ground line have been drafted. The designer should use the computer visualization programs within CADD to visualize how the layout will appear in the field. The designer should review several alternatives to ensure that the most pleasing and practical design is selected.

9-2.0 GRADES

9-2.01 Terrain (Definitions)

1. Level. Highway sight distances are either long or could be made long without major construction expense. The terrain is generally considered to be flat, which has minimal impact on vehicular performance.
2. Rolling. The natural slopes consistently rise above and fall below the roadway grade and, occasionally, steep slopes present some restriction to the desirable highway alignment. In general, rolling terrain generates steeper grades, causing trucks to reduce speeds below those of passenger cars.
3. Mountainous. Longitudinal and transverse changes in elevation are abrupt, and benching and side hill excavation are frequently required to provide the desirable highway alignment. Mountainous terrain aggravates the performance of trucks relative to passenger cars, resulting in some trucks operating at crawl speeds.

In Connecticut, only the rolling level terrain criteria will be applicable because, even though a roadway may pass through a level or hilly site, the area as a whole is still considered to be rolling terrain.

9-2.02 Critical Length of Grade

In addition to the maximum grade, the designer must consider the length of the grade. The critical length of grade is the maximum length of a specific upgrade on which a loaded truck can operate without an unreasonable reduction in speed. The highway gradient in combination with the length of grade will determine the truck speed reduction on upgrades. The following will apply to the critical length of grade:

1. Design Vehicle. For critical-length-of-grade determinations, the Department has adopted the 180 kilograms/kiloWatt (kg/kW) truck as the most representative design vehicle for Connecticut.
2. Criteria. Figure 9-2A provides the critical lengths of grade for a given percent grade and acceptable truck speed reduction. Although these figures are based on an initial truck speed of 90 km/h, they apply to any design speed. For design purposes, use the 15 km/h speed reduction curve to determine if the critical length of grade is exceeded.
3. Measurement. Vertical curves are part of the length of grade. Figure 9-2B illustrates how to measure the length of grade to determine the critical length of grade from Figure 9-2A.

4. Highway Types. The critical-length-of-grade criteria applies equally to two-lane or multi-lane highways and applies equally to urban and rural facilities.
5. Application. If the critical length of grade is exceeded, the designer should either flatten the grade, if practical, or should evaluate the need for a truck-climbing lane (see Section 9-2.04).

* * * * *

Example 9-2.1

Given: Level Approach
 G = +4%
 L = 350 m (length of grade)
 Rural Arterial

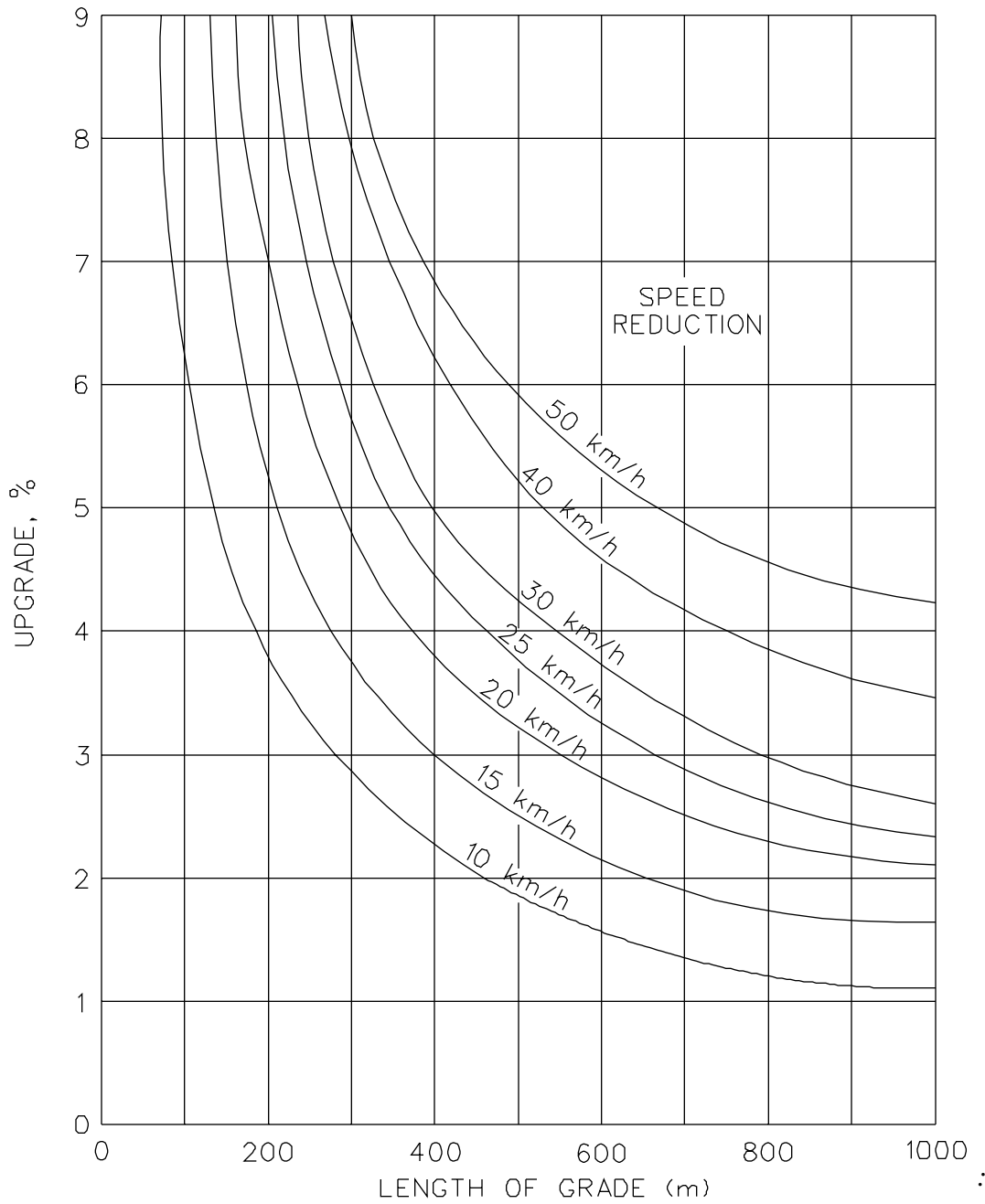
Problem: Determine if the critical length of grade is exceeded.

Solution: Figure 9-2A yields a critical length of grade of 280 m for a 15-km/h speed reduction. The length of grade (L) exceeds this value. Therefore, the designer should flatten the grade, if practical, or evaluate the need for a climbing lane.

9-2.03 Maximum and Minimum

The highway gradient will significantly impact vehicular operations and safety. The Department has adopted criteria for maximum gradient based on functional classification, urban/rural location, design speed and project scope of work. These values are presented in Chapters Two, Four and Five. Flatter grades should be used wherever practical.

The minimum longitudinal gradient is 0.5%. This applies to all highways with or without curbs.

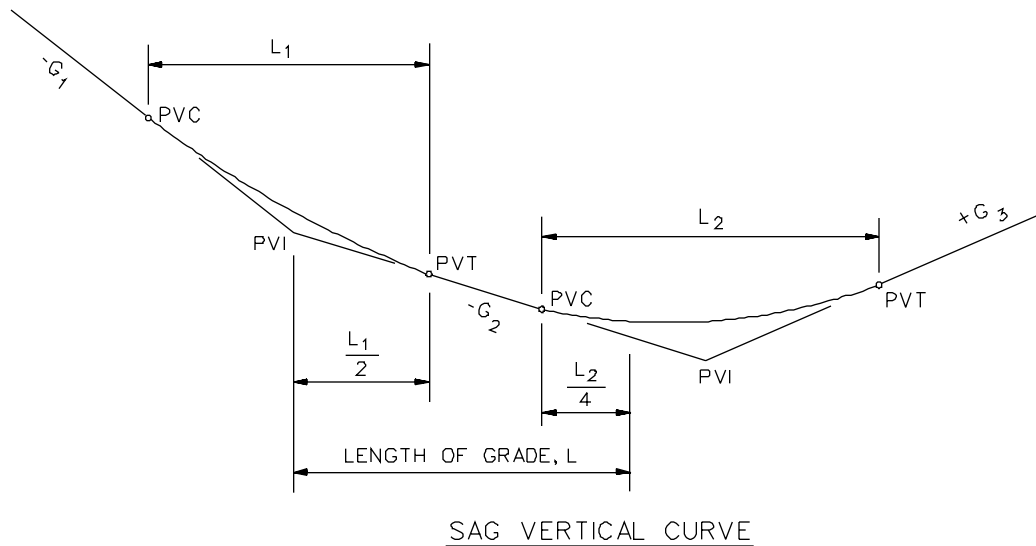
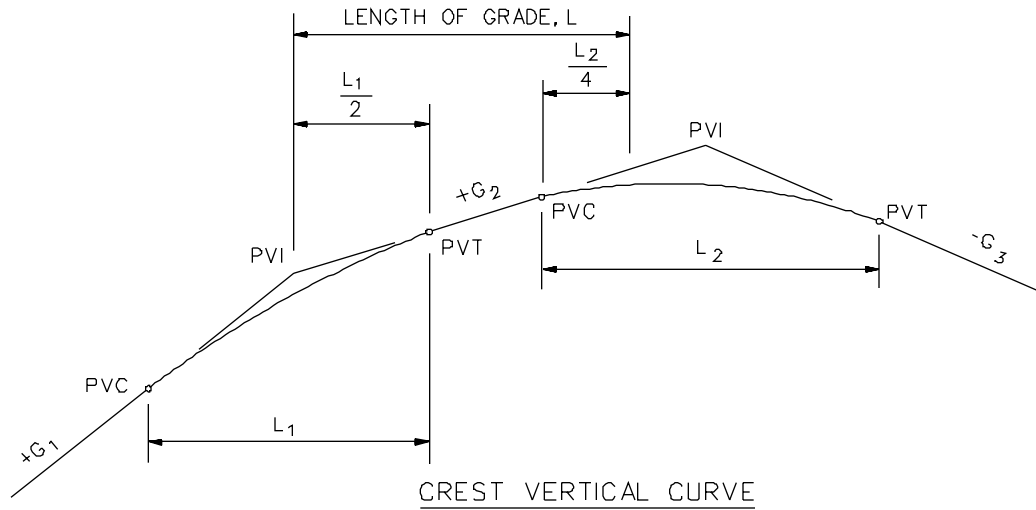


Notes

1. Typically, the 15 km/h curve will be used.
2. Figure based on a truck with initial speed of 90 km/h. However, it may be used for any design speed.

**CRITICAL LENGTH OF GRADE
(180 kg/kW Truck)**

Figure 9-2A

Notes:

1. For vertical curves where the two tangent grades are in the same direction (both upgrades or both downgrades), 50% of the curve length will be part of the length of grade.
2. For vertical curves where the two tangent grades are in opposite directions (one grade up and one grade down), 25% of the curve length will be part of the length of grade.
3. The above diagram is included for illustrative purposes only. Broken-back curves are to be avoided wherever practical.

MEASUREMENT FOR LENGTH OF GRADE**Figure 9-2B**

9-2.04 Truck-Climbing Lanes

9-2.04.01 Warrants

A truck-climbing lane may be warranted to allow a specific upgrade to operate at an acceptable level of service. A truck-climbing lane will generally be warranted if the following conditions are satisfied:

1. the critical length of grade is exceeded for the 15 km/h speed reduction curve (see Figure 9-2A; and
2. one of the following conditions exists:
 - a. the level of service (LOS) on the upgrade is E or F, or
 - b. there is a reduction of two or more LOS when moving from the approach segment to the upgrade; and
3. the construction costs and the construction impacts (e.g., environmental, right-of-way) are considered reasonable.

Truck-climbing lanes may also be warranted where the above criteria are not met if, for example, there is an adverse accident experience on the upgrade related to slow-moving trucks. In addition, on 4-lane freeways if the speed profile reveals an operating speed of less than 50 km/h at any point, a climbing lane will be warranted regardless of the results of the capacity analysis.

9-2.04.02 Capacity Analysis

The objective of the capacity analysis procedure is to determine if the warranting criteria in Section 9-2.04.01 are met. This is accomplished by calculating the service flow rate for each LOS level (A through D) and comparing this to the actual flow rate on the upgrade. Because a LOS worse than D warrants a truck-climbing lane, it is not necessary to calculate the service flow rate for LOS E.

The designer should analyze the operations on the grade using the procedures set forth in the *Highway Capacity Manual*. Note that the default values for determining the appropriate passenger car equivalent (E) values in the *Highway Capacity Software* (HCS) are acceptable for determining the LOS on climbing lanes (i.e., the default truck in the HCS is acceptable).

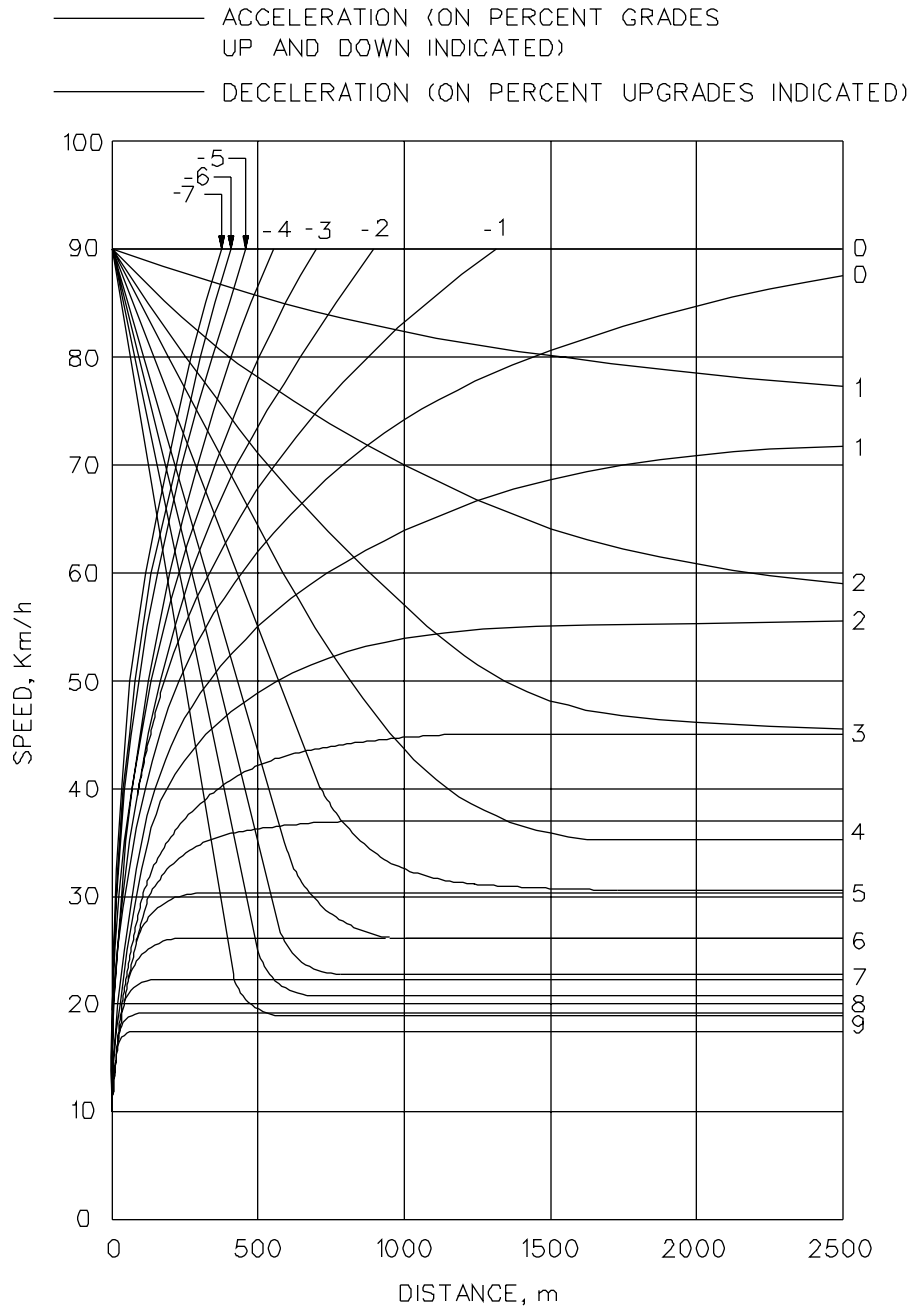
To determine if a climbing lane is warranted, these basic steps should be followed:

1. Review the project to determine if a climbing lane should be considered. Steep and/or long grades should be considered for climbing lanes.
2. For highways with a single grade, the critical length of grade can be directly determined from Figure 9-2A. However, most highways have a continuous series of grades. Often, it is necessary to find the impact of a series of significant grades in succession. If several different grades are present, then a speed profile must be developed using Figure 9-2C and the procedures set forth in the *Highway Capacity Manual*. If there is a 15 km/h reduction, then the first warrant is met. The speed profile should note the truck speed at the beginning of the full-width climbing lane, the PVC, the PVT and the end of the full-width lane.
3. Determine the total traffic volumes, the truck volumes on the grade and those on the approach prior to the upgrade.
4. Using the procedures set forth in the *Highway Capacity Manual*, determine the appropriate level of service for both the approach and the grade. If the level of service on the upgrade is E/F or if there is a reduction of 2 or more levels of service on the upgrade from the approaches, then the second warrant is met.

9-2.04.03 Design

Figure 9-2D summarizes the design criteria for climbing lanes. It should be noted, that actual placement of the tapers for the beginning and end of climbing lanes should consider sight distance to the tapers. The placement of the terminal taper should maximize the available sight distance. The shoulder width along the climbing lane will be the normal shoulder width for the appropriate highway classification. The tables in Chapters Four and Five provide the shoulder widths.

The Traffic Standard Details provide the typical signing and pavement marking patterns for the climbing lanes.



Note: For design speeds above 90 km/h, use an initial speed of 90 km/h. For design speeds 90 km/h and below, use the design speed as the initial speed.

**PERFORMANCE CURVES FOR LARGE TRUCKS
(180 g/W)**

Figure 9-2C

Highway Type	Design				
	Begin Climbing Lane	End Climbing Lane	Taper Length (Begin/End)	Lane Width	Shoulder Width
Freeways	70 km/h	80 km/h	90 m/250 m	3.6 m	Same as preceding roadway section.
Other Facilities	15 km/h below design speed or 70 km/h, whichever is less.	15 km/h below design speed or 70 km/h, whichever is less	25:1/(1)	See Chapters Four and Five	Same as preceding roadway section.

Note: (1) The taper length on other facilities for ending the climbing lane will be determined by the following taper rates:

Design Speed (km/h)	End Taper Rates
30	10:1
40	15:1
50	20:1
60	25:1
70	45:1
80	50:1
90	60:1
100	65:1
110	70:1
120	75:1

DESIGN CRITERIA FOR CLIMBING LANES

9-3.0 VERTICAL CURVES

9-3.01 General

The principal concern in the design of crest vertical curves is to ensure that at least stopping sight distance is provided. Headlight sight distance will usually control the design of sag vertical curves. Two factors affect the availability of sight distance — the algebraic difference between gradients of the intersecting tangents and the length of the vertical curve. With a small algebraic difference in grades, the length of the vertical curve may be relatively short. To obtain the same sight distance with a large algebraic difference in grades, a much longer vertical curve will be necessary. If the grade break is 0.5 percent or less, then the designer may use an "angle" point (i.e., no vertical curve).

All vertical curves are in the shape of a parabola. Figure 9-3A illustrates the geometric details of a symmetrical vertical curve. Figure 9-3B provides an example of how to determine the elevations along a vertical curve.

9-3.02 Crest Vertical Curves

The basic equations for crest vertical curves are:

$$L = KA \text{ or } L = 0.6V^3 \quad \text{whichever is larger} \quad (\text{Equations 9-3.1 and 9-3.2})$$

$$L = \frac{AS^2}{200(\sqrt{h_1} + \sqrt{h_2})^2} \quad (\text{Equation 9-3.3})$$

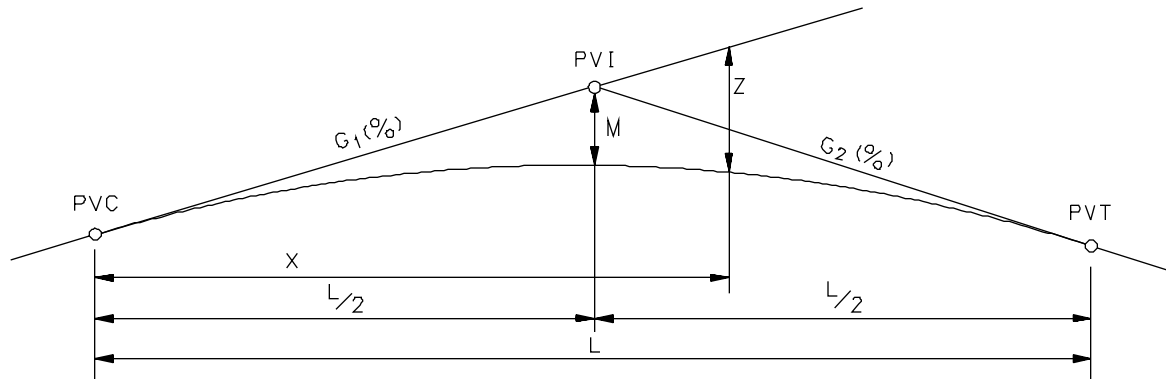
where:

- L = length of vertical curve (m)
- A = algebraic difference between the two tangent grades, percent
- S = sight distance (m)
- h_1 = height of eye above road surface (m)
- h_2 = height of object above road surface (m)
- V = design speed (km/h)

For the design of crest vertical curves, the following will apply:

1. Stopping Sight Distance. Stopping sight distance is the minimum design for crest vertical curves. A height of eye of 1070 mm and a height of object of 150 mm are used. Using Equation 9-3.3, this yields the following equation:

$$L = \frac{AS^2}{404} \quad (\text{Equation 9-3.4})$$



- M = Mid-ordinate (m)
 Z = Any tangent offset (m)
 L = Horizontal length of vertical curve (m)
 X = Horizontal distance from PVC or PVT to any ordinate "Z" (m)
 \$G_1\$ & \$G_2\$ = Rates of grade, expressed algebraically, in percent

ALL EXPRESSIONS TO BE CALCULATED ALGEBRAICALLY

$$ELEV. \text{ OF PVI} = ELEV. \text{ PVC} + G_1 \frac{L}{200}$$

$$ELEV. \text{ OF PVT} = ELEV. \text{ PVC} + (G_1 + G_2) \frac{L}{200}$$

For offset "Z" at distance "X" from PVC or PVT:

$$Z = M \left(\frac{X}{L/2} \right)^2 \text{ or } Z = \frac{X^2 (G_2 - G_1)}{200 L}$$

For slope "S" of a line tangent to any point on the vertical curve at an "X" distance measured from the PVC:

$$S, \text{ in percent} = G_1 - \left[X \left(\frac{G_1 - G_2}{L} \right) \right]$$

CALCULATING HIGH OR LOW POINT ON CURVE

$$X_T = \frac{L G_1}{G_1 - G_2}$$

Where "\$X_T\$" equals the horizontal distance from the PVC to the high or low point on the curve in meters.

Elevation of high or low point on curve equals:

$$ELEV. \text{ PVC} - \frac{L G_1^2}{(G_2 - G_1) 200}$$

SYMMETRICAL VERTICAL CURVE EQUATIONS

Figure 9-3A

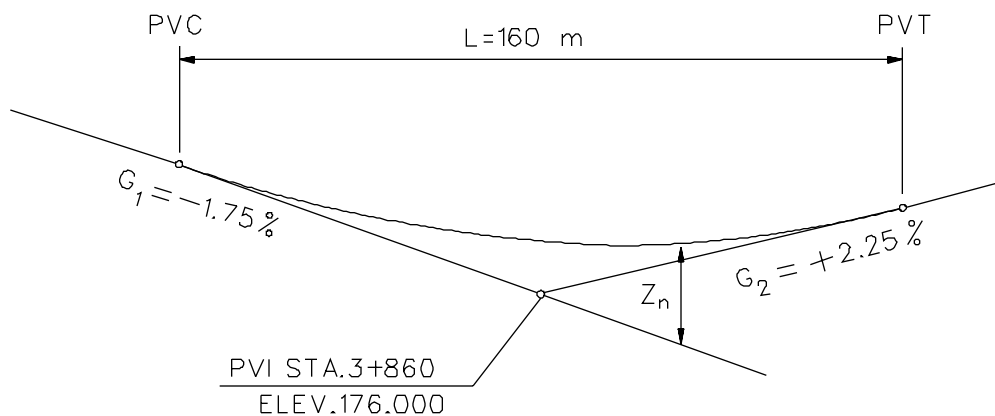
Example 9-3.1

Given: $G_1 = -1.75\%$
 $G_2 = +2.25\%$
 Elev. of PVI = 176.000 m
 Station of PVI = 3 + 860.00
 $L = 160$ m

Problem: Compute the grade for each 20-m station. Compute the low point elevation and stationing.

Solution:

1. Draw a diagram of the vertical curve and determine the station of the beginning (PVC) and the end (PVT) of the curve.



Beginning Station (PVC) = PVI Sta - $\frac{1}{2}L = (3 + 860) - (0 + 080) = 3 + 780$

End Station (PVT) = PVI Sta + $\frac{1}{2}L = (3 + 860) + (0 + 080) = 3 + 940$

2. From the vertical curve equations in Figure 9-3A:

$$M = \frac{(G_2 - G_1) L}{800} = \frac{[2.25 - (-1.75)] 160}{800} = 0.80 \text{ m}$$

$$Z = M \left(\frac{X}{L/2} \right)^2 = \frac{4M}{L^2} X^2 = \frac{4 \times 0.80}{25600} X^2 = \frac{X^2}{8000}$$

VERTICAL CURVE COMPUTATIONS
(Example 9-3.1)

Figure 9-3B

Example 9-3.1

Solution: (continued)

3. Set up a table to show the vertical curve elevations at the 20-meter stations:

Station (n)	Inf.	Tangent Elevation (Along G_1)	X	X^2	Z_n	Grade Elevation
3 + 780	PVC	177.400	0	0	0	177.400
3 + 800		177.050	20	400	0.050	177.100
3 + 820		176.700	40	1600	0.200	176.900
3 + 840		176.350	60	3600	0.450	176.800
3 + 860	PVI	176.000	80	6400	0.800	176.800
3 + 880		175.650	100	10 000	1.250	176.900
3 + 900		175.300	120	14 400	1.800	177.100
3 + 920		174.950	140	19 600	2.450	177.400
3 + 940	PVT	174.600	160	25 600	3.200	177.800

4. Calculating low point:

$$X_T = \frac{LG_1}{G_1 - G_2} = \frac{160 (-1.75)}{-1.75 - 2.25} = \frac{-280}{-4.00} = 70 \text{ meters from PVC}$$

therefore, the Station at low point is:

$$(3 + 780) + (0 + 070) = (3 + 850)$$

elevation of low point on curve equals:

$$\text{Elev. PVC} - \frac{LG_1^2}{(G_2 - G_1) 200} = 177.400 - \frac{160 (-1.75)^2}{(2.25 - (-1.75)) 200} = 177.400 - 0.613 = 176.787 \text{ m}$$

VERTICAL CURVE COMPUTATIONS**(Example 9-3.1)**

(Continued)

Figure 9-3B

Figure 9-3C presents the K-values for crest vertical curves. These values have been calculated by using the SSD values from Figure 7-1A and Equation 9-3.4.

2. Grade Adjustments. When determining S for crest vertical curves, the designer should consider the effects of grade on stopping sight distance (SSD). The following thresholds may be used for determining the thresholds for "Level" K-values:

$$V \geq 80 \text{ km/h} : -1\% < G < +1\%$$

$$V < 80 \text{ km/h} : -2\% < G < +2\%$$

The selection of "G" at a crest vertical curve will depend on which grade is steeper and whether the roadway is one way or two way. On a 1-way roadway, "G" should always be the grade on the far side of the crest when considering the direction of travel. On a 2-way roadway, "G" should always be the steeper of the two grades on either side of the crest.

For design exception purposes, only the "Level" SSD value will require an exception. For designs where, because of rounding in the charts, the "Level" SSD is met but not the K-value, an exception will not be required.

3. Decision Sight Distance. Section 7-2.0 discusses the general warrants for decision sight distance. The procedure will determine the appropriate "S" and height of object for the specific site conditions. These values should then be used in Equation 9-3.3 to determine the necessary curve length at the site.
4. Drainage. Drainage should be considered in the design of crest vertical curves where curbed sections are used. Drainage problems should not be experienced if the vertical curvature is sharp enough so that a minimum longitudinal grade of at least 0.3% is reached at a point about 15 m from either side of the apex. To ensure that this objective is achieved, the length of the vertical curve should be based upon a K-value of 50 or less. For crest vertical curves on curbed sections where this K-value is exceeded, the drainage design should be more carefully evaluated near the apex.

For uncurbed sections of highway, drainage should not be a problem at crest vertical curves.

9-3.03 Sag Vertical Curves

Headlight sight distance is the primary design control for sag vertical curves. The height of the headlights is assumed to be 600 mm. The upward divergence of the beam is 1° from the longitudinal axis of the vehicle. The curvature of the sag should allow sufficient pavement illumination to provide adequate sight distance. These criteria yield the following equations:

Design Speed (km/h)	Downgrades			Level 0%	Upgrades		
	-9%	-6%	-3%		+3%	+6%	+9%
30	4	4	4	3 - 3	3	3	3
40	7	7	7	6 - 6	6	6	6
50	14	13	13	11 - 9	11	9	9
60	28	23	21	18 - 14	18	16	16
70	49	42	36	33 - 23	30	28	25
80	81	68	56	49 - 33	46	42	39
90	115	99	85	72 - 46	68	64	60
100	168	149	126	105 - 64	99	90	85
110	270	216	181	155 - 81	143	131	120
120	367	295	246	209 - 105	188	174	161

- Notes:
1. For grades intermediate between columns, use a straight-line interpolation to calculate the K-value.
 2. Only the "Level" SSD are applicable for design exception purposes.

K-VALUES FOR CREST VERTICAL CURVES

Figure 9-3C

$$L = KA \text{ or } L = 0.6V \quad \text{whichever is larger} \quad (\text{Equations 9-3.5 and 9-3.6})$$

$$L = \frac{AS^2}{120 + 3.5S} \quad (\text{Equation 9-3.7})$$

For the design of sag vertical curves, the following will apply:

1. Stopping Sight Distance (SSD). Figure 9-3D presents the K-values for sag vertical curves. These values have been calculated by using the SSD values from Figure 7-1A and Equation 9-3.7.
2. Grade Adjustments. Section 9-3.02 discusses the application of SSD to crest vertical curves pertaining to the grade correction. The grade correction and the thresholds also apply to sag vertical curves.

For design exception purposes, only the "Level" SSD value will require an exception. For designs where, because of rounding in the charts, the "Level" SSD is met but not the K-value, an exception will not be required.

3. Decision Sight Distance. Section 7-2.0 discusses the general warrants for decision sight distance. The procedure will determine the appropriate "S" and height of object for the specific site conditions. These values should then be used in Equation 9-3.7 to determine the necessary curve length at the site.
4. Drainage. Drainage considerations also impact the design of sag curves. The criteria is the same as for crest vertical curves, which yields a $K = 50$ for the maximum length of curve. Where this K value is exceeded, the designer should consider special drainage treatments, especially on curbed pavements. In addition, the designer should avoid the placement of bridges or other structures at the low point of sag vertical curves because of the potential drainage problems.

Design Speed (km/h)	Downgrades			Level 0%	Upgrades		
	-9%	-6%	-3%		+3%	+6%	+9%
30	6	6	6	4 - 4	4	4	4
40	9	9	9	8 - 8	8	8	8
50	15	14	14	13 - 11	13	11	11
60	23	20	19	18 - 15	18	16	16
70	33	30	27	26 - 20	24	23	22
80	44	40	35	33 - 26	31	30	29
90	53	49	46	41 - 31	40	38	37
100	66	62	56	51 - 38	49	46	45
110	86	76	69	63 - 44	60	58	55
120	101	90	82	75 - 51	70	68	65

- Notes:
1. For grades intermediate between columns, use a straight-line interpolation to calculate the K-value.
 2. Only the "Level" SSD are applicable for design exception purposes.

K-VALUES FOR SAG VERTICAL CURVES

Figure 9-3D

9-4.0 VERTICAL CLEARANCES

Figure 9-4A summarizes the minimum vertical clearances for new bridges for various highway classifications and conditions.

Type	Clearance
Freeway or Expressway Under	5.05 m over the entire roadway width (1) (2)
Arterial Under	5.05 m over the entire roadway width (1)
Collector Under	4.50 m over the entire roadway width (1)
Local Under	4.50 m over the entire roadway width (1)
Railroad Under Highway	6.858 m from the top of the rail to the bottom of the structure (electrified only); 6.248 m other railroads (5)
Highway Under Sign Truss or Pedestrian Bridge	5.35 m over the entire roadway width
Parkway Under	4.50 m over the entire roadway width

- Notes:
1. Table values allow 150 mm for future resurfacing.
 2. The minimum vertical clearance beyond the edge of shoulder must be sufficient to accommodate a 4.35-m vehicle in height by 2.6 m in width. On the Interstate system, the minimum vertical clearance is 5.05 m beyond the edge of shoulder.
 3. For vertical clearances in the vicinity of airports, see FHPM 7-4-3 which discusses airspace management on Federal-aid highways.
 4. Department practice is to post a "low-clearance" sign on structures with vertical clearances less than or equal to 4.35 m.
 5. Exceptions to the vertical clearances over railroads require approval from the Connecticut Legislature and ConnDOT.

MINIMUM VERTICAL CLEARANCES (New Bridges)

Figure 9-4A

9-5.0 REFERENCES

1. *A Policy on Geometric Design of Highways and Streets*, AASHTO, 1994.
2. *Highway Capacity Manual*, TRB, 1994.

Chapter Ten

CROSS SECTIONS

Table of Contents

	<u>Page</u>
10-1.0	ROADWAY SECTION 10-1(1)
10-1.01	<u>Travel Lanes</u> 10-1(1)
	10-1.01.01 Width 10-1(1)
	10-1.01.02 Cross Slope 10-1(1)
10-1.02	<u>Shoulders</u> 10-1(2)
	10-1.02.01 Shoulder Widths/Types 10-1(2)
	10-1.02.02 Shoulder Cross Slope 10-1(2)
10-1.03	<u>Turn Lanes</u> 10-1(3)
10-1.04	<u>Parking Lanes</u> 10-1(4)
10-1.05	<u>Curbs</u> 10-1(4)
	10-1.05.01 Types 10-1(5)
	10-1.05.02 Safety 10-1(5)
	10-1.05.03 Application on Low-Speed Roads/Streets 10-1(5)
	10-1.05.04 Application on High-Speed Highways 10-1(6)
10-2.0	ROADSIDE ELEMENTS 10-2(1)
10-2.01	<u>Sidewalks</u> 10-2(1)
	10-2.01.01 Guidelines for Sidewalk Construction 10-2(1)
	10-2.01.02 Sidewalk Design Criteria 10-2(1)
10-2.02	<u>Fill and Cut Slopes</u> 10-2(2)
10-2.03	<u>Utility Placement</u> 10-2(3)
10-3.0	MEDIANS 10-3(1)
10-3.01	<u>Median Widths</u> 10-3(1)
10-3.02	<u>Median Types</u> 10-3(2)

Table of Contents
(Continued)

	<u>Page</u>
10-3.02.01 Flush Medians	10-3(2)
10-3.02.02 Raised Medians	10-3(2)
10-3.02.03 Depressed Medians	10-3(4)
10-4.0 BRIDGE AND UNDERPASS CROSS SECTION	10-4(1)
10-4.01 <u>Bridges</u>	10-4(1)
10-4.01.01 New Construction	10-4(1)
10-4.01.02 Major Reconstruction (Non-Freeways)	10-4(1)
10-4.02 <u>Underpasses</u>	10-4(2)
10-5.0 RIGHT-OF-WAY	10-5(1)
10-6.0 TYPICAL SECTIONS	10-6(1)
10-7.0 REFERENCES	10-7(1)

Chapter Ten

CROSS SECTIONS

Chapters Four and Five "Geometric Design Tables" present the design values for the widths of the various cross section elements on new construction and major reconstruction projects. These are based on the functional classification (freeway, arterial, collector or local road or street). Chapters Four and Five also provide typical tangent and superelevated cross section figures. Chapter Two provides design values for cross section widths on 3R projects. Chapter Ten discusses cross section elements and provides additional information and guidance which should be considered in the highway design.

10-1.0 ROADWAY SECTION

10-1.01 Travel Lanes

10-1.01.01 Width

Travel lane widths will vary between 2.7 m and 3.6 m, depending upon the functional classification, traffic volumes and rural/urban location. Chapters Two, Four and Five provide specific criteria for travel lane widths for these various conditions.

10-1.01.02 Cross Slope

Surface cross slopes are required for proper drainage of through travel lanes on tangent sections. To determine the appropriate slope, the following will apply:

1. Two-Lane Highways. Crown the traveled way at the centerline with a cross slope of 1.5-2.0% sloping away from the centerline.
2. Multi-Lane Highways. For multi-lane highways, the following will apply:
 - a. Undivided Facilities. For undivided facilities, crown the pavement at the centerline. The cross slope of the travel lanes adjacent to the crown should be 1.5-2.0%. The lanes beyond this should be sloped at 2%.

- b. **Divided Facilities.** For divided facilities, the pavement is crowned at the centerline of each roadway. For three-lane sections, the pavement is typically crowned along the lane edge between the middle lane and the lane adjacent to the median. The right two lanes are sloped to the outside and the median lane to the inside.

The cross slope of the lanes adjacent to the crown should be 1.5-2.0%. The lanes beyond this should be sloped at 2%.

- c. **Uneven Sections.** Where an uneven cross section is used (e.g., three lanes in one direction and one lane in the other), or to match a short section of a new road to an existing section, it may be appropriate to place the crown line in a different location.
3. **Breaks.** In general, all cross slope breaks should occur at lane edges. One exception to this may be where a two-way, left-turn lane is provided.
 4. **Bridges.** Carry the approach roadway cross section across the bridge.

10-1.02 Shoulders

10-1.02.01 Shoulder Widths/Types

Shoulder widths will vary according to project scope of work, functional classification, urban or rural location, traffic volumes and the presence of curbs. Chapters Two, Four and Five present the recommended shoulder widths for these various conditions. All shoulders on State routes should be paved. For roads under local jurisdictions and if requested by the municipality, a well-graded, stabilized aggregate or surface-treated shoulder will be acceptable. There should be no drop off between the traveled way and the graded shoulder. Where curbing is provided, the shoulder must be paved. The designer should also note that, in no case, will the area outside of the curb be considered as part of the shoulder width.

10-1.02.02 Shoulder Cross Slope

The shoulder cross slope will vary depending on the shoulder width and whether or not there is curbing. Chapters Two, Four and Five provide the shoulder cross slope criteria. In addition, the designer should consider the following:

1. **Narrow Shoulders.** If the shoulder width is less than 1.2 m, the shoulder cross slope will be the same as the travel lane cross slope. This applies to both tangent and superelevated sections.

2. Shoulder Adjacent to Traveled Way (Tangent Section). For highways without curbs, the typical shoulder cross slope is 4%. Where curbs are present, the typical shoulder cross slope is 6%. Where wide shoulders are used with 100-mm curbing, use a 4% cross slope.
3. Shoulder Adjacent to Traveled Way (Superelevated Section). On the low side, the shoulder cross slope will remain equal to its rate on the tangent section until the superelevated rate exceeds that value. Then, the shoulder will be sloped at the same rate as the superelevated travel lanes.

On the high side, the break between the travel lane and shoulder cross slope will be designed according to the miscellaneous detail in Figures 4H and 5J. The location of the break is dependent on the width of the shoulder. Shoulders less than 1.2 m are not broken. This detail applies to the entire range of superelevation rates (1.5% to 6.0%).

4. Shoulders on Bridges. On bridges, the shoulder cross slopes will match the approach roadway shoulder slopes. For ramps, the following will apply:
 - a. Tangent Section. The lower side shoulder will slope at the same rate as the travel lane. On the high side, the last 1.2 m will slope away in the same manner as the high-side shoulder adjacent to a superelevated mainline (see Figure 12-4B).
 - b. Superelevated Section. The division between the ramp travel lane and shoulder may vary, and it is often determined by the pavement markings. Regardless of this division, 1.2 m of the ramp width should slope away from the remaining ramp width on the high side of the superelevated section. The details of the break between the two sections will be determined by the detail in Figures 4H and 5J.

10-1.03 Turn Lanes

Turn lanes include left- and right-turn lanes. Chapters Two, Three and Four provide the specific travel lane and shoulder width criteria for turn lanes. See Section 10-1.01.02 for turn lane cross slopes.

10-1.04 Parking Lanes

Chapters Two and Five provide the recommended widths for parking lanes. Where a parking lane is currently being used as a travel lane during peak hours, or where it may potentially be converted to a travel lane in the future, and if curbing is present, increase the parking lane width to 3.9 m.

Many urban streets provide on-street parking. In addition to parking lane width, the designer must consider the following:

1. Capacity. In general, on-street parking reduces capacity, impedes traffic flow, produces undesirable traffic operations and increases the accident potential. Therefore, the designer should carefully consider these impacts before introducing on-street parking to an urban street. If these problems have become unacceptable on an urban street with existing on-street parking, the designer should eliminate parking. However, if sufficient replacement off-street parking is unavailable, it may be impractical to completely eliminate the on-street parking. As an alternative, parking may be prohibited during peak-traffic hours to improve the level of service during periods of maximum flow.
2. Parallel Versus Angle Parking. Parallel on-street parking is greatly preferred over angle parking. Angle parking has been associated with higher accident rates, because parked vehicles are required to back into the flow of traffic where adjacent parked vehicles may block the line of sight. Therefore, where on-street parking is being introduced to an urban street, the designer should provide parallel parking. Where angle parking currently exists, the designer should, if practical, convert these to parallel parking.
3. Intersection Sight Distance. Parking should be prohibited within the corner sight triangles for intersection sight distance at intersections and driveways. See Section 11-2.0 for the detailed criteria for intersection sight distance.
4. Railroads. Parking should be prohibited within 15 m of the nearest rail of a railroad/ highway crossing.

Coordinate all design decisions related to on-street parking with the Division of Traffic Engineering.

10-1.05 Curbs

Curbs are used extensively at the outside of the shoulder on urban streets and occasionally on rural highways. Curbs contain the pavement drainage within the road and away from adjacent properties, provide pavement delineation, assist in channelization and driveway control for orderly roadside development, provide a physical

separation between vehicles and pedestrians, and are considered aesthetically pleasing. However, do not use curbs on highways with design speeds of 80 km/h or greater, except under special conditions.

10-1.05.01 Types

There are generally two types of curbs — mountable and barrier. By definition, mountable curbs have a height of 150 mm or less with a batter no steeper than 3 vertical to 1 horizontal. Barrier curbs range in height between 150 mm and 225 mm with a batter steeper than 3 vertical to 1 horizontal. Typically, ConnDOT barrier curbs are vertical. The *Connecticut Standard Drawings* provide the design details for the various types of curbs used by the Department.

10-1.05.02 Safety

When impacted by a vehicle, curbs may result in the loss of vehicular control. In addition, a curb close to the travel lane may cause a driver to shy away, which reduces highway capacity. For these reasons, the disadvantages of a curb must be weighed against its benefits before a curb is introduced on any highway facility. Where a curb and barrier are used together, see Section 13-6.0 for design details.

10-1.05.03 Application on Low-Speed Roads/Streets

A low-speed road or street is defined as one which has a design speed of 70 km/h or less. However, for this section on curbing, it will be considered to be less than 80 km/h. In urban areas, curbs have a major benefit in containing the drainage within the pavement area and in channelizing traffic into and out of adjacent properties. On rural, low-speed roads curbs should only be used where drainage is necessary or where roadside development is a problem.

The designer must also select the type of curb for the project. The following guidance should be used:

1. Non-State Facilities. On non-State highways, the curb should be the type that currently exists or should be as agreed upon with the local government.
2. 3R Projects. For 3R projects on State highways, the designer should match the existing curb type.

3. Curb Type. For major reconstruction or new construction projects on State highways, the designer should select the most practical type of curb. The *Connecticut Standard Drawings* provide the various curb types used by the Department (e.g., BCLC, concrete, stone curbing). The designer should consider initial cost, life expectancy, availability of materials, construction operations, maintenance requirements and appearance. For example, stone curbing may be justified on heavily traveled urban streets with parking lanes, street-cleaning operations and heavy use of de-icing materials. The superior durability of the stone curbing may make it a more cost-effective selection.
4. Stone Curbing. Whenever stone curbing is used, Connecticut policy is that granite will always be used, except where existing curbs are bluestone.
5. Sidewalks. Where sidewalks are adjacent to the roadway or where they may be constructed in the future, curbs should be included in the project design.
6. Intersections. At intersections, curbs may be used to channelize vehicular paths and provide a target area for islands. In these cases, use mountable curbs.
7. Handicapped. Curbs should be designed with curb ramps at all pedestrians crosswalks to provide adequate access for the safe and convenient movement of physically handicapped individuals. See Section 15-1.0 for details on the design and location of curb ramps.

10-1.05.04 Application on High-Speed Highways

In general, curbs should not be used on highways with a design speed of 80 km/h or greater because of their adverse effect on vehicular behavior when impacted. Their use is limited to these conditions:

1. Drainage. Where containing the drainage within the pavement area is absolutely essential, mountable curbing may be used. For more information, the designer should refer to the Department's *Drainage Manual* for more specific uses of a curb for drainage purposes.
2. Bridges. For approaches to a bridge superstructure, use granite stone transition curbing in advance of the bridge. This curbing will transition to the protruding blunt end of the bridge curbing and, therefore, helps guide the motorist away from the bridge curb. On a one-way structure, the

transition curbing serves no purpose on the trailing end and should not be provided, unless required for drainage.

3. Raised Medians. Mountable curbing is acceptable for design speeds up to 80 km/h.

Where curbing is determined to be necessary, use a 100-mm mountable curbing as shown in the *Connecticut Standard Drawings*.

10-2.0 ROADSIDE ELEMENTS

10-2.01 Sidewalks

10-2.01.01 Guidelines for Sidewalk Construction

ConnDOT Policy "HWYS-19 — SIDEWALKS" provides the Department's guidelines for when a new sidewalk should be considered or where an existing sidewalk should be replaced. This Policy also discusses the State's municipalities' funding and maintenance responsibilities.

10-2.01.02 Sidewalk Design Criteria

In determining the sidewalk design, the designer should consider the following:

1. Widths. Sidewalk widths may vary from 1.2 m to 2.4 m with 1.5 m considered typical. On bridges, the typical width is 1.7 m. High pedestrian volumes may warrant widths greater than 1.5 m. In special cases (e.g., schools), the designer may need to conduct a detailed capacity analysis to determine the sidewalk width. Use the *Highway Capacity Manual* for this analysis.
2. Central Business Districts (CDB) Areas. The entire area between the curb and building is often fully used as a paved sidewalk.
3. Appurtenances. The designer should also consider the impacts of roadside appurtenances within the sidewalk (e.g., fire hydrants, parking meters, utility poles). These elements will reduce the effective width because they interfere with pedestrian activity. Preferably, place these appurtenances behind the sidewalk. If they are placed within the sidewalk, the sidewalk should have a minimum clear width of 1.0 m to 1.2 m. The clear width will be measured from the edge of the appurtenance to the edge of the sidewalk. The 1.0 m minimum is necessary to meet the handicapped accessibility requirements (see Section 15-1.0).
4. Cross Slope. The typical cross slope on the sidewalk is 2% towards the roadway. If the sidewalk is on an accessible route for handicapped individuals, then the maximum cross slope will be 2% (see Section 15-1.0).
5. Buffer Areas. If the available right-of-way is sufficient, consider providing a buffer area between the curb and sidewalk. These areas provide space for snow storage and allow a greater separation between vehicle and pedestrian. The buffer area should be at least 0.6 m wide to be effective. The designer should consider providing buffer areas between 2.4 m to 3.0 m wide. Buffer areas may also be used for the placement of roadside appurtenances, if necessary. However, this is

undesirable because the proximity to the traveled way increases the likelihood of vehicle/fixed-object accidents. Also, their presence in buffer areas detracts from the appearance of the highway environment.

Section 13b-17-27 of the Department's "Highway Encroachment Permit Regulations" contains additional information related to the design of sidewalks. Section 15-1.0 of the *Highway Design Manual* contains information related to accessibility requirements for handicapped individuals which applies to sidewalk design.

10-2.02 Fill and Cut Slopes

Fill and cut slopes should be designed to ensure the stability of the roadway and be as flat as practical to enhance roadside safety. Much of the necessary information for design will be provided in the Soils Report, if one is necessary for the project. The designer should consider the following when selecting a fill or cut slope design:

1. Fill Slopes. Fill slopes should be 1:6 or flatter. All soils will be stable at this rate. Maintenance efforts are greatly reduced, the erosion potential is reduced, and the slopes are safely traversable at 1:6. For fill heights between 3.0 m and 7.5 m, 1:4 slopes are acceptable. For fill heights greater than 7.5 m, 1:2 slopes protected by guide rail are typical. If site conditions require a slope steeper than 1:2, slope retaining structures are normally used. Any proposed slope steeper than 1:2 must be approved by the Soils and Foundation Section. The typical section figures in Chapters Four and Five provide additional information on slope rates for various classes of highway.
2. Clear Zones. The steeper the fill slope, the greater the clear zone will be where guide rail is not provided (see Figure 13-2A).
3. Slope Rounding. Round slope transitions adjacent to shoulders at the top of fills. As indicated in the typical cross section figures in Chapters Four and Five, the recommended rounding is 2.4 m. Measure this from the edge of the shoulder to where the rounded section intercepts the fill slope. For safety purposes, this will be sufficient with one exception. Where the design speed is 110 km/h and where an unprotected 1:4 slope is provided, the recommended rounding distance is 3.5 m (Note: Rounding is not necessary on fill slopes protected by guide rail.)

The typical rounding at the toe of a fill slope and at the top of a cut slope is 3.0 m.

4. Erosion Control. Erosion possibilities should be minimized. To the extent practical, preserve the natural and existing drainage patterns. Severely rutted side slopes can cause vehicular rollover even on relatively flat slopes. In good soil, turf can be established on slopes as steep as 1:2.

However, flatter slopes obviously reduce the erosion potential and should be used where feasible. The Department's *Drainage Manual* discusses erosion prevention in more detail.

5. Rock Cuts. Slopes up to vertical are possible in rock cuts using presplitting methods. Where practical, place the bottom of the rock-cut slope outside of the calculated clear zone. All jagged rock outcroppings exposed to possible vehicular impacts should be removed. Figures 4J and 5L provide details for rock cuts. The Department's Soils and Foundation Section will determine the appropriate slope in rock cuts.
6. Earth Cuts. In earth cuts, a rounded swale will normally be provided. Deep earth cuts may warrant terracing. These reduce erosion and enhance soil stability. The recommendation of the Soils and Foundation Section will govern.

10-2.03 Utility Placement

Space for the placement of utilities is an integral part of the highway cross section. To ensure that there will be adequate space, the designer should consider utility placement early in the project development.

10-3.0 MEDIANS

10-3.01 Median Widths

The median width is measured from the edge of the two inside travel lanes and includes the left shoulders if present. The design width will depend on the functional class, type of median, availability of right-of-way, construction costs, maintenance considerations, traffic operations at crossing intersections, safety and field conditions. Chapters Two, Four and Five provide the design range for median widths based on the functional classification and area type. In general, the median should be as wide as can be used advantageously. In addition, the designer should consider the following when determining the appropriate median width:

1. Left Turns. Consider the need for left-turn bays when selecting a median width.
2. Crossing Vehicles. A median should be approximately 8.0-m wide to safely allow a crossing passenger vehicle to stop between the two roadways. In areas where trucks are commonly present (e.g., truck stops), increase the median width to allow trucks to stop between roadways. Median widths from 9 m to 15 m should be carefully considered. These widths may encourage drivers to attempt the crossing independently; however, they may not be wide enough to fully protect longer vehicles from the through traffic.
3. Signalization. At signalized intersections, wide medians can lead to inefficient traffic operations and may increase crossing times.
4. Median Barrier. A median barrier is warranted for medians 20 m or less on freeways and other divided arterials. If feasible, the median should be wide enough to eliminate the need for a barrier.
5. Operations. Several vehicular maneuvers at intersections are partially dependent on the median width. These include U-turns and turning maneuvers at median openings, which are discussed in Chapter Eleven. The designer should evaluate the likely maneuvers at intersections and provide a median width that will accommodate the selected design vehicle.
6. Uniformity. In general, try to provide a uniform median width. However, variable-width medians may be advantageous where right-of-way is restricted, at-grade intersections are widely spaced (800 m or more), or an independent alignment is practical.
7. Roadway Elements. Do not reduce the widths of the other roadway cross section elements to provide additional median width.

8. Wide Medians. Median widths in the range of 15 m to 24 m may cause confusion as drivers may be confused about the intended operations for the multiple intersection encountered (e.g., going the wrong way on a one-way roadway).
9. Preferences. Drivers prefer medians that are obviously narrow or are wide enough to provide adequate refuge to allow independent crossings.

The typical cross section figures in Chapters Four and Five illustrate typical median types and other design details for median cross sections.

10-3.02 Median Types

The type of median selected will depend upon many factors, including:

1. drainage,
2. availability for median width,
3. snow and ice impacts,
4. impacts of superelevation development,
5. urban or rural location, and
6. traffic volumes.

10-3.02.01 Flush Medians

Flush medians may be used on urban highways and streets. A flush median should be crowned to avoid ponding water on the median area. A slightly depressed median in conjunction with median drains can be used to avoid carrying all of the drainage across the travel lanes.

10-3.02.02 Raised Medians

Raised medians are often used on urban highways and streets, both to control access and left turns and to improve the capacity of the facility. Figure 5H illustrates a typical raised median.

Advantages

When compared to flush medians, raised medians offer several advantages:

1. Mid-block left turns are controlled.
2. Left-turn channelization can be more effectively delineated if the median is wide enough.
3. A distinct location is available for traffic signs, signals, pedestrian refuge and snow storage.
4. The median edges are much more discernible during and after a snowfall.
5. Drainage collection may be improved.
6. Limited physical separation is available.

Disadvantages

The disadvantages of raised medians when compared to flush medians are:

1. They are more expensive to construct and more difficult to maintain.
2. They may need greater widths to serve the same function (e.g., left-turn lanes at intersections) because of the raised island and offset between curb and travel lane.
3. Curbs may result in adverse vehicular behavior upon impact.
4. Prohibiting mid-block left turns may overload street intersections and may increase the number of U-turns.
5. They may complicate the drainage design.
6. Access for emergency vehicles (e.g., fire, ambulance) may be more difficult.

Design

If a raised median will be used, the designer should consider the following in the design of the median:

1. Design Speed. Raised medians should only be used where the design speed is 80 km/h or less.
2. Curb Type. Either barrier or mountable curbs may be used.

3. Appurtenances. If practical, the placement of appurtenances within the median is strongly discouraged (e.g., traffic signal poles, light standards).
4. Width. The width of a raised median is measured from the two inside edges of the traveled ways and, therefore, includes the left shoulders. The width of a raised median should be sufficient to allow for the development of a channelized left-turn lane. Therefore, the typical width is 6.6 m, which provides for:
 - a. a 3.6-m left-turn lane,
 - b. a 0.6-m shoulder between the turn lane and raised island,
 - c. a 0.6-m shoulder between the opposing traveled way and the raised island, and
 - d. a minimum 1.8-m raised island.

If practical at an unsignalized intersection, a raised median should be 7.5 m in width to permit storage of a vehicle crossing or turning left onto the mainline.

5. Minimum Width. Under restricted conditions, the recommended minimum width of a raised median should be 2.4 m. This assumes a minimum 1.2-m raised island with 0.6-m shoulders on each side adjacent to the through travel lanes.

10-3.02.03 Depressed Medians

A depressed median is typically used on rural freeways. Depressed medians have better drainage and snow storage characteristics than flush or raised medians and, therefore, are preferred on major highways.

Figures 4F and 5G illustrate the use of depressed medians on rural and urban freeways and expressways. A depressed median should typically be 30 m wide in rural areas and 27 m wide in urban areas. This allows for the addition of future travel lanes on the inside while still maintaining a sufficient width of a depressed median. The designer should consider providing wider median widths, within the constraints of additional right-of-way and construction costs. When selecting a width for a depressed median, consider the following:

1. Median Barriers. All medians 20 m or less on freeways will require a median barrier. Therefore, to eliminate the need for a median barrier, consider providing a depressed median width greater than 20 m.
2. Slopes. Figures 4F and 5G illustrate a median slope range of 1:6 to 1:12, slopes greater than 1:10 should only be used if there is no median barrier placed on the slope. The designer should make

every reasonable effort to provide a median width which will allow the flatter slopes but still provide the necessary depth for the depressed median.

3. Longitudinal Gradient. The center longitudinal gradient of a depressed median should be a minimum of 0.5%.

10-4.0 BRIDGE AND UNDERPASS CROSS SECTION

The bridge or underpass cross section will depend upon the cross section of the approaching roadway, its functional classification, and whether the project entails new construction, major reconstruction, 3R work (non-freeways), 4R work (freeways), or a spot improvement.

10-4.01 Bridges

This section presents the Department's criteria for bridges which are within the limits of a new construction project (all functional classes) or within the limits of a major reconstruction project (non-freeways). The designer should reference the following sections for the Department's criteria on bridge widths for other conditions:

1. 4R freeway projects -- Section 3-1.04.
2. 3R non-freeway projects -- Section 2-7.02.
3. Bridge rehabilitation/replacement (freeways) -- Section 3-1.04.
4. Bridge rehabilitation/replacement (spot improvements, non-freeways) -- Section 3-2.03.

10-4.01.01 New Construction

This refers to bridges within the limits of a new construction project. In all cases, the full approach roadway width, including shoulders, will be carried across the structure. The approach width will be determined by the criteria in Chapters Four and Five. Where sidewalks are provided, they will be 1.7-m wide as measured from the gutter line.

10-4.01.02 Major Reconstruction (Non-Freeways)

This refers to bridges within the limits of a major reconstruction project on a non-freeway facility. The Department's criteria are as follows:

1. Bridge Reconstruction. The bridge substructure and/or superstructure may be partially or entirely reconstructed as part of the major reconstruction project. For example, this would be necessary if the project included the addition of travel lanes. If this work includes rehabilitation of the bridge deck, carry the full approach width, including shoulders, across the structure. Connecticut General Statutes (CGS) 13a-86 requires a minimum bridge width of 8.534 m on any 2-lane highway maintained by the Commissioner, exclusive of any sidewalk width. No exceptions to this criteria will be

allowed, unless in the judgment of the Commissioner a lesser width is warranted. Note that the criteria in CGS 13a-86 does not apply to bridges on highways maintained by a municipality.

2. Bridges to Remain in Place. If an existing bridge within the project limits is structurally sound and if it meets the Department's design loading structural capacity, it is unlikely to be cost effective to improve the geometrics of the bridge. These are considered existing bridges to remain in place. However, the geometric deficiencies may be severe, and/or there may be an adverse accident experience at the bridge. Therefore, the designer should consider widening the bridge to meet the approach roadway width as part of the major reconstruction project. Figure 10-4A provides the minimum widths for existing bridges to remain in place within the limits of a major reconstruction project. In addition, all existing bridge rails and the approach transitions will be evaluated to determine if they meet the Department's current criteria.

10-4.02 Underpasses

The discussion in this section will apply to all functional classes and to all project scopes of work.

The approaching roadway cross section, including clear zones, should be carried through the underpass. If an auxiliary lane passes through the underpass adjacent to the mainline, measure the clear zone distance from the edge of the auxiliary lane. The lateral clearances for any collector-distributor roads should be treated separately from the mainline, with its clear zone based on its own design speed, side slope and traffic characteristics.

When determining the cross section width of a highway underpass, the designer should also consider the likelihood of future roadway widening. Widening an existing underpass in the future can be extremely expensive and it may be warranted, if some flexibility is available, to allow for possible future developments. Therefore, the designer should evaluate the potential for further development in the vicinity of the underpass which would significantly increase traffic volumes. The Bureau of Policy and Planning should be consulted for its projections. As an example, a reasonable allowance for future widening may be to provide sufficient lateral clearance for one additional lane in each direction.

Functional Class	Design Year AADT	Clear Bridge Width (Note 1)
Arterial	All	Approach Traveled Way +1.2 m
Collector	0-1500	6.6 m
	1500-2000	7.2 m
	>2000	8.4 m
Local	0-250	6.0 m
	250-1500	6.6 m
	1500-2000	7.2 m
	> 2000	8.4 m

Notes:

1. Clear Bridge Width. This is the width between curbs or rails, whichever is less.
2. Long Bridges (Locals/Collectors). For bridges on these facilities with a total length greater than 30 m, the widths in the table do not apply. These structures should be analyzed individually considering the existing width, safety, traffic volumes, remaining structural life, design speed, costs to widen, etc.

**WIDTHS FOR EXISTING BRIDGES TO REMAIN IN PLACE
(Major Reconstruction Projects)**

Figure 10-4A

10-5.0 RIGHT-OF-WAY

For information on the types of right-of-ways (e.g., permanent, temporary, easements), the designer should review the Department's *Policies and Procedures for Property Maps*. The right-of-way width should be sufficiently wide to provide the selected cross section elements and dimensions, to provide proper drainage, to allow maintenance of the facility and to provide for future expansion of the cross section. However, restrictions along the highway corridor may require some compromises in determining the ROW width. In these cases, the selected highway cross section may be limited by the available ROW.

The following summarizes the Department's criteria for determining the ROW width:

1. Freeways (All Projects). The upper range of the ROW width should be the sum of the travel lane and median width plus 30 m beyond the edge of the outside travel lane on each side or side slope requirements, whichever governs. In urban areas, the minimum ROW width will be the sum of the travel lane and median widths plus the roadside clear zone on each side or side slope requirements, whichever governs.
2. Other Arterials and Collectors (New Construction/Major Reconstruction). The ROW width will be determined on a project-by-project basis. In determining the ROW width, the designer should consider travel lane widths, median widths, roadside clear zones, utility strips, side slope requirements, etc.
3. Other Arterials and Collectors (3R Projects). The acquisition of significant amounts of ROW is often outside the scope of a 3R project. Therefore, the existing ROW will often be unchanged by the 3R project. However, the designer should, wherever practical, secure additional ROW to allow cost-effective geometric and roadside safety improvements.
4. Local Roads and Streets (All Projects). The ROW width will be as required for the purpose of the project and will be determined by the local government.

ROW width should be uniform, but this is not a necessity. In urban areas, variable widths may be necessary due to the existing development; varying side slopes and embankment heights may make it desirable to vary ROW width; and, ROW limits will likely have to be adjusted at intersections and freeway interchanges. The following special ROW controls should also be considered:

1. Sight Distances. At horizontal curves and intersections additional ROW may be warranted to ensure that the necessary sight distance is always available in the future.

2. Restricted Areas. In areas where the necessary ROW widths cannot be reasonably obtained, the designer should consider using steeper slopes, revising grades, or using slope retaining structures.
3. Railroads. On sections of highway adjacent to railroads, avoid any encroachment on railroad ROW whenever feasible.
4. Interchanges. Special ROW considerations at interchanges are discussed in Chapter Twelve.

10-6.0 TYPICAL SECTIONS

Chapters Four and Five present several typical section figures for both normal and superelevated sections. The figures are based on:

1. rural or urban location;
2. multilane or two-lane;
3. type of median (e.g., depressed, raised, with a median barrier); and
4. curbed or uncurbed.

In addition, Figure 5M presents a typical section for a high-volume/incident management freeway. “Incident management” refers to events (e.g., accidents) which have the potential to produce major disruptions to the flow of traffic on a freeway. The critical feature of this typical section is the provision of a left shoulder with sufficient width to assist in accommodating traffic in the event of a highway incident in the interim.

The use of this typical section will be determined on a case-by-case basis.

10-7.0 REFERENCES

1. *A Policy on Geometric Design of Highways and Streets*, AASHTO, 1994.
2. *Highway Capacity Manual*, TRB, 1994.
3. *Roadside Design Guide*, AASHTO, 1995.
4. TS-80-204, *Design of Urban Streets*, FHWA, January, 1980.
5. *Parking Principles*, Special Report No. 125, Highway Research Board, 1971.
6. FHWA-RD-79-75/76, *Safety Aspects of Curb Parking*, FHWA, 1979.

Chapter Eleven

INTERSECTIONS AT-GRADE

Table of Contents

		<u>Page</u>
11-1.0	GENERAL DESIGN CONSIDERATIONS	11-1(1)
11-1.01	<u>Capacity</u>	11-1(1)
	11-1.01.01 Design Year and Level of Service	11-1(1)
	11-1.01.02 Capacity Methodology for Signalized Intersections	11-1(1)
11-1.02	<u>Design Vehicle</u>	11-1(2)
11-1.03	<u>Intersection Alignment</u>	11-1(2)
11-1.04	<u>Intersection Profile</u>	11-1(4)
	11-1.04.01 Approach Gradient	11-1(4)
	11-1.04.02 Cross Section Transitions	11-1(4)
11-1.05	<u>Intersection Spacing</u>	11-1(6)
11-2.0	INTERSECTION SIGHT DISTANCE (ISD)	11-2(1)
11-2.01	<u>Stop-Controlled Intersections</u>	11-2(1)
	11-2.01.01 Theoretical Discussion (Upper ISD Values)	11-2(1)
	11-2.01.02 Theoretical Discussion (Minimum ISD Values)	11-2(5)
	11-2.01.03 ISD Application	11-2(5)
	11-2.01.04 ISD Worksheet	11-2(8)
11-2.02	<u>Stopped Vehicle Turning Left Across Oncoming Traffic</u>	11-2(8)
11-2.03	<u>Signal-Controlled Intersections</u>	11-2(12)
11-3.0	TURNING RADII (Right Turns)	11-3(1)
11-3.01	<u>Types of Treatment</u>	11-3(1)
11-3.02	<u>Design Vehicle Selection</u>	11-3(1)
11-3.03	<u>Designs for Pavement Edge/Curb Line</u>	11-3(3)
	11-3.03.01 Tolerable Encroachment	11-3(5)
	11-3.03.02 Inside Clearance	11-3(5)
	11-3.03.03 Parking Lanes/Shoulders	11-3(5)
	11-3.03.04 Pedestrians	11-3(8)
	11-3.03.05 Summary	11-3(8)

Table of Contents

(Continued)

	<u>Page</u>
11-4.0	TURNING ROADWAYS 11-4(1)
11-4.01	<u>Guidelines</u> 11-4(1)
11-4.02	<u>Design Criteria</u> 11-4(1)
11-4.02.01	Design Speed 11-4(1)
11-4.02.02	Horizontal Alignment 11-4(3)
11-4.02.03	Width 11-4(6)
11-4.02.04	Angle of Turn 11-4(6)
11-4.02.05	Acceleration/Deceleration Lanes 11-4(11)
11-5.0	AUXILIARY TURNING LANES 11-5(1)
11-5.01	<u>Guidelines for Right-Turn Lanes</u> 11-5(1)
11-5.02	<u>Guidelines for Left-Turn Lanes</u> 11-5(1)
11-5.03	<u>Design Details for Auxiliary Turning Lanes</u> 11-5(8)
11-5.04	<u>Typical Treatments for Auxiliary Turning Lanes</u> 11-5(8)
11-5.05	<u>Dual Turn Lanes</u> 11-5(11)
11-5.06	<u>Extension of Additional Through Lanes</u> 11-5(15)
11-6.0	MEDIAN OPENINGS 11-6(1)
11-6.01	<u>Guidelines</u> 11-6(1)
11-6.02	<u>Design</u> 11-6(1)
11-6.03	<u>Median Openings on Freeways</u> 11-6(3)
11-7.0	CHANNELIZATION 11-7(1)
11-7.01	<u>Design Principles</u> 11-7(1)
11-7.02	<u>Design Details (Islands)</u> 11-7(1)
11-8.0	DRIVEWAYS 11-8(1)
11-8.01	<u>Design</u> 11-8(1)
11-8.01.01	Detailed Criteria 11-8(1)
11-8.01.02	Criteria (Existing Driveways) 11-8(6)
11-8.02	<u>Driveway Spacing and Corner Clearances</u> 11-8(7)
11-8.03	<u>Major Traffic Generators</u> 11-8(7)
11-9.0	REFERENCES 11-9(1)

Chapter Eleven

INTERSECTIONS AT-GRADE

11-1.0 GENERAL DESIGN CONSIDERATIONS

11-1.01 Capacity

11-1.01.01 Design Year and Level of Service

To perform the capacity analysis, the designer must select a future design year. For new construction and major reconstruction, this is typically 20 years from the construction completion date. For 3R and spot improvement projects, the intersection should be designed to accommodate current traffic volumes to 10-year future traffic volumes. If the intersection is within the limits of a longer project, the design year for the intersection will be the same as that for the project.

The geometric design tables in Chapters Two, Four and Five present the recommended levels of service for highways based on functional classification and urban or rural location. The intersection level of service for the selected design year should meet these criteria so that the highway facility will operate at a consistent serviceability. At a minimum, the intersection should operate at no worse than LOS D.

When a project has experienced a significant delay during design, the designer may be required to perform an updated capacity analysis. The need for this updated analysis will be determined on a case-by-case basis.

11-1.01.02 Capacity Methodology for Signalized Intersections

The Division of Traffic Engineering is responsible for most capacity calculations at intersections. The Department has adopted the unsignalized and signalized intersection methods (Chapters Nine and Ten) presented in the *Highway Capacity Manual* (HCM). For use of other computerized capacity analysis programs, the designer should contact the Division of Traffic Engineering to determine which programs and versions are acceptable to the Department.

11-1.02 Design Vehicle

Designs for right and left turns should accommodate the turning paths of the applicable design vehicle. The detailed design criteria for right turns at intersections are presented in Section 11-3.0. The Department has adopted the following design vehicles for intersection design:

1. P — passenger car
2. SU — single unit vehicle (e.g., delivery truck)
3. BUS — intercity or city transit bus
4. WB-15 — semitrailer truck or tractor-trailer combination with a 12.2-m semitrailer
5. WB-19 ("Large" Truck) — tractor with 14.6-m semitrailer.

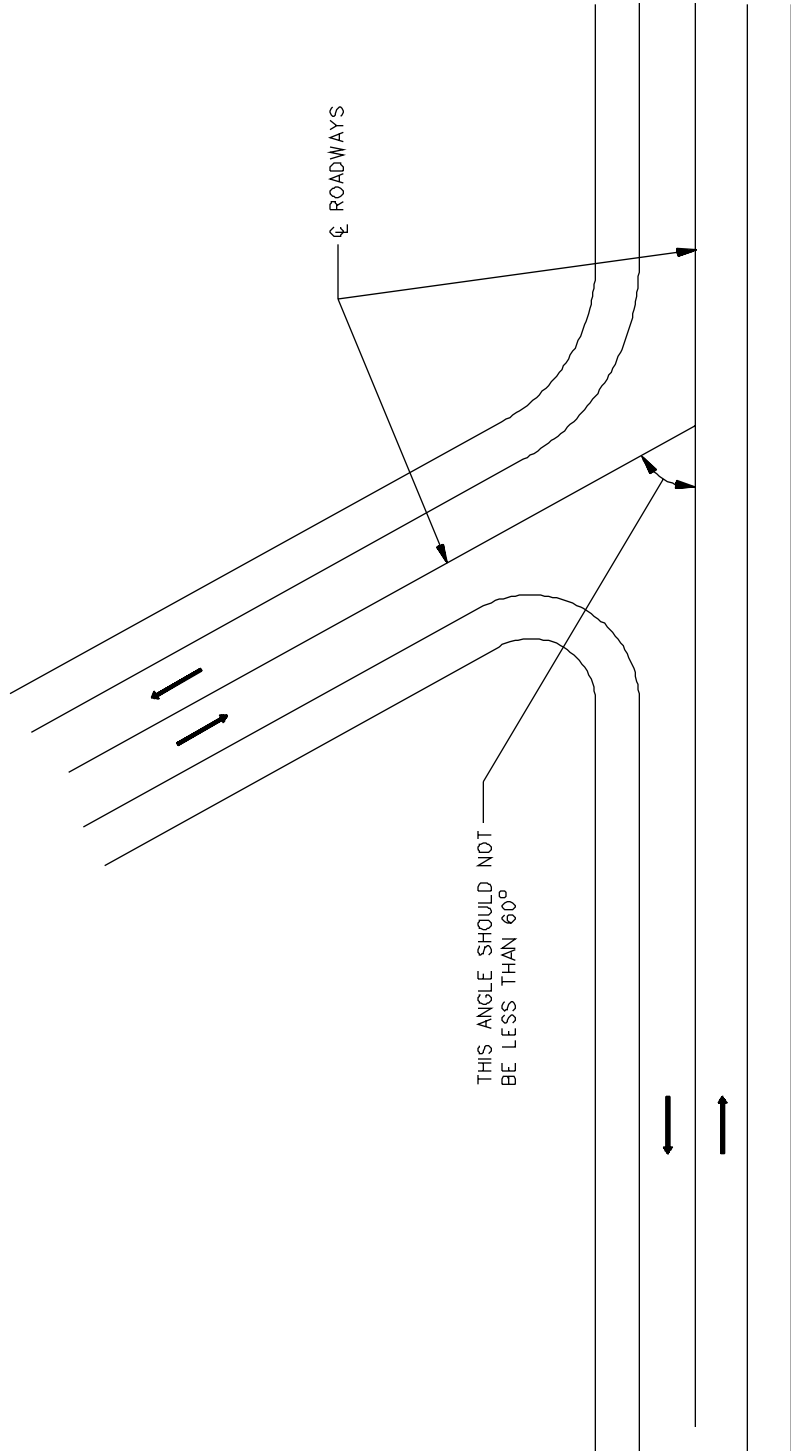
The turning characteristics of the applicable design vehicle are used to test the adequacy of an existing or proposed design at an intersection. The designer can determine the amount of vehicular encroachment upon adjacent lanes when making a right turn. This, combined with several other factors discussed in Section 11-3.0, will allow the designer to select the appropriate turning treatment.

11-1.03 Intersection Alignment

All legs of an intersection should be on tangent rather than curved sections. Where a minor road intersects a major road on a horizontal curve, this complicates the geometric design of the intersection — particularly sight distance, turning movements, channelization and superelevation. If relocation of the intersection is not practical, the designer may be able to realign the minor road to intersect the major road perpendicular to a tangent at a point on the horizontal curve. Although this is an improvement, this arrangement may still result in difficult turning movements if the superelevation is high.

At-grade intersections should intersect at angles between 60° and 90°. (See Figure 11-1A.) Excessively skewed intersections increase the travel distance across the major highway, adversely affect sight distance, and complicate the designs for turning movements. If the angle of intersection is less than 60°, the intersections should be realigned if practical.

The alignment should direct the through vehicle into the appropriate receiving lane across the intersection.



SKEWED INTERSECTIONS

Figure 11-1A

11-1.04 Intersection Profile

11-1.04.01 Approach Gradient

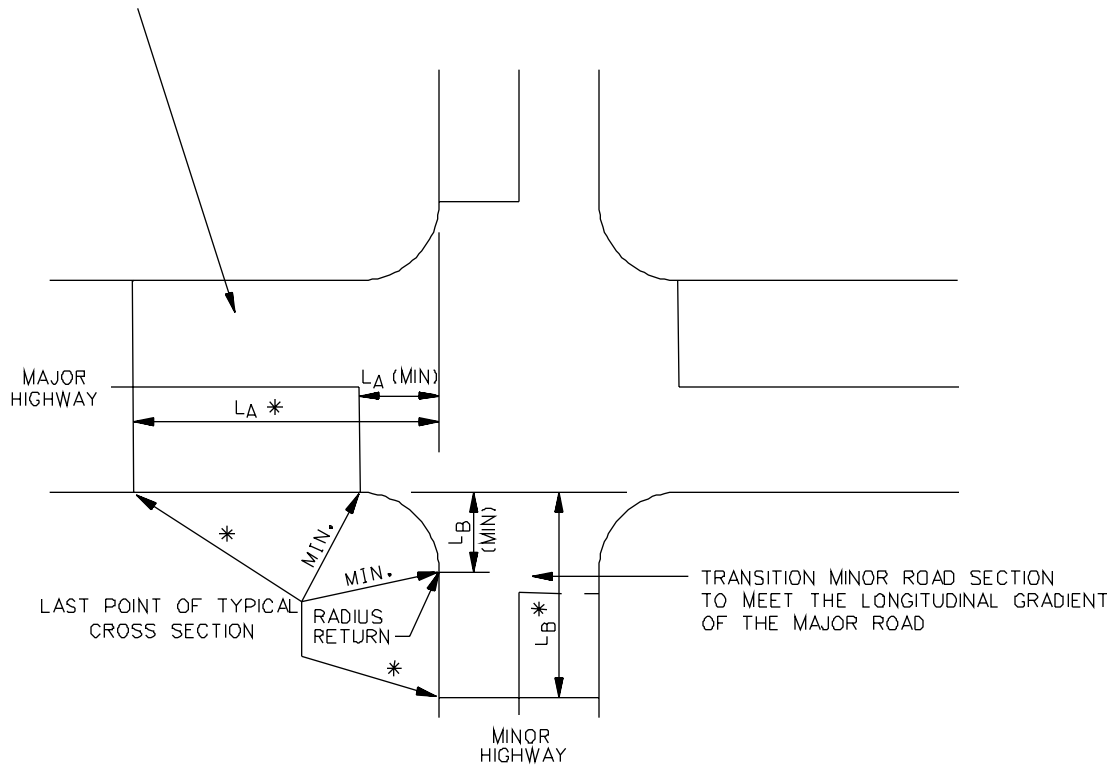
The vertical profile of an at-grade intersection should be as level as practical, subject to drainage requirements. This also applies to the distance along any intersection leg, called the landing area, where vehicles stop waiting to pass through the intersection. Grades approaching or leaving the intersection will affect vehicular deceleration distances (and therefore stopping sight distance) and vehicular acceleration distances. Therefore, the gradient on the landing area should be 3% or less. When designing the profile of a minor road crossing a major highway, the designer should maintain stopping sight distance to the brake lights of the preceding vehicle, approximately 450 mm.

11-1.04.02 Cross Section Transitions

One or more of the approaching legs of the intersection may need to be transitioned (or warped) to meet the cross section of the two crossing roads. The designer should consider the following:

1. **Stop Controlled.** When the minor road is stop controlled, the profile and cross section of the major road will normally be maintained through an intersection, and the cross slope of the stop-controlled leg will be transitioned to match the major road cross slope and profile.
2. **Signalized Intersection.** At signalized intersections, or potential signalized intersections, the cross section of the minor road will typically be transitioned to meet the profile and cross slope of the major road. If both intersecting roads have approximately equal importance, the designer may want to consider transitioning both roadways to form a plane section through the intersection. Where compromises are necessary between the two major roadways, the smoother riding characteristics should be provided for the roadway with the higher traffic volumes and operating speeds.
3. **Transition Rates.** Where one or both intersecting roadways are transitioned, the designer must determine the length and rate of transition from the normal section to the modified section; see Figure 11-1B. Consider providing a transition design that meets the general principles of superelevation transition which apply to that roadway (i.e., open-road or low-speed urban street conditions). See Chapter Eight for a complete discussion on superelevation development. Where these criteria are applied to transition rates, the applied design speed is typically:
 - a. 50 km/h for a stop-controlled leg,
 - b. the highway design speed for a free-flowing leg, or
 - c. the highway design speed for all legs of a signalized intersection.

PROFILE AND CROSS-SECTION OF MAJOR HIGHWAY IS TYPICALLY MAINTAINED THROUGH AN INTERSECTION. IF BOTH INTERSECTING ROADS HAVE APPROXIMATELY EQUAL IMPORTANCE OR TO MEET DIFFICULT FIELD CONDITIONS, BOTH ROADWAYS MAY BE TRANSITIONED.



L_A = TRANSITION LENGTH FOR MAJOR HIGHWAY

L_B = TRANSITION LENGTH FOR MINOR HIGHWAY

* = TRANSITION LENGTH BASED ON SUPERELEVATION TRANSITION CRITERIA FOR THE ROADWAY

Notes:

1. See discussion in Section 11-1.04.02.
2. Spot elevations of the pavement area should be provided to determine drainage requirements, roadway profiles and their effect on the turning path of the design vehicle.

PAVEMENT TRANSITIONS THROUGH INTERSECTIONS

Figure 11-1B

At a minimum, the approaching legs of an intersection should be transitioned within the curb or curve radius length of the intersection consistent with practical field conditions (see Figure 11-1B).

11-1.05 Intersection Spacing

Short distances between intersections should be avoided if practical because they tend to impede traffic operations. For example, if two intersections are close together and require signalization, they may need to be considered as one intersection for signalization purposes. To operate safely, each leg of the intersection may require a separate green cycle, thereby greatly reducing the capacity for both intersections. To operate efficiently, signalized intersections should be 400 m apart.

In addition, short gaps between opposing "T" intersections should also be avoided. Drivers tend to encroach into the opposing lanes (corner cutting) so that they can make their turning maneuvers in one movement. In general, all new intersections should preferably be at least 120 m apart.

11-2.0 INTERSECTION SIGHT DISTANCE (ISD)

11-2.01 Stop-Controlled Intersections

This section presents the Department's ISD criteria for stop-controlled intersections. Where all legs of an intersection are stop controlled, minimum ISD are acceptable. Because of the more difficult maneuvers at a stop-controlled side road, the use of ISD values in the upper range are encouraged. However, for design exceptions only the minimum values are applicable. A design exception will not be required where the minimum ISD is not met due to the presence of parked vehicles within the roadway. The presence of permanent objects such as buildings, cut slopes, parking lots, etc., within the minimum ISD will require a design exception. The critical maneuvers for ISD are turning movements either to the left or to the right. The ISD required for crossing movement is less than the left-turn movement.

11-2.01.01 Theoretical Discussion (Upper ISD Values)

The Department has adopted ISD criteria which differ from those adopted by AASHTO. The Department's upper ISD criteria are based on the Department's October 1985 report "Parameters Affecting Intersection Sight Distance."

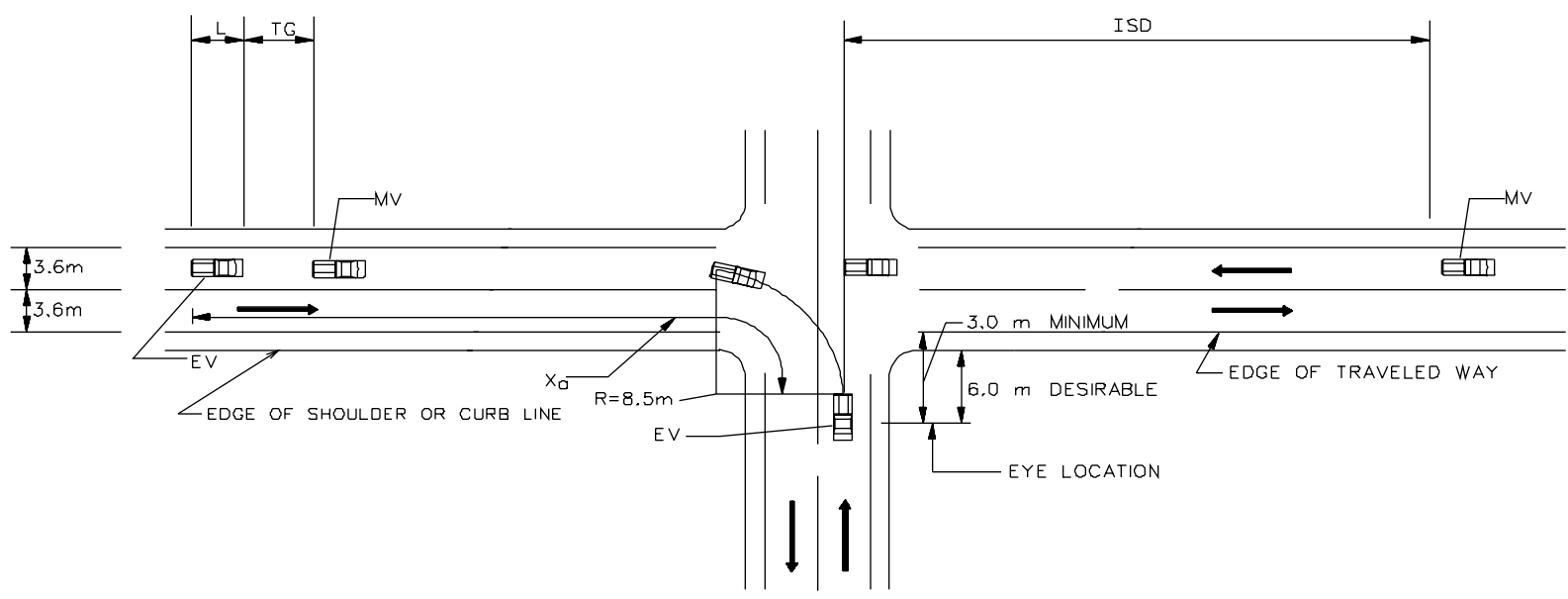
Figure 11-2A illustrates the Department's theoretical assumptions for its upper ISD criteria. The ISD model, in summary, assumes that a mainline driver approaches an intersection at design speed as a vehicle enters the highway from a side road ahead of the mainline driver. The mainline driver reacts to the vehicle by releasing the accelerator and/or slightly touching the brake. The mainline driver decelerates at a comfortable rate until a reduced speed, 10% below design speed, is reached. From this point, the mainline driver cruises at the reduced speed until the vehicle is tailgate distance away from the accelerating (entering) vehicle. The entering vehicle is accelerating according to the rates developed by the Department's research study.

The calculations for the ISD values are based on the following equation:

$$ISD = \frac{1}{3.6} \left(V * J + \frac{V^2 - RV^2}{2D} + (RV)(TR) \right) - (X_a - 10.7 - TG)$$

where:

ISD	=	intersection sight distance, m
V	=	design speed (major road), km/h
RV	=	reduced speed (mainline vehicle), km/h
D	=	deceleration rate (mainline vehicle), km/h/sec
J	=	reaction time (mainline vehicle), sec
TR	=	time traveled at reduced speed (mainline vehicle), sec
X _a	=	distance accelerating (entering) vehicle travels, m
TG	=	tailgate distance, m



Notes:

1. See Section 11-2.01.01 for definition of terms.
2. ISD for right-turning vehicle is determined in a similar manner.

**INTERSECTION SIGHT DISTANCE
(Theoretical Model)
Figure 11-2A**

The theoretical ISD model developed by the Department is intended to find a balance between an acceptable level of safety and what can be practically provided at intersections. The model assigns a reasonable level of responsibility to both the entering vehicle (EV) and mainline vehicle (MV). The following summarizes the major assumptions within the Department's ISD model:

1. Design Vehicle. The passenger car (P) has been selected for the ISD model.
2. Reaction Time of EV. The model assumes 1 second for the entering driver to release the brake and depress the accelerator.
3. Acceleration Rate of EV. Based on the Department's research, the ISD model assumes that the EV will accelerate at the rates presented in Figure 11-2B. From the acceleration rates, the distance X_a can be determined. These are also provided in Figure 11-2B.
4. Reaction Time of MV (J). This is the time required from the moment the entering vehicle begins its maneuver until the mainline driver releases the accelerator. These times are presented in 11-2C. The reaction time of EV (i.e., 1 second) has been added to this value.
5. Deceleration Rate of MV (D). These are based on the Department's field tests as part of the ISD research study. The objective was to determine "comfortable" rates of vehicular deceleration. It was decided to assume deceleration in gear at high speeds and to assume lightly actuating the brakes at low speeds. Deceleration rates are presented in Figure 11-2C. For comparison, the Department's deceleration rates are equal to about 25% of the AASHTO "comfortable" deceleration/braking rates (Figure II-17 of the 1994 *Green Book*).
6. Reduced Speed of MV (RV). The Department's ISD model assumes that the MV will reduce its speed to 90% of the mainline design speed. Likewise, this is the speed to which the EV will accelerate to before being overtaken by the MV.
7. Tailgate Distance (TG). This is the distance between the MV and the EV when the EV has accelerated to 90% of the design speed on the major road. The TG distance is based on providing one car length (5.8 m) for each 15 km/h of speed (i.e., $5.8 \times RV/15$).
8. Eye Location. The ISD values will establish one leg of the sight triangle which needs to be visible to the EV. The leg on the stop-controlled road or street will be determined by the assumed location of the eye. This is established as 3.0 m to 6.0 m behind the "reference" line. The reference line will normally be the edge of shoulder or curb line. However, it may fall between the shoulder edge and travel way edge, if there is reasonable justification to do so.
9. Height of Eye/Object. Both of these values will be 1070 mm.

Initial Speed (km/h)	Final Speed (km/h)	Time (Ta) (sec)	Distance (Xa) (m)	Average Acceleration Rate ① (km/h / sec)
0	30	5.7	27	5.26
0	40	8.4	54	4.71
0	50	11.3	90	4.42
0	60	14.5	138	4.14
0	70	17.9	199	3.91
0	80	21.3	272	3.76
0	90	25.0	359	3.60
0	100	28.8	459	3.47

Note: ① These criteria are based on field studies reported in Reference 8. These are 85th percentile values; i.e., 85% of all cars will accelerate at a faster rate than in the table.

**ISD BASE DATA
(Entering Driver)**

Figure 11-2B

Mainline Design Speed (V) (km/h)	Reduced Speed (RV) (km/h)	Reaction Time (J) (sec)	Deceleration Rate (D) (km/h sec)
40	36	3.0	1.48
50	45	3.6	1.60
60	54	4.3	1.73
70	63	4.9	1.86
80	72	5.5	1.99
90	81	6.1	2.13
100	90	6.7	2.25

**ISD BASE DATA
(Mainline Driver)**

Figure 11-2C

11-2.01.02 Theoretical Discussion (Minimum ISD Values)

The minimum ISD values are developed using the following criteria:

1. the SSD criteria from the AASHTO *A Policy on Geometric Design of Highways and Streets*; or
2. the SSD criteria from NCHRP 270 *Parameters Affecting Stopping Sight Distance* (Table 27); or
3. the minimum distance for a vehicle to clear the travel lane(s) from the left (minimum ISD to the left), or the minimum distance for a vehicle to clear the entire intersection (minimum ISD to the right); whichever is larger.

11-2.01.03 ISD Application

The designer will use the criteria in Figure 11-2D and Figure 11-2E to determine the applicable ISD values. The designer must make every reasonable effort to meet the values in the upper range of the ISD criteria; only for severely restricted locations will the minimum ISD be acceptable. As illustrated in Figure 11-2D, the ISD criteria are based on the distance "X" the turning vehicle must travel from the shoulder or curb line to clear the opposing traffic. This allows the application of the Department's ISD model to multilane highways. The designer should also consider the following when determining the ISD criteria:

1. The minimum "X" distance will be 6.6 m, even if the actual "X" is less than this value.
2. Each successive column approximately represents an additional lane of opposing traffic (3.6 m).
3. The eye location is 3.0 m to 6.0 m behind the reference line. The eye location is independent of "X".

The table assumes that a right-turning vehicle will turn into the outer travel lane in that direction. A left-turning vehicle will turn into the inner travel lane in that direction.

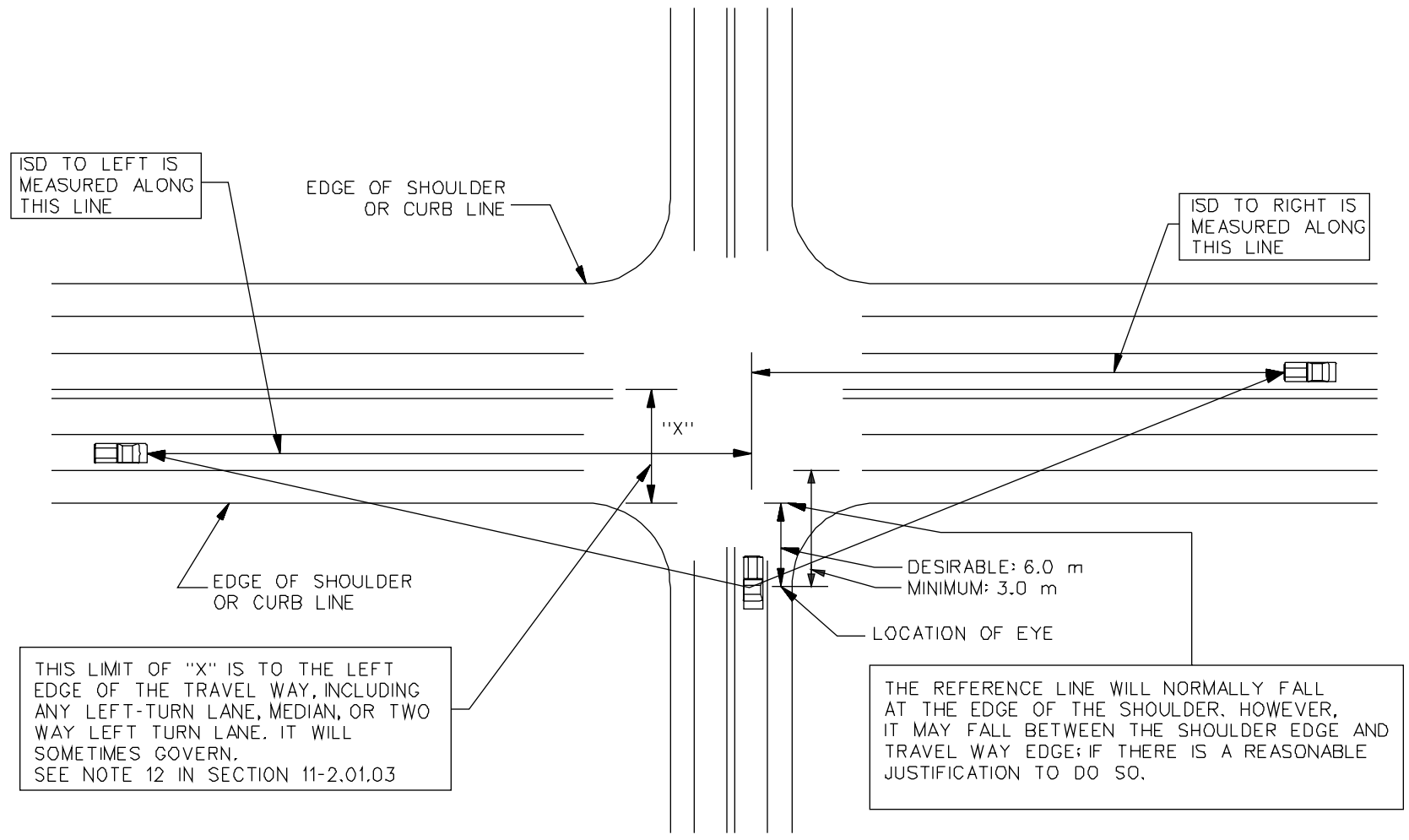
5. If the opposing direction of travel includes an exclusive right- or left-turn lane(s) or narrow median, these will be included in the "X" distance when reading into the table.
6. For values of "X" which are between columns, the designer should read into the next highest column.

Design Speed (km/h)	Application	WIDTH OF OPPOSING LANES (m)				
		≤ 6.6	10.2	13.8	17.4	21.0
		Intersection Sight Distance (m)				
40	Upper	72	92	102	109	116
	Minimum Right	72	72	79	87	95
	Minimum Left	72	72	72	72	74
50	Upper	102	127	139	149	157
	Minimum Right	90	95	107	117	125
	Minimum Left	90	90	90	90	92
60	Upper	139	169	184	195	206
	Minimum Right	109	127	141	153	163
	Minimum Left	109	109	109	109	111
70	Upper	184	219	236	250	261
	Minimum Right	130	165	181	195	207
	Minimum Left	130	130	130	130	130
80	Upper	235	275	295	311	324
	Minimum Right	169	209	228	244	257
	Minimum Left	169	169	169	169	169
90	Upper	296	341	363	381	396
	Minimum Right	218	263	284	302	317
	Minimum Left	218	218	218	218	218
100	Upper	364	414	439	459	475
	Minimum Right	276	326	350	369	386
	Minimum Left	276	276	276	276	276

Notes:

1. See Figure 11-2E for application of ISD criteria.
2. See Figure 11-2.01.03 for additional information on ISD criteria.

INTERSECTION SIGHT DISTANCE CRITERIA
Figure 11-2D



Notes:

- 1. See Figure 11-2D for ISD values.
- 2. See discussion in Section 11-2.01.03.

**INTERSECTION SIGHT DISTANCE
(Application)**

Figure 11-2E

7. If a divided highway has a median width of 7.5 m or more, the ISD application can be evaluated in two movements.
8. It is assumed that the roadway being entered is relatively level over the ISD distances.
9. If the angle of intersection is less than 60°, the designer should adjust the "X" distance and ISD accordingly.
10. At some intersections, the designer may want to increase the ISD distances to account for large numbers of buses or trucks which may use the intersection.
11. The height of eye and object is 1070 mm.
12. For minimum ISD to the right, the designer must determine the applicable "X" value to read into Figure 11-2D. If "X" is the same for both directions of travel, then this value will be used. However, if the main road has unbalanced lanes, the "X" distance will be different for the two directions of travel. In this case, the designer will use the larger of the two values to read into Figure 11-2D for minimum ISD to the right.
13. The intersection sight line should clear the non-pavement surface by 150 mm or more to accommodate long grass, snow accumulations, etc.

11-2.01.04 ISD Worksheet

The ISD that is required at each intersection may vary for each approach. Use Figure 11-2H, at the end of Section 11-2.0, to document the required and actual ISD available at an intersection.

11-2.02 Stopped Vehicle Turning Left Across Oncoming Traffic

At all intersections regardless of traffic control, the designer must evaluate the sight distance needs for a stopped vehicle turning left across oncoming traffic. This applies to all vehicles which may make a left turn across the opposing lanes of travel. The driver will need to see straight ahead a sufficient distance to turn left and clear the opposing travel lanes before an approaching vehicle reaches the intersection. Figure 11-2G illustrates the theoretical assumptions for the ISD criteria for a stopped vehicle turning left. Figure 11-2F presents the ISD values. The calculations are based on the following equation:

$$ISD = \frac{V}{36} (t + 1)$$

- where:
- V = design speed, km/h
 - t = time, seconds, for traversing the distance "d"
 - d = (10.7 m + A) = distance traveled by TV to clear outer travel lane of opposing traffic, m
 - A = distance between center of lane from where TV turns to edge of outer travel lane of opposing traffic, m

The following summarizes the major assumptions within the ISD model:

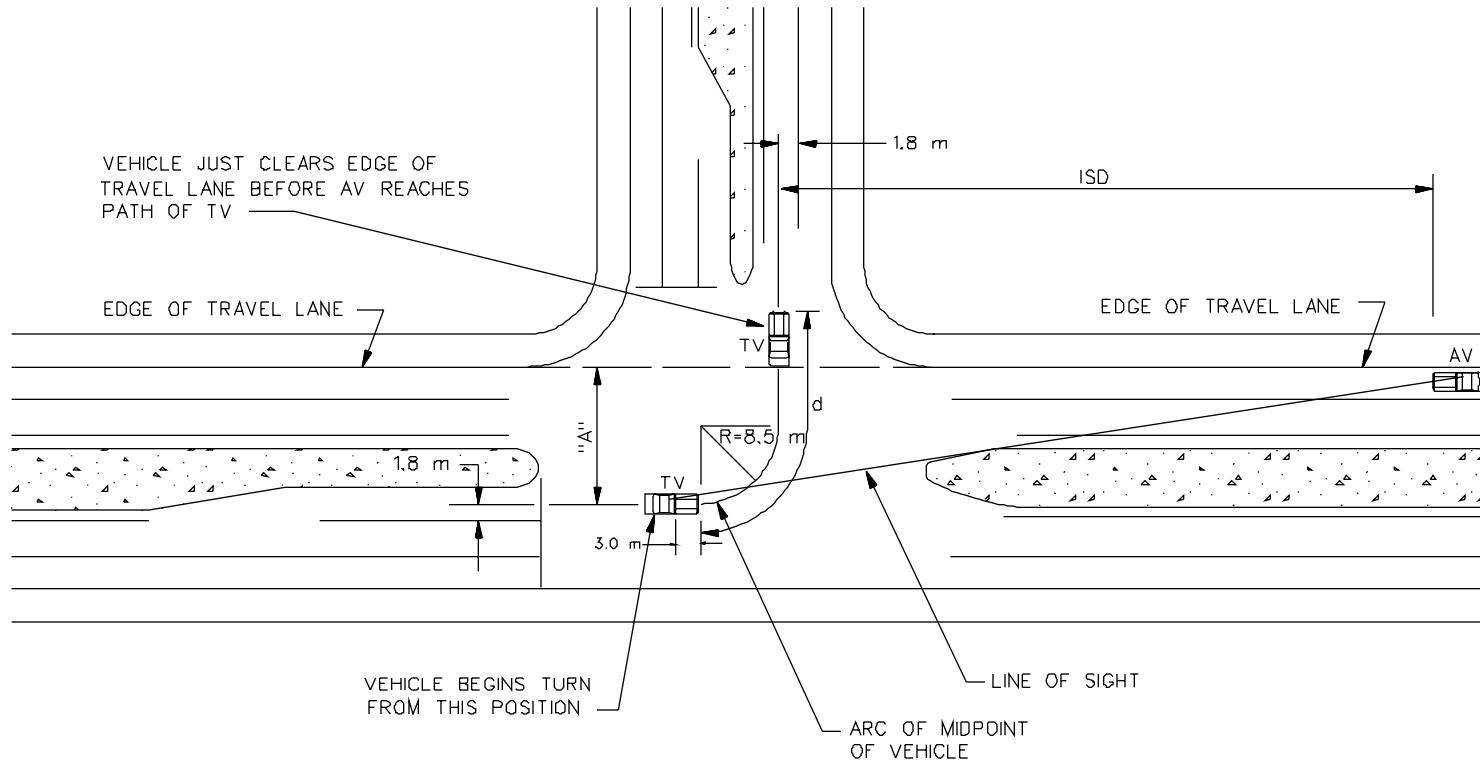
1. Design Vehicle. This will be the passenger car (P).
2. Turning Vehicle (TV) Action. The TV will move forward beyond the stop line, always remaining in line with the lane from which it will turn. It will stop when its front bumper is a distance equal to the turning radius away from the center of the lane into which it will turn. When it begins its turning maneuver, the TV will turn at this radius until it is lined up with the lane on the crossroad and then travel in a straight line to complete the clearing maneuver. The TV will always turn into the inside through travel lane.

"A" (m)	Design Speed						
	40	50	60	70	80	90	100
5.5	58	73	87	102	116	131	145
6	59	74	88	103	118	133	147
7	61	76	91	106	121	136	151
8	62	78	93	109	124	140	155
9	64	80	96	112	127	143	159
10	65	82	98	114	130	147	163
11	67	83	100	117	133	150	167
12	68	85	102	119	136	153	170
13	70	87	104	122	139	157	174
14	71	89	107	124	142	160	178
15	72	90	109	127	145	163	181
20	79	99	118	138	158	178	197

- Notes:
1. See Figure 11-2G for application of ISD criteria.
 2. See Section 11-2.02 for additional information.
 3. Values are in meters.

**INTERSECTION SIGHT DISTANCE CRITERIA
(Stopped Vehicle Turning Left Across Oncoming Traffic)**

Figure 11-2F



Notes:

1. See Figure 11-2F for ISD values.
2. See Section 11-2.02 for discussion and application.
3. Criteria apply to all intersections.

**INTERSECTION SIGHT DISTANCE
(Stopped Vehicle Turning Left Across Oncoming Traffic)**

Figure 11-2G

3. Approaching Vehicle (AV) Action. The AV will travel at the design speed (V) and will maintain this speed through the intersection (i.e., it will not slow down).
4. Turning Radius. This will be 8.5 m for the mid-section of the TV. This radius will be constant throughout the turn.
5. Acceleration Rate. The TV will accelerate at the rates found by the Department's field study (Figure 11-2B).
6. Reaction Time of TV. The model assumes one second for the turning driver to release the brake and depress the accelerator.
7. Clearance Interval. The clearance between the TV and the AV is assumed to be zero.
8. Effect of Median Width. This represents additional distance the TV must traverse. The model assumes the TV will not move laterally to the left within the intersection area, even if the opportunity is available.
9. Effect of Exclusive Left-Turn Lane. If one is present, the TV will turn from it; if one is not present, the TV will turn from the inner through lane. If a dual left-turn lane is present, the TV will turn from the outer left-turn lane, which will yield a greater ISD need.

For application, the ISD criteria for a stopped vehicle turning left will apply to all opportunities for this maneuver at all intersections. The following procedure should be used:

1. Find the ISD value from Figure 11-2F for the applicable design speed and "A" value at the intersection.
2. Use the ISD value to locate the front bumper of the AV as indicated in Figure 11-2G. This will represent the "object" location.
3. Find the "eye" location as indicated in Figure 11-2G.
4. The line of sight between the eye and object should be clear of all obstacles. The heights of eye and object are each 1070 mm.

11-2.03 Signal-Controlled Intersections

The minimum ISD requirements in Figure 11-2D will apply to all approach legs to a signalized intersection.

INTERSECTION SIGHT DISTANCE

Project Number: _____

INTERSECTION: _____

NAME OF N/S ROADWAY	DISTANCE FROM EYE LOCATION TO NEAREST THROUGH LANE	APPROACH SPEED OF CROSSING TRAFFIC	UPPER ISD (Figure 11-2D)	MINIMUM ISD (Figure 11-2D)	ACTUAL ISD AVAILABLE*
NORTHBOUND LEFT LANE LOOKING LEFT					
NORTHBOUND RIGHT LANE LOOKING RIGHT					
SOUTHBOUND LEFT LANE LOOKING LEFT					
SOUTHBOUND RIGHT LANE LOOKING RIGHT					
EASTBOUND LEFT LANE LOOKING LEFT					
EASTBOUND RIGHT LANE LOOKING RIGHT					
WESTBOUND LEFT LANE LOOKING LEFT					
WESTBOUND RIGHT LANE LOOKING RIGHT					

*A design exception will be required for each location where this is less than the minimum.

11-3.0 TURNING RADII (Right Turns)

11-3.01 Types of Treatment

At intersections, the designer must decide how best to accommodate right-turning vehicles. A design must be selected for the edge of pavement or curb lines, which may be one of the following types:

1. simple radius,
2. simple radius with entering and exiting tapers,
3. 3-centered symmetric compound curve, or
4. 3-centered asymmetric compound curve.

Each basic design type has its advantages and disadvantages. The simple radius is the easiest to design and construct and, therefore, it is the most common. However, the designer should also consider the benefits of the simple radius with an entering and exiting taper. Its advantages as compared to other designs include:

1. The simple radius with tapers provides approximately the same transitional benefits as the compound curvature arrangements, but it is easier to design, survey and construct.
2. To accommodate a specific vehicle with no encroachment, a simple radius requires greater intersection pavement area than a radius with tapers. For large vehicles, a simple radius is often an unreasonable design, unless a channelized island is used.
3. A simple radius results in greater distances for pedestrians to cross than a radius with tapers.
4. For angles of turn greater than 90°, a radius with tapers is a better design than a simple radius, primarily because less intersection area is required.

11-3.02 Design Vehicle Selection

In general, the selected design vehicle should be the largest vehicle likely to make the turn with some frequency. Therefore, the appropriate design vehicle may vary from intersection to intersection, and the selection will involve an assessment of the number and types of vehicles which will make the turn. Figure 11-3A presents suggested criteria which the designer should use as a starting point.

For Turn Made From	For Turn Made Onto	Minimum Suggested Design Vehicle	Turning Radii (m) (3)
Freeway Ramp	All	Moving WB-15*	18
Arterial	Arterial	Moving WB-15	18
	Collector	Moving SU	18
	Local	Moving SU	18
Collector	Arterial	Moving SU	18
	Collector	Moving SU	18
	Local	Moving SU	18
Local	Arterial	Stopped SU	13
	Collector	Stopped SU	13
	Local	Stopped SU	13

*WB-19 must be physically able to make the turn.

Notes:

1. *The criteria apply to both urban and rural intersections.*
2. *See Section 11-3.02 for a discussion of the selection of a WB-19 truck for intersection design.*
3. *Radius is for the outer wheel of the turning vehicle.*

DESIGN VEHICLE SELECTION

Figure 11-3A

The WB-19 design vehicle (large truck) is allowed on the National Truck Network (the Interstate highway system and other freeways in Connecticut). Large trucks must have reasonable access to truck facilities for a distance of 1.5 km from the Network route. Therefore, large trucks may be allowed to make right turns at some at-grade intersections, and the designer should consider this possibility. The designer should exercise judgment when deciding which intersections should be designed according to the turning characteristics of the large truck. Some intersections (e.g., those near truck stops) are obvious candidates. The designer should also consider whether or not an intersection may in the future need to accommodate the large truck. Individuals or entities may apply for access permits for greater distances through the Commissioner of CONNDOT by applying to the Motor Transport Services Division in the Bureau of Public Transportation. Finally, the designer should consider that even longer trucks than the WB-19 vehicle may today or in the future be negotiating the intersection. Where a significant number of these are expected, the designer should take this into consideration.

11-3.03 Designs for Pavement Edge/Curb Line

Once the designer has selected the design vehicle (Figure 11-3A) and the type of right-turn treatment (e.g., simple radius), he/she must now determine the appropriate design for the pavement edge or curb line. Figure 11-3B presents recommended criteria. The designer should consider that there are certain assumptions built into these numbers. The following presents the major assumptions:

1. Encroachment. The criteria in Figure 11-3B will allow the indicated vehicle to make the turn entirely within its lane of travel; i.e., no encroachment into adjacent lanes will occur.
2. Speed. The criteria in Figure 11-3B have been developed assuming a turning speed of less than 15 km/h.
3. Inside Clearance. The criteria in the table assumes that a 0.5-m clearance is maintained throughout most of the turn and that the clearance is never less than 0.2 m.
4. Parking Lanes/Shoulders. The criteria in the table assume that no parking lanes or shoulders are available which would, of course, allow the vehicle additional space on the inside to make the turn.

Because of these assumptions, the criteria in Figure 11-3B should serve as a starting point to determine the design for the pavement edge or curb line. To determine the final design, the designer must use a turning template for the selected design vehicle. The designer should also consider the discussion in the following sections.

Angle of Turn	Design Vehicle	Simple Curve Radius (m)	Simple Curve Radius With Taper			3-Centered Compound Curve Symmetric		3-Centered Compound Curve Asymmetric	
			Radius (m)	Offset (m)	Taper	Radii (m)	Offset (m)	Radii (m)	Offset
30	P	18							
	SU	30							
	WB-12	45							
	WB-15	60							
	WB-19	110	6.7	1.0	15:1				
45	P	15							
	SU	23							
	WB-12	36							
	WB-15	53	36	0.6	15:1	60-30-60	1.0		
	WB-19	70	43	1.2	15:1	140-72-140	0.6	36-43-150	1.0-2.6
60	P	12							
	SU	18							
	WB-12	28							
	WB-15	45	29	1.0	15:1	60-23-60	1.7	60-23-84	0.6-2.0
	WB-19	50	43	1.2	15:1	120-30-120	4.5	34-30-67	3.0-3.7
75	P	11	8	0.6	10:1	30-8-30	0.6		
	SU	17	14	0.6	10:1	36-14-36	0.6		
	WB-12		18	0.6	15:1	36-14-36	1.5	36-14-60	0.6-2.0
	WB-15		20	1.0	15:1	45-15-45	2.0	45-15-69	0.6-3.0
	WB-19		43	1.2	20:1	134-23-134	4.5	43-30-165	1.5-3.6
90	P	9	6	0.8	10:1	30-6-30	0.8		
	SU	15	12	0.6	10:1	36-12-36	0.6		
	WB-12		14	1.2	10:1	36-12-36	1.5	36-12-60	0.6-2.0
	WB-15		18	1.2	15:1	55-18-55	2.0	36-12-60	0.6-3.0
	WB-19		36	1.2	30:1	120-21-120	3.0	48-21-110	2.0-3.0
105	P		6	0.8	8:1	30-6-30	0.8		
	SU		11	1.0	10:1	30-11-30	1.0		
	WB-12		12	1.2	10:1	30-11-30	1.5	30-17-60	0.6-2.5
	WB-15		17	1.2	15:1	55-14-55	2.5	45-12-64	0.6-3.0
	WB-19		35	1.0	30:1	160-15-160	4.5	110-23-180	1.2-3.2
120	P		6	0.5	10:1	30-6-30	0.6		
	SU		9	1.0	10:1	30-9-30	1.0		
	WB-12		11	1.5	8:1	36-9-36	2.0	30-9-55	0.6-2.7
	WB-15		14	1.2	15:1	55-12-55	2.6	45-11-67	0.6-3.6
	WB-19		30	1.5	25:1	160-21-160	3.0	24-17-160	5.2-7.3
135	P		6	0.5	15:1	30-6-30	0.5		
	SU		9	1.2	8:1	30-9-30	1.2		
	WB-12		9	2.5	6:1	36-9-36	2.0	30-8-55	1.0-4.0
	WB-15		12	2.0	10:1	48-11-48	2.7	40-9-56	1.0-4.3
	WB-19		24	1.5	20:1	180-18-180	3.6	30-18-195	2.1-4.3
150	P		6	0.6	10:1	23-6-23	0.6		
	SU		9	1.2	8:1	30-9-30	1.2		
	WB-12		9	2.0	8:1	30-9-30	2.0	28-8-48	0.3-.3.6
	WB-15		11	2.1	6:1	48-11-48	2.1	36-9-55	1.0-4.3
	WB-19		18	3.0	10:1	145-17-145	4.5	43-18-170	2.4-3.0
180	P		5	0.2	20:1	15-5-15	0.2		
	SU		9	0.5	10:1	30-9-30	0.5		
	WB-12		6	3.0	5:1	30-6-30	3.0	26-6-45	2.0-4.0
	WB-15		8	3.0	5:1	40-8-40	3.0	30-8-55	2.0-4.0
	WB-19		17	3.0	15:1	245-14-245	6.0	30-17-275	4.5-4.5

Note: Many assumptions have been made in the development of these criteria. See Section 11-3.03 for a discussion.

EDGE OF PAVEMENT DESIGNS FOR TURNS AT INTERSECTIONS

Figure 11-3B

11-3.03.01 Tolerable Encroachment

To determine the tolerable encroachment, the designer should evaluate several factors, including traffic volumes, one-way or two-way operation and the functional classes of the intersecting roads or streets. Figure 11-3C presents recommended criteria for tolerable encroachment for right-turning vehicles. The designer must evaluate these criteria against the construction and right-of-way impacts for meeting the encroachment recommendations. For example, if these impacts are significant and if through and/or turning volumes are relatively low, the designer may decide to accept encroachment for the design vehicle which exceeds the criteria in Figure 11-3C. Considering local conditions, the width of local side road at the back of the curb return should be 9.0 m.

11-3.03.02 Inside Clearance

The following will apply to the assumed inside clearance of the turning vehicle:

1. Maximum. The selected design vehicle will make the right turn while maintaining approximately a 0.5-m clearance from the pavement edge or curb line and will not come closer than 0.2 m.
2. Minimum. At restricted sites, it may be necessary to assume a less generous clearance. At a minimum, the selected design vehicle may be allowed to make the right turn such that its wheels will almost touch the pavement edge or curb line. This means that the vehicle will overhang beyond the edge. Therefore, the designer must ensure that the turning vehicle will not impact any obstructions (e.g., signal poles, mailboxes, signs).

11-3.03.03 Parking Lanes/Shoulders

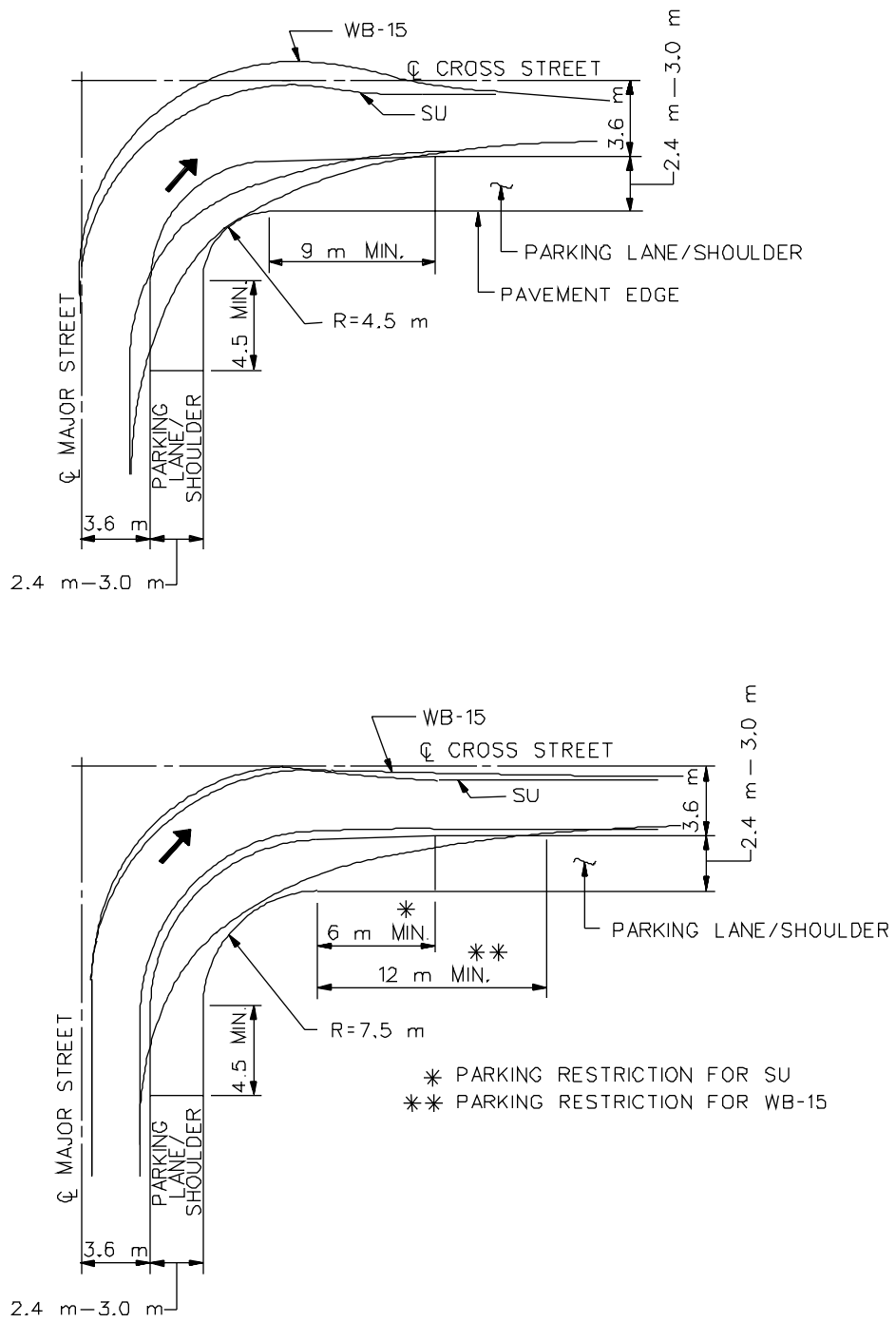
At many intersections, parking lanes and/or shoulders will be available on one or more approach legs, and this additional roadway width may be carried through the intersection. This will greatly decrease the turning problems for large vehicles at intersections with small curb radii. Figure 11-3D illustrates the turning paths of several design vehicles with curb radii of 4.5 m or 7.5 m and where 2.4-m to 3.0-m parking lanes are provided. The presence of a shoulder 2.4 m to 3.0 m in width will have the same impact as a parking lane. The figure also illustrates the necessary distance to restrict parking before the PC (4.5 m) and after the P.T. (6 m to 12 m) on the cross street. The designer will, of course, need to check the proposed design with the applicable turning template and encroachment criteria. The designer should not consider the beneficial effects of a parking lane if the lane will be used for through traffic part of the day or if parking will likely be prohibited in the future.

Type of Traffic Control	For Turn Made From	For Turn Made Onto	Tolerable Encroachment for Selected Design Vehicle	
			For Road/Street From Which Turn Made	For Road/Street Onto Which Turn Made
Stop - Controlled	Stop-Controlled Road/Street	Through Road/Street	No encroachment into adjacent lanes	No encroachment beyond outermost or right travel lane
	Through Road/Street	Stop-Controlled Road/Street	No encroachment into adjacent lanes	No encroachment into opposing lanes of travel
Signalized	Either Road/Street	Either Road/Street	No encroachment into adjacent lanes	No encroachment into opposing lanes of travel

- Notes:
1. See Figure 11-3A for design vehicle selection.
 2. For all conditions, the design vehicle is assumed to be in the outermost through travel lane or exclusive right-turn lane, whichever applies, before the turn is made.
 3. The table indicates those conditions where the turning vehicle cannot encroach into the opposing lanes of travel. In addition, for roads/streets with two or more through travel lanes, consider providing a design so that the turning vehicle does not encroach beyond the outermost or right travel lane.
 4. For the indicated tolerable encroachment (e.g., none into adjacent lanes), the design vehicle should not come closer than 0.2 m to the lane at any point in the turn.
 5. Regardless of the selected design vehicle or the criteria for encroachment, a WB-15 should physically be able to make all turns at all intersections without backing up and without impacting curbs, parked cars, utility poles, mailboxes or any other obstruction.

RECOMMENDED TOLERABLE ENCROACHMENTS FOR RIGHT-TURNING VEHICLES

Figure 11-3C



EFFECT OF CURB RADII AND PARKING ON TURNING PATHS

Figure 11-3D

11-3.03.04 Pedestrians

The greater the turning radius or the number of lanes, the farther pedestrians must walk in the roadway. This is especially important to handicapped individuals. Therefore, the designer should consider this when determining the edge of pavement or curb line design. This may lead to, for example, the decision to use a turning roadway (see Section 11-4.0) to provide a pedestrian refuge. In addition, where the pedestrian must cross more than four lanes, the designer should evaluate the accommodation of pedestrian traffic.

11-3.03.05 Summary

In summary, the designer should determine the proper design for the edge of pavement or curb line to accommodate right-turning vehicles as follows:

1. Select the type of turning treatment:
 - a. simple radius,
 - b. simple radius with entering and exiting tapers,
 - c. 3-centered symmetric compound curve, or
 - d. 3-centered asymmetric compound curve.

Use Figure 11-3B as a starting point.

2. Select the design vehicle (Figure 11-3A).
3. Determine the tolerable encroachment (Figure 11-3C).
4. Determine the appropriate inside clearance (Section 11-3.03.02).
5. Consider the benefits of any parking lanes or shoulders (Section 11-3.03.03).
6. Consider impacts on pedestrians (Section 11-3.03.04).
7. Check all proposed designs with the applicable vehicular turning template.
8. Revise design as necessary to accommodate the right-turning vehicle or determine that this is not practical because of adverse impacts.

11-4.0 TURNING ROADWAYS

Turning roadways are channelized areas (painted or raised) at intersections at-grade.

11-4.01 Guidelines

The need for a turning roadway will be determined on a case-by-case basis. The designer should consider using turning roadways when:

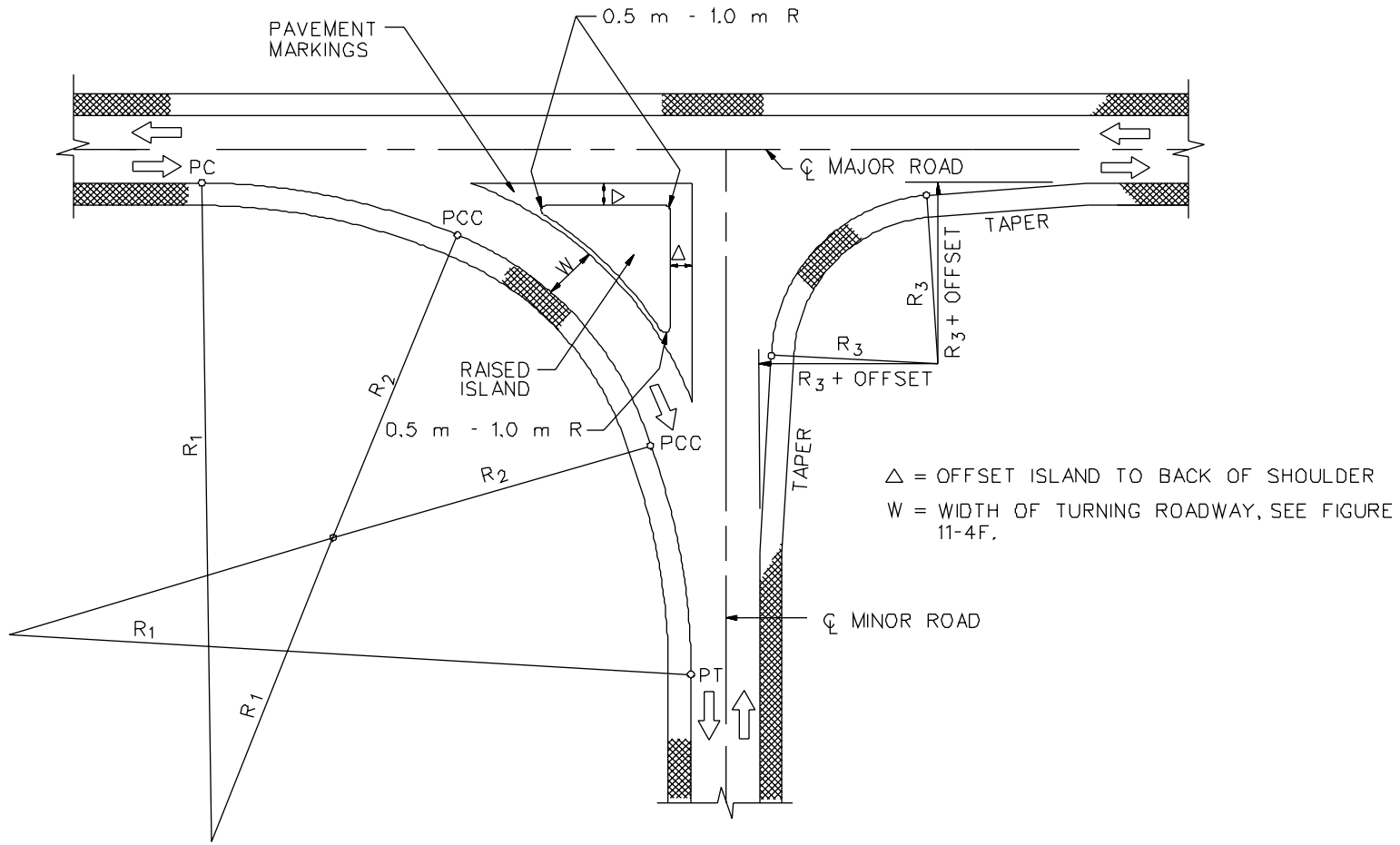
1. there is a need to allow right turns at 25 km/h or more on, for example, rural or urban arterials;
2. the angle of turn will be greater than 90°;
3. the volume of right turns is especially high;
4. there is significant amount of unused pavement; and/or
5. the selected design vehicle is a semi-trailer combination.

11-4.02 Design Criteria

Figure 11-4A illustrates a typical design for a turning roadway at an urban intersection. The following sections provide additional guidance on the design of a turning roadway.

11-4.02.01 Design Speed

Where practical, the design speed on a turning roadway should be within 30 km/h of the mainline design speed. However, a turning roadway even at a low design speed (e.g., 20 km/h) will still provide a significant benefit to the turning vehicle regardless of the speed on the approaching highway. Typically, the design speed for a turning roadway will be in the range of 20-30 km/h. For 3-centered compound curves, this criteria applies to the design speed of the sharpest curve.



EXAMPLE DESIGN FOR TURNING ROADWAY

Figure 11-4A

11-4.02.02 Horizontal Alignment

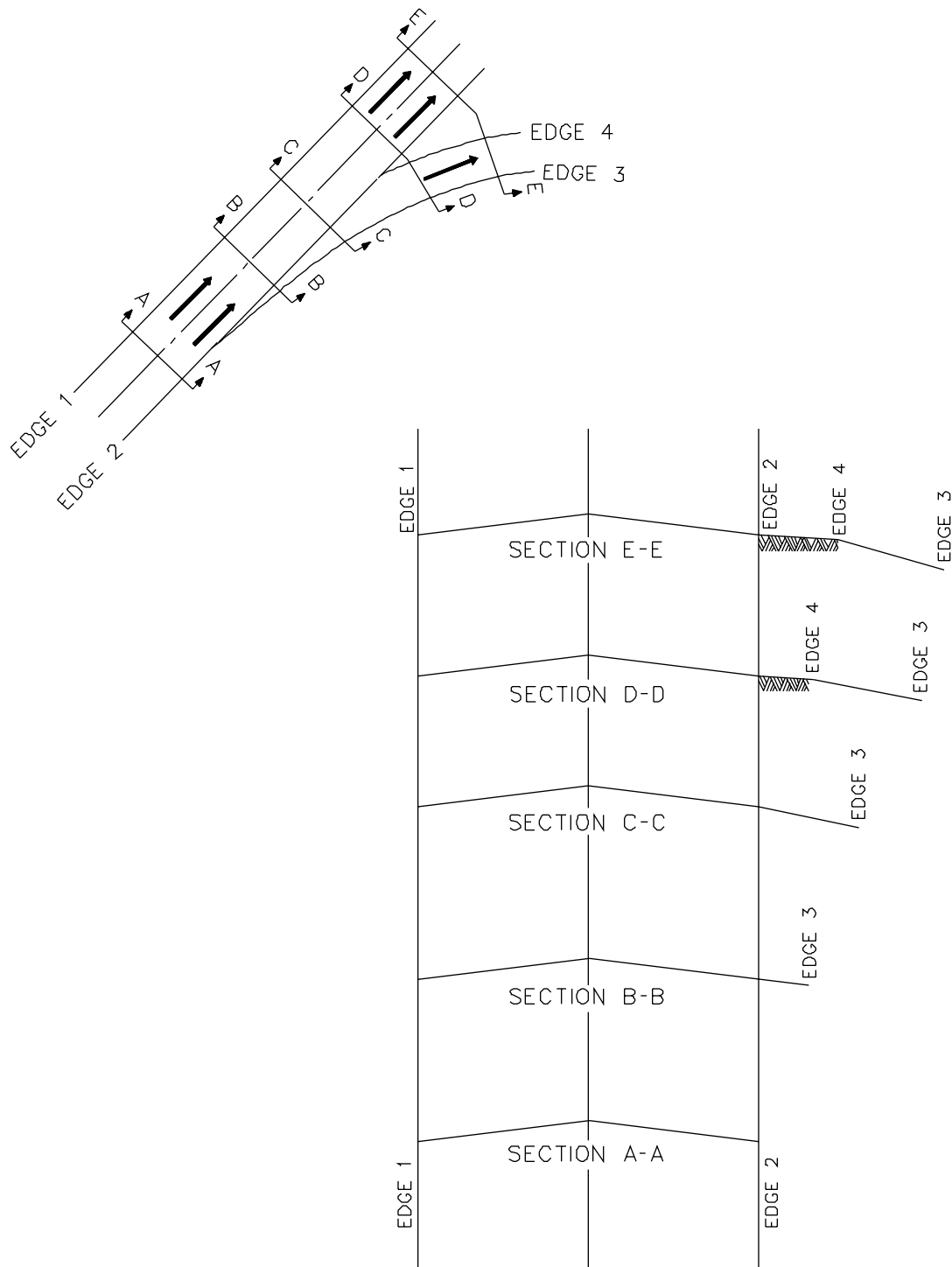
The horizontal alignment of turning roadway design differs from that of open-roadway conditions, which are discussed in Chapter Eight. The following discusses several of the assumptions used to design horizontal alignment for turning roadways:

1. Curvature Arrangement. For many turning roadway designs, a 3-centered compound curve is the preferred curvature arrangement.
2. Superelevation. Turning roadways are often relatively short in length. This greatly increases the difficulty of superelevating the roadway. Therefore, a flexible approach is used for superelevating turning roadways. Figure 11-4B provides a range of superelevation rates that the designer may select for various combinations of curve radii and design speeds. For many turning roadways with low design speeds (e.g., 20-30 km/h), the superelevation rate will typically be 2%. The maximum superelevation rate for turning roadways should not exceed 6%. Selection of the appropriate superelevation rate will be based on field conditions and will be determined on a site-by-site basis.
3. Superelevation Transitions. When a turning roadway is superelevated, the transition length should meet the criteria presented in Chapter Eight for the relative longitudinal slope. However, due to the restrictive nature of turning roadways and their typically short lengths, actual transition lengths will be determined on a case-by-case basis. The designer should review the field conditions, deceleration and acceleration taper lengths, right-of-way restrictions and construction costs to produce a practical design for superelevation transition lengths at turning roadways.
4. Superelevation Development. Figure 11-4C illustrates a schematic of superelevation development at a turning roadway. The actual development will depend upon the practical field conditions combined with a reasonable consideration of the theory behind horizontal curvature. The following presents criteria which should be met:
 - a. No change in the normal cross slope is necessary up to Section B-B. Here, the width of turning roadway is nominally less than 1 m.
 - b. The full width of the turning roadway should be attained at Section D-D. The amount of superelevation at D-D will depend upon the practical field conditions.
 - c. Beyond Section D-D, the turning roadway pavement should be rotated as needed to provide the required superelevation for the design speed of the turning roadway.

Radius (m)	Range in Superelevation Rate for Turning Roadways with Design Speed (km/h) of					
	20	30	40	50	60	70
15	2%-6%	—	—	—	—	—
25	2%-6%	2%-6%	—	—	—	—
50	2%-5%	2%-6%	4%-6%	—	—	—
70	2%-4%	2%-6%	3%-6%	6%	—	—
100	2%-3%	2%-4%	3%-6%	5%-6%	—	—
150	2%-3%	2%-3%	3%-5%	4%-6%	6%	—
200	2%	2%-3%	2%-4%	3%-5%	5%-6%	—
300	2%	2%-3%	2%-3%	3%-4%	4%-5%	5%-6%
500	2%	2%	2%	2%-3%	3%-4%	4%-5%

**SUPERELEVATION RATES
(Turning Roadways)**

Figure 11-4B



Note: The axis of rotation is first about Edge 2 and then about Edge 4.

**DEVELOPMENT OF SUPERELEVATION AT
TURNING ROADWAY TERMINALS**

- d. The minimum superelevation transition length should meet the criteria set forth in Item #3.
 - e. The superelevation treatment for the existing portion of the turning roadway should be similar to that described for the entering portion. However, for stop-control merges the superelevation on the turning roadway should match the cross slope on the merging highway or street.
5. Minimum Radius. The minimum turning roadway radii are based on design speed, side-friction factors and superelevation (see Chapter Eight). Figure 11-4D presents minimum radii for various turning roadway conditions. As discussed in Item #2, a range of superelevation rates may be used. Therefore, Figure 11-4D presents minimum radii for several assumed superelevation rates. In addition, the lengths of the entering and exiting curves should meet the criteria in Note 3 of Figure 11-4D.
6. Cross Slope Rollover. Figure 11-4E presents the maximum allowable algebraic difference in the cross slopes between the mainline and turning roadway where they are adjacent to each other. In Figure 11-4C, these criteria apply between Section A-A and Section D-D. This will likely be a factor only when a superelevated mainline is curving to the left.

11-4.02.03 Width

Turning roadway widths are dependent upon the turning radii and design vehicle selected. Figure 11-3A provides the criteria for selection of the appropriate design vehicle. Figure 11-4F presents the turning roadway pavement widths for various design vehicles based on 1-lane, one-way operation with no provision for passing a stalled vehicle. This design is generally appropriate for most at-grade intersections. The pavement widths in Figure 11-4F provide an extra 1.8-m clearance beyond the design vehicle's swept path. This additional width provides extra room for maneuverability, driver variances and the occasional larger vehicle.

11-4.02.04 Angle of Turn

Figure 11-4F is applicable to highways which intersect at 90°. Figure 11-4G presents turning roadway criteria for oblique angles of intersection.

Turning Roadway Design Speed (km/h)	Maximum Side Friction (f)	Assumed Super-Elevation (e)	Calculated Radius (m)	Design Radius (m)
20	0.35	2%	9	10
		4%	8	10
		6%	8	10
30	0.28	2%	24	25
		4%	22	25
		6%	21	25
40	0.23	2%	50	50
		4%	47	50
		6%	43	45
50	0.19	2%	94	95
		4%	86	90
		6%	79	80
60	0.17	2%	149	150
		4%	135	135
		6%	123	125

Notes:

1. For design speeds greater than 60 km/h, use rural conditions. See Chapter Eight.
2. See Figure 11-4B for the recommended range of superelevation rates for a given radius and design speed. The lower values are more appropriate for urban and high-volume areas.
3. A flatter curve, no more than twice the design radius of the sharper curve, should be used to transition into and out of the sharper radius. The length of the flatter transition curve will be:

Radius of Sharper Curve (m)		30	50	60	75	100	125	150 or more
Length of Flatter Transition Curve	Minimum (m)	12	15	20	25	30	35	45
	Upper Range (m)	20	20	30	35	45	55	60

MINIMUM RADII FOR TURNING ROADWAYS

Figure 11-4D

Design Speed of Curve at Section D-D* (km/h)	Maximum Algebraic Difference in Cross Slope at Crossover Line (%)
20-30	5-8
40-50	5-6
>50	4-5

* See Figure 11-4C

PAVEMENT CROSS SLOPE AT TURNING ROADWAY TERMINALS

Figure 11-4E

Radius on Inner Edge of Pavement, R(m)	Width of Turning Roadways (m)			
	P	SU	WB-15	WB-19
15	3.9	5.4	7.8	7.8
25	3.9	5.1	6.6	7.5
30	3.9	4.8	6.3	6.9
50	3.6	4.8	5.7	6.3
75	3.6	4.8	5.1	5.7
100	3.6	4.5	5.1	5.4
125	3.6	4.5	4.8	5.1
150	3.6	4.5	4.8	5.1
Tangent	3.6	4.5	4.8	4.5

Notes:

1. *If barrier curb is used on one side, then a curb offset of 0.3 m should be added to the table value.*
2. *If barrier curb is used on both sides, then a curb offset of 0.6 m (0.3 m on each side) should be added to the table value.*

PAVEMENT WIDTHS FOR TURNING ROADWAYS

Figure 11-4F

Angle of Turn (degrees)	Design Classification	Three-Centered Compound Curves		Width of Lane (m)	Approx. Island Size (m ²)
		Radii (m)	Offset (m)		
75	A	45-23-45	1.0	4.2	5.5
	B	45-23-45	1.5	5.4	5.0
	C	55-28-55	1.0	6.0	5.0
90	A	45-15-45	1.0	4.2	5.0
	B	45-15-45	1.5	5.4	7.5
	C	55-20-55	2.0	6.0	11.5
105	A	36-12-36	0.6	4.5	6.5
	B	30-11-30	1.5	6.6	5.0
	C	55-14-55	2.4	9.0	5.5
120	A	30-9-30	0.8	4.8	11.0
	B	30-9-30	1.5	7.2	8.5
	C	55-12-55	2.5	10.2	20.0
135	A	30-9-30	0.8	4.8	43.0
	B	30-9-30	1.5	7.8	35.0
	C	48-11-48	2.7	10.5	60.0
150	A	30-9-30	0.8	4.8	130.0
	B	30-9-30	2.0	9.0	110.0
	C	48-11-48	2.1	11.4	160.0

Notes:

- Asymmetric three-centered compound curves and straight tapers with a simple curve can also be used without significantly altering the width of roadway or corner island size.
- Painted island delineation is recommended for islands less than 7 m² in size.
- Design classification:
 - A — Primarily passenger vehicles; permits occasional single-unit truck to turn with restricted clearances.
 - B — Provides adequately for SU; permits occasional WB-15 to turn with slight encroachment on adjacent traffic lanes.
 - C — Provides fully for WB-15.

TURNING ROADWAY DESIGN
Figure 11-4G

11-4.02.05 Acceleration/Deceleration Lanes

As discussed in Section 11-4.02.01, the design speed on the turning roadway should be within 30 km/h of the mainline design speed. Where this is not practical, the designer should consider using a deceleration lane. They are especially beneficial where mainline and turning volumes are high; at these intersections, the deceleration lane may also be needed for storage. An acceleration lane for the exiting portion of the turning roadway may also be justified. However, it may not be used to good advantage if the turning roadway will be stop controlled. Acceleration and deceleration lanes should be considered at intersections which include turning roadways for arterials with a design speed of 80 km/h or more. Refer to Section 11-5.0 for the design details of the auxiliary lanes.

11-5.0 AUXILIARY TURNING LANES

This section presents criteria for the design and guidelines for auxiliary lanes at intersections. In particular the designer should consider that deceleration lanes are advantageous, especially on high-speed highways. A driver leaving the highway has no choice but to slow down in the through travel lane if a deceleration lane is not provided.

11-5.01 Guidelines for Right-Turn Lanes

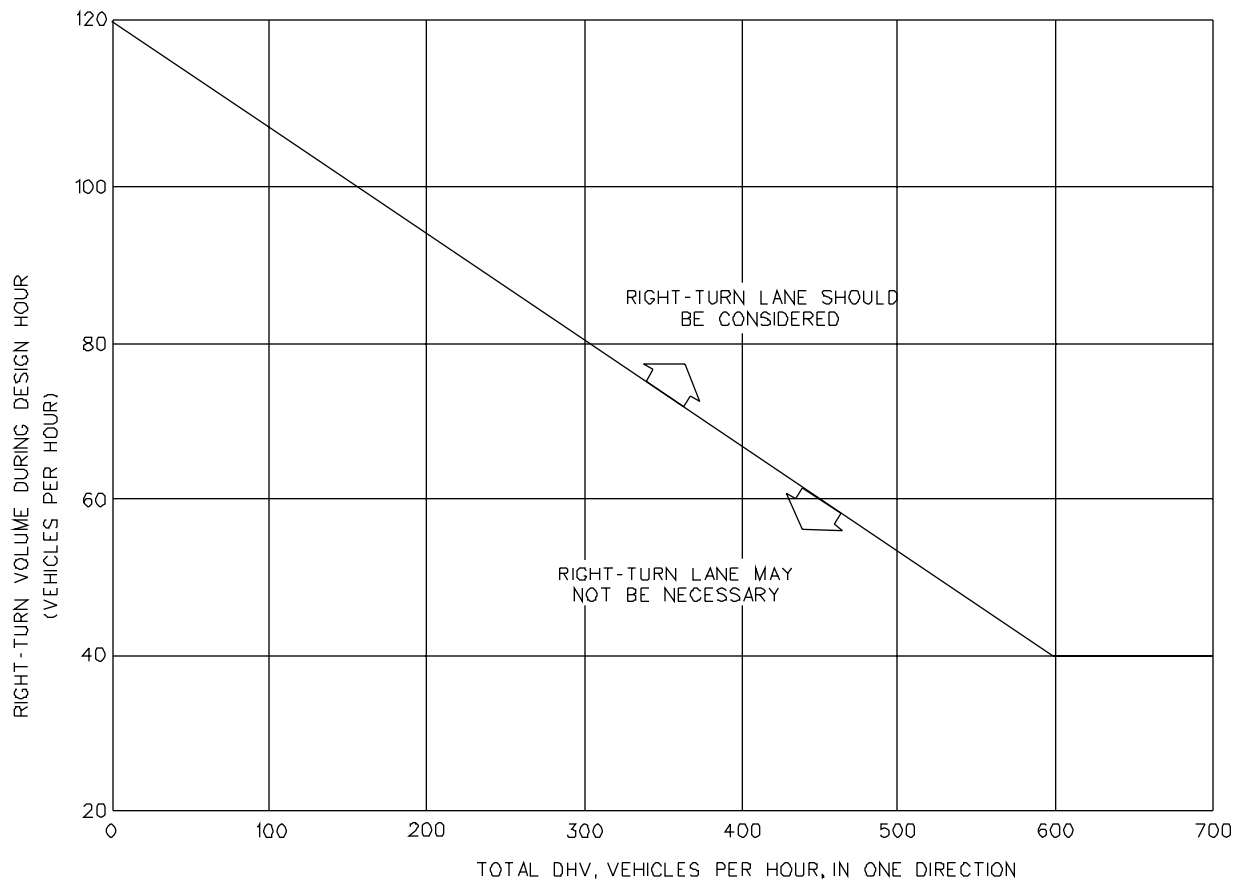
In general, exclusive right-turn lanes should be provided for at-grade intersections as follows:

1. at any unsignalized intersection on a 2-lane urban or rural highway which satisfies the criteria in Figure 11-5A;
2. at any intersection where a capacity analysis determines a right-turn lane is necessary to meet the level-of-service criteria; or
3. at any intersection where the accident experience, existing traffic operations, sight distance restriction or engineering judgment indicates a significant problem related to right-turning vehicles.

11-5.02 Guidelines for Left-Turn Lanes

In general, exclusive left-turn lanes should be provided for at-grade intersections as follows:

1. on all divided urban and rural highways with a median wide enough to allow a left-turn lane (this applies to intersections with public roads and to major traffic generators);
2. for all approaches at arterial/arterial intersections;
3. at any unsignalized intersection on a 2-lane urban or rural highway which satisfies the criteria in Figures 11-5B, 11-5C, 11-5D, 11-5E or 11-5F;



Note: For highways with a design speed below 80 km/h and DHV < 300 and Right Turns > 40, an adjustment should be used. To read the vertical axis of the chart, subtract 20 from the actual number of right turns.

Example:

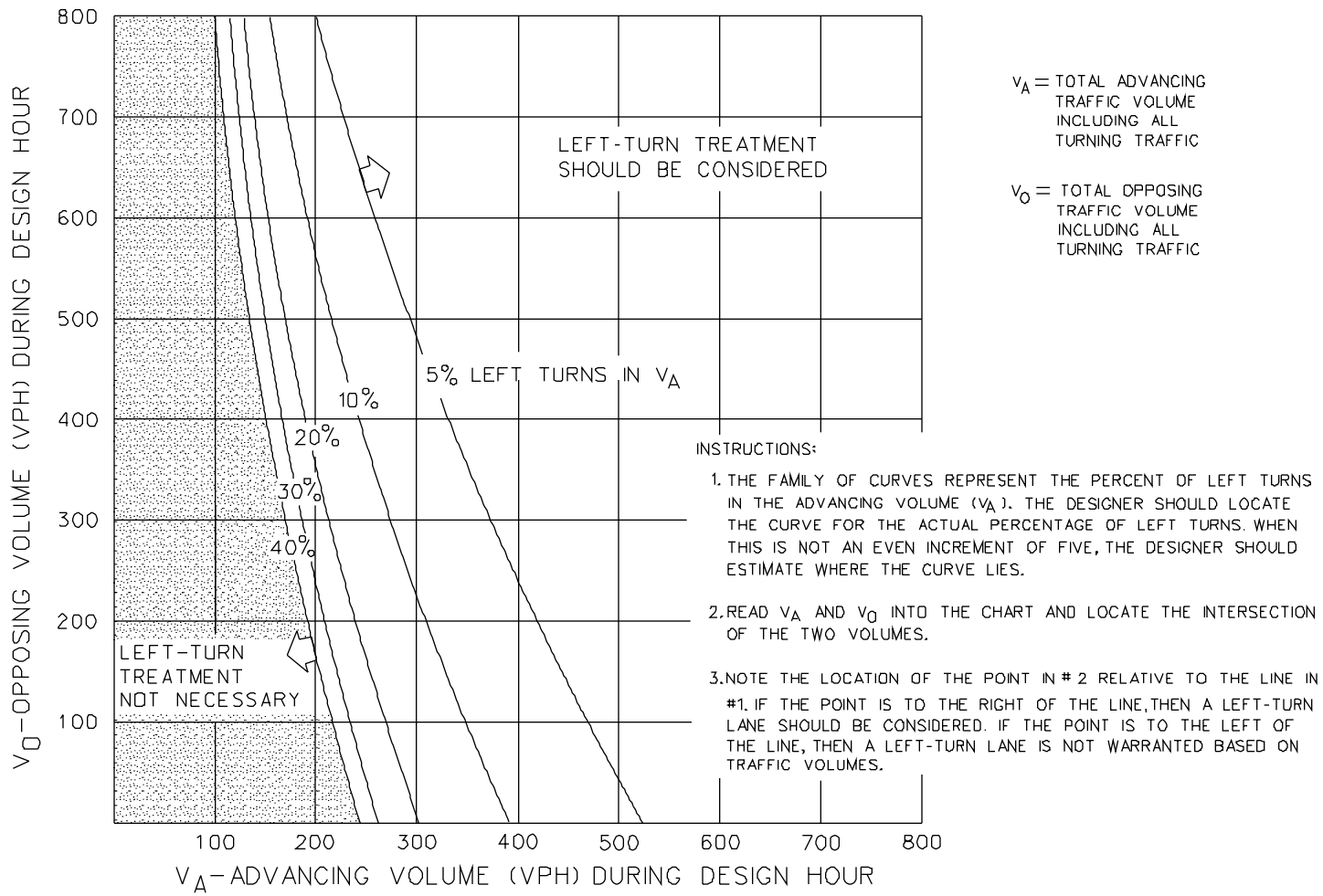
Given: Design Speed = 60 km/h
 DHV = 250 VPH
 Right Turns = 100 VPH

Problem: Determine if a right-turn lane is warranted.

Solution: To read the vertical axis, use $100 - 20 = 80$ VPH. The figure indicates that a right-turn lane is not warranted, unless other factors (e.g., high accident rate) indicate a lane is needed.

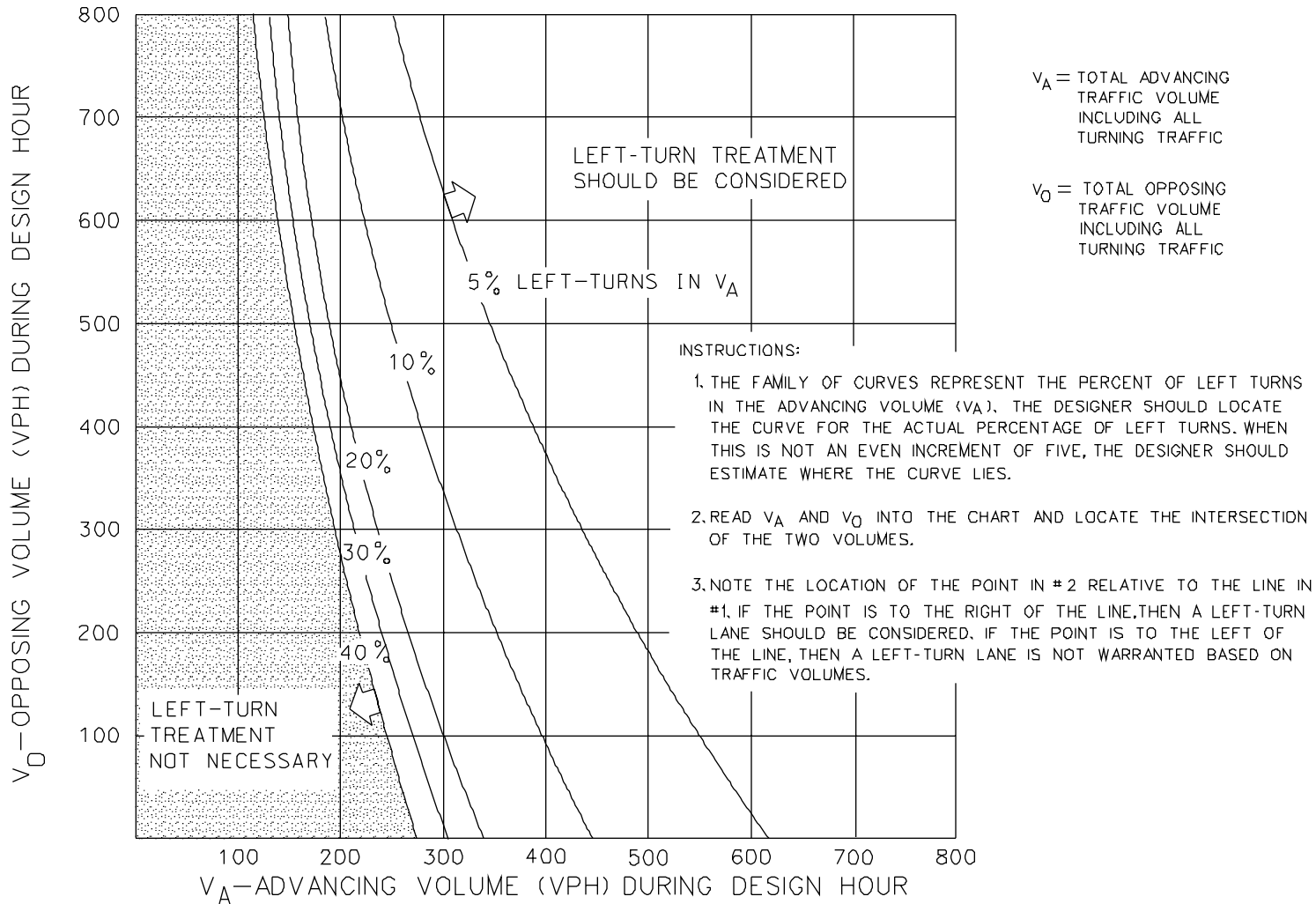
**GUIDELINES FOR RIGHT-TURN LANES
 AT UNSIGNALIZED INTERSECTIONS ON 2-LANE HIGHWAYS**

Figure 11-5A



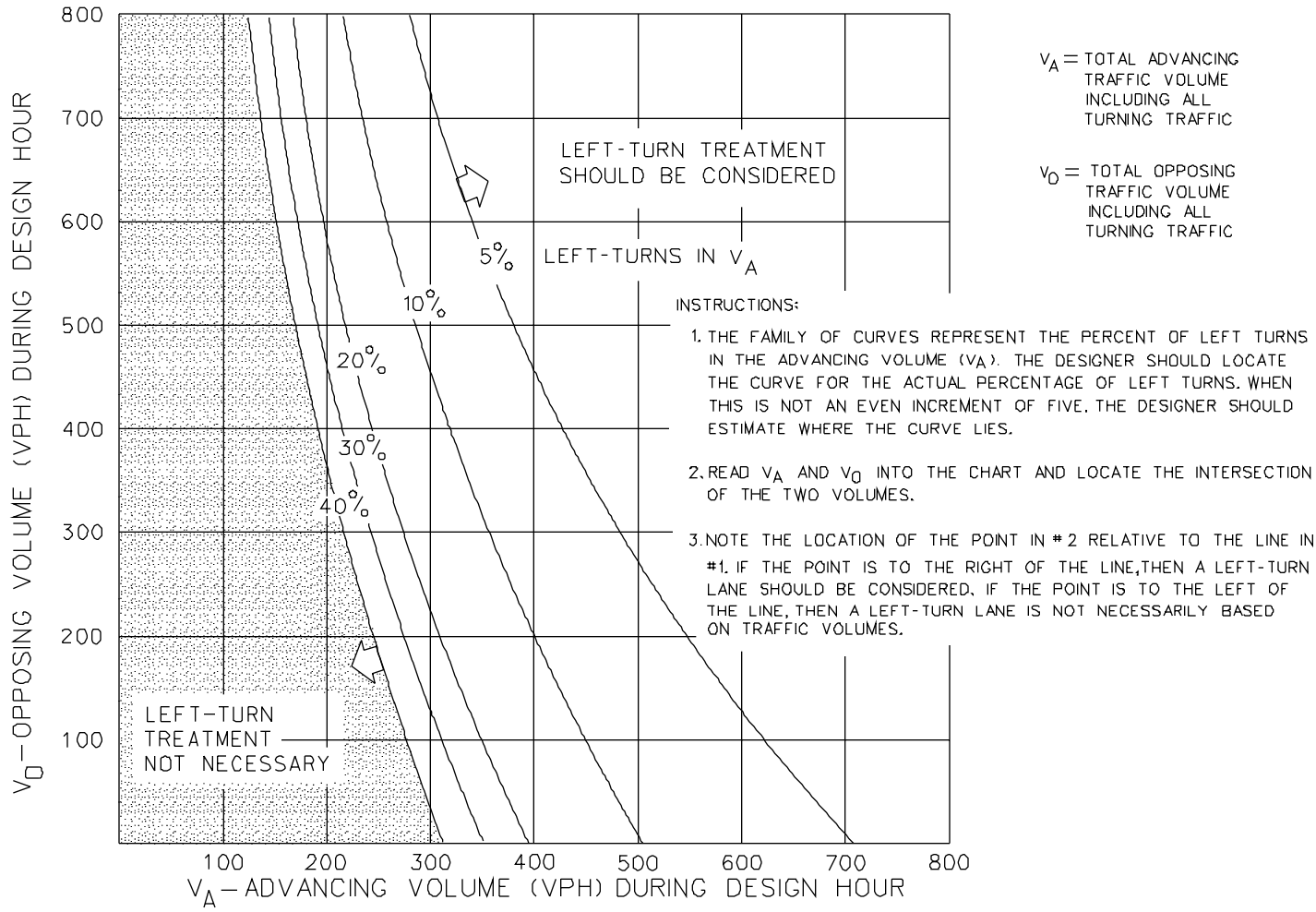
VOLUME GUIDELINES FOR LEFT-TURN LANES AT UNSIGNALIZED INTERSECTIONS ON 2-LANE HIGHWAYS (100 km/h)

Figure 11-5B



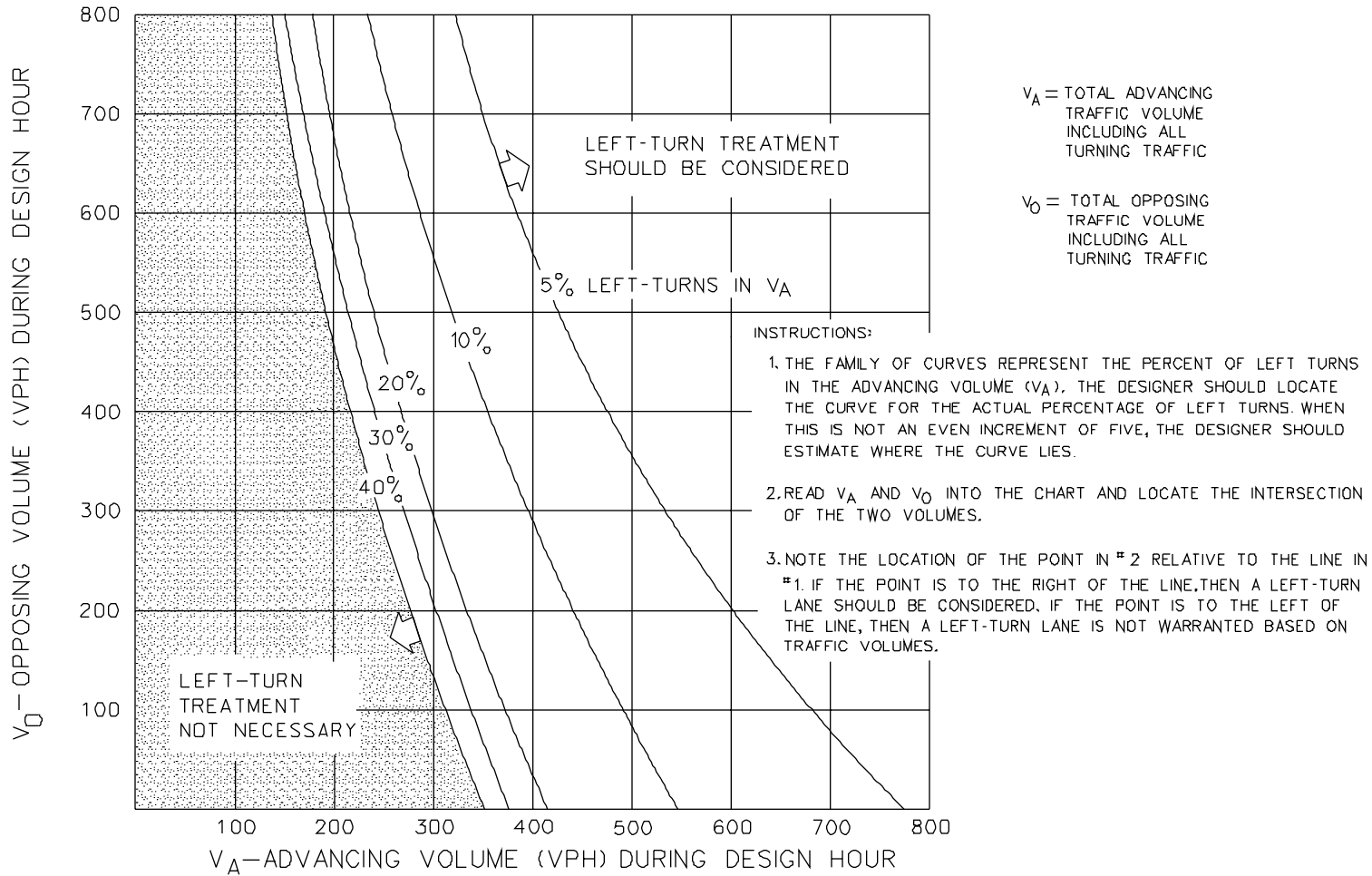
VOLUME GUIDELINES FOR LEFT-TURN LANES AT UNSIGNALIZED INTERSECTIONS ON 2-LANE HIGHWAYS (90 km/h)

Figure 11-5C



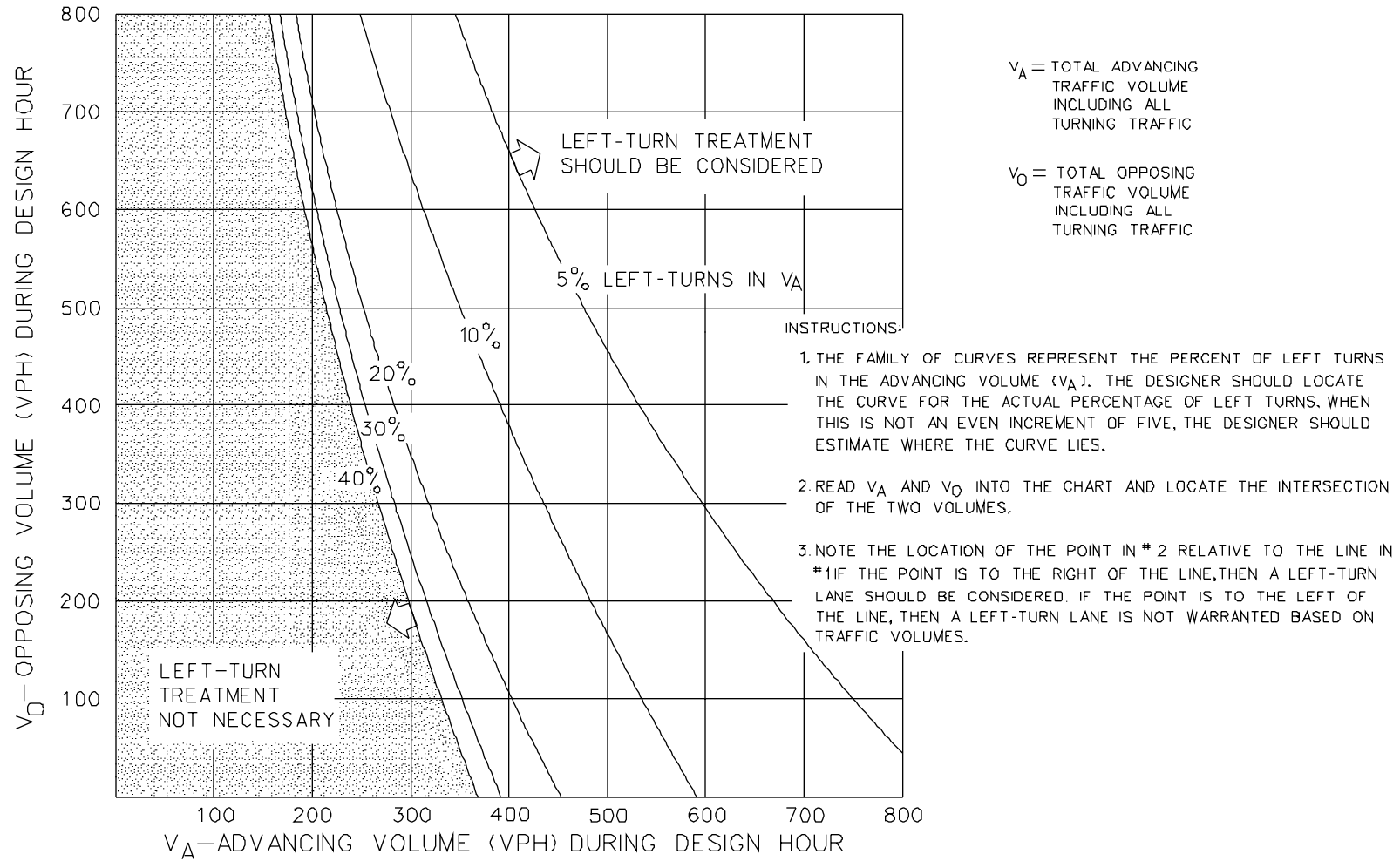
VOLUME GUIDELINES FOR LEFT-TURN LANES AT UNSIGNALIZED INTERSECTIONS ON 2-LANE HIGHWAYS (80 km/h)

Figure 11-5D



VOLUME GUIDELINES FOR LEFT-TURN LANES AT UNSIGNALIZED INTERSECTIONS ON 2-LANE HIGHWAYS (70 km/h)

Figure 11-5E



VOLUME GUIDELINES FOR LEFT-TURN LANES AT UNSIGNALIZED INTERSECTIONS ON 2-LANE HIGHWAYS (60 km/h)

Figure 11-5F

4. at any intersection where a capacity analysis determines a left-turn lane is necessary to meet the level-of-service criteria;
5. at any intersection included or expected to be within an interconnected signal system where the presence of standing left-turning vehicles would disrupt the progression of platooned traffic; or
6. at any intersection where the accident experience, traffic operations, sight distance restrictions or engineering judgment indicates a significant problem related to left-turning vehicles.

11-5.03 Design Details for Auxiliary Turning Lanes

The following criteria will apply to the design of auxiliary turning lanes:

1. Length. The length of a turning lane will be the sum of its taper and storage lengths. Figure 11-5G provides the design criteria that should be used to determine these lengths. The designer will coordinate with the Division of Traffic Engineering to determine if additional length to accommodate deceleration within the auxiliary lane is warranted.
2. Width. The width of the turn lane should be according to the functional class, urban/rural location and project scope of work. Chapters Two, Four and Five present the applicable widths for auxiliary lanes. When curbing is provided, at a minimum, a 0.6-m shoulder should be provided along the turning lane.
3. Parking Lanes. A right-turn lane in an urban area will often require parking restrictions beyond the typical restricted distances from the intersection. Also, it may require relocating near-side bus stops to the far side of the intersection.
4. Median Openings. These should be designed according to the criteria in Section 11-6.0.

11-5.04 Typical Treatments for Auxiliary Turning Lanes

The following presents typical treatments for right- and left-turn lanes:

1. Right-Turn Lanes. Figure 11-5H illustrates the typical development of an exclusive right-turn lane. Note the insertion of short horizontal curves ($R = 15$ m) at the beginning and end of the taper. Consider providing these where curbs define the edge of the turn lane.

Design Element	Design Speed (km/h)	Traffic Control	Upper	Lower
Taper Rate	50	All	1:8	1:8
	60		1:8	1:8
	70		1:8	1:8
	80		1:15	1:8
	90		1:15	1:8
Storage Length (Full Width)	All	Unsignalized	Based on number and type of vehicles likely to arrive in an average 2-minute period during the design hour. (See Notes 1, 5, 6)	Based on number and type of vehicles likely to arrive in an average 1-minute period during the design hour. (See Notes 1, 2, 5, 6)
		Signalized	Based on 2.0 times the average number of cars that will store in the turning lane during the design hour. (See Notes 3, 4, 5, 6)	Based on 1.5 times the average number of cars that will store in the turning lane during the design hour. (See Notes 2, 3, 4, 5, 6)

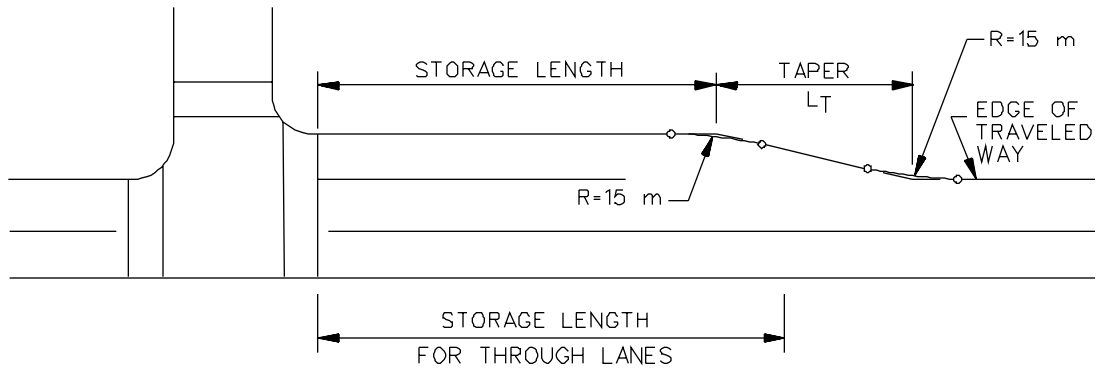
Notes:

- Vehicular Lengths. Use the following design lengths per vehicle for calculating storage length:

P:	7.5 m	BUS:	13.5 m
SU:	10.5 m	Semitrailer:	18.5 m
- Minimum Storage Length. For all intersections where traffic volumes are too low to govern, the minimum storage length will be 15 m ($T \leq 10\%$) or 26 m ($T > 10\%$), where T is the percent of trucks turning. These minimum lengths may also apply to right-turn lanes at unsignalized intersections if there is little likelihood of the turning vehicle having to wait.
- Queue Length of Through Traffic. In addition to the table criteria, the length of the turning lane should exceed the calculated queue length in the through travel lane adjacent to the turning lane for the design hour.
- Highway Capacity Manual. The designer should use the criteria in the HCM to calculate storage length.
- Overall Length. The length of the auxiliary lane should include consideration of the number of vehicles expected to be stored and the extent to which deceleration should take place in the auxiliary lane.
- Division of Traffic Engineering. The designer should coordinate with the Division of Traffic Engineering to determine the design length of the turning lane.

LENGTHS OF AUXILIARY TURNING LANES

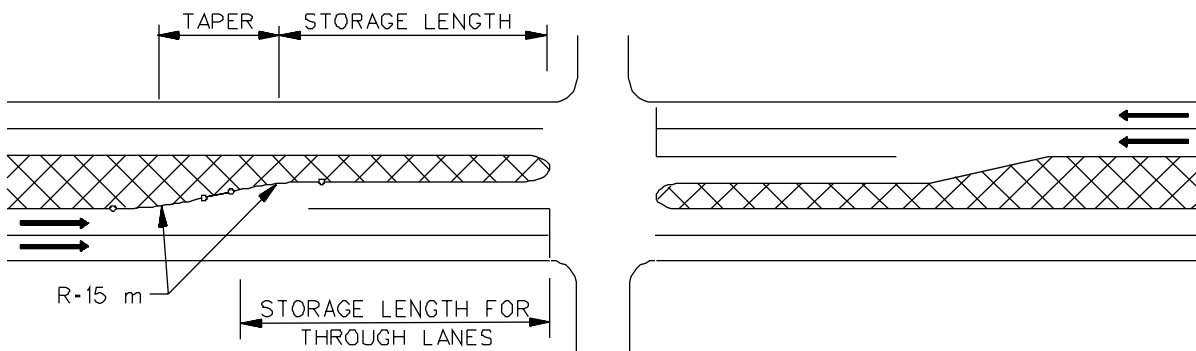
Figure 11-5G



Note: See Figure 11-5G for criteria on taper rate and storage length.

TYPICAL RIGHT-TURN LANE

Figure 11-5H



Note: See Figure 11-5G for criteria on taper rate and storage length.

TYPICAL LEFT-TURN LANE ON DIVIDED HIGHWAY

Figure 11-5I

2. Channelized Left-Turn Lanes. On divided highways, the design presented in Figure 11-5I will apply to the development of an exclusive left-turn lane in the median. Figure 11-5J illustrates the typical development of a channelized left-turn lane on a 2-lane highway. The objective is to transition the pavement widening to meet the MUTCD criteria.
3. By-Pass Area. Figure 11-5K illustrates the typical design for a by-pass area. This is a relatively inexpensive design to provide for through and left-turn movements at intersections. The by-pass area is appropriate for T-intersections (signalized or unsignalized) where left-turning volumes are light to moderate. It may be used at signalized 4-way intersections, but only if turning volumes are light.

The decision to use either the channelized left-turn lane (Figure 11-5J) or the by-pass area (Figure 11-5K) will be based on comparative costs, accident history, right-of-way availability, through and turning traffic volumes, design speed and available sight distance.

11-5.05 Dual Turn Lanes

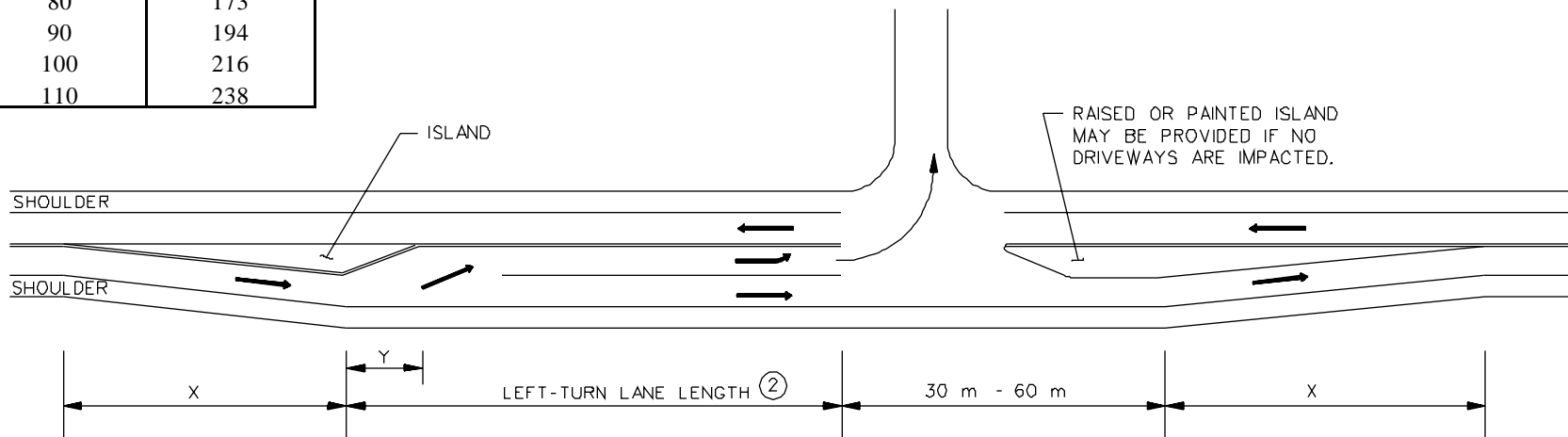
Dual right- and left-turn lanes should be considered when:

1. there is not sufficient space to provide the calculated length of a single turn lane;
2. the calculated length of a single turn lane becomes prohibitive; or
3. the necessary time for a protected left-turn phase becomes unattainable to meet the level-of-service criteria (average delay per vehicle).

Dual right-turn lanes do not work as well as dual left-turn lanes because of the more restrictive space available for two abreast right turns. If practical, the designer should find an alternative means to accommodate the high number of right-turning vehicles. For example, a turning roadway may accomplish this purpose.

A dual-turn lane (both lanes exclusive) can potentially discharge approximately 1.9 times the number of cars which will discharge from a single exclusive turn lane. However, to work properly, several design elements must be carefully considered. Figure 11-5L presents both dual right- and left-turn lanes to illustrate the more important design elements. The designer should consider the following:

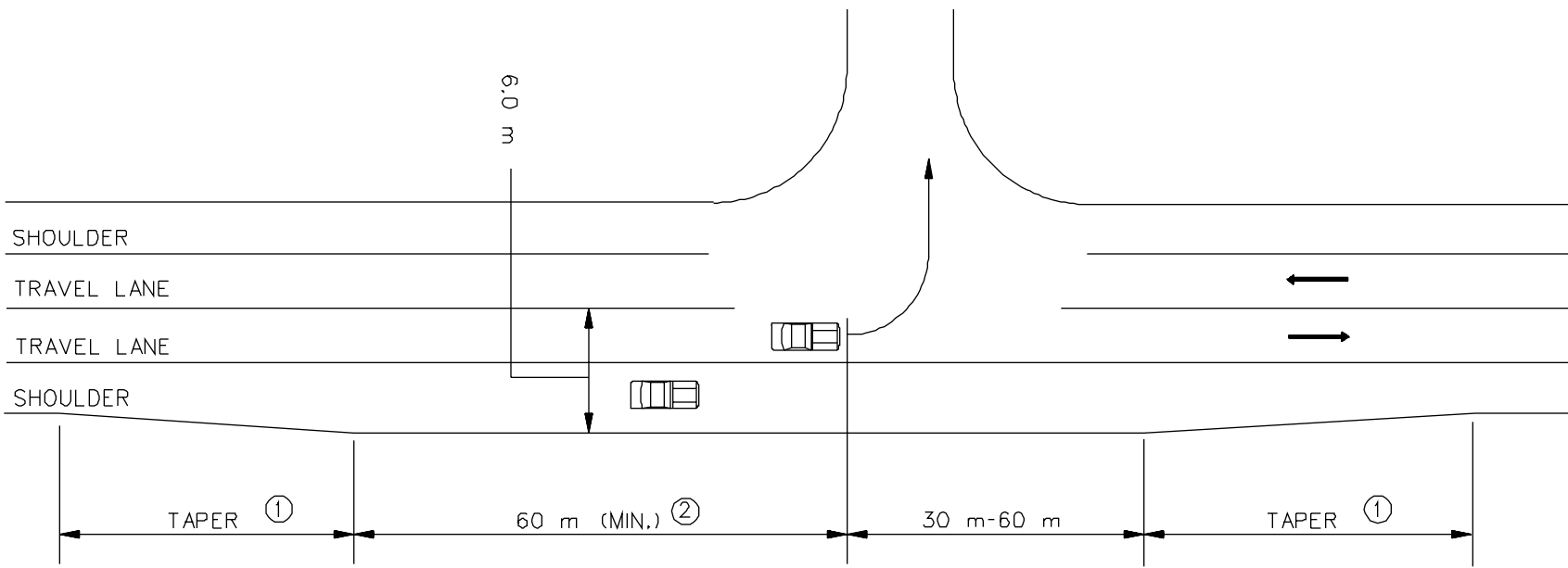
Design Speed (km/h)	x (m)①
30	21
40	37
50	58
60	84
70	151
80	173
90	194
100	216
110	238



- Notes:
1. Tangent distance (x) assumes the MUTCD taper rate (see Note 7 in Figure 11-5G) and a 3.6-m travel lane.
 2. See Figure 11-5G for criteria on taper (y) and storage length of left-turn lane.

CHANNELIZED LEFT-TURN LANE ON 2-LANE HIGHWAY

Figure 11-5J



Notes: 1. The taper distance is calculated from:

$$L = 0.6 WS \text{ (} S \geq 70 \text{) or } L = WS^2 / 155 \text{ (} S \leq 60 \text{)}$$

L = length, m

W = bypass lane width increase, m

S = design speed, km/h

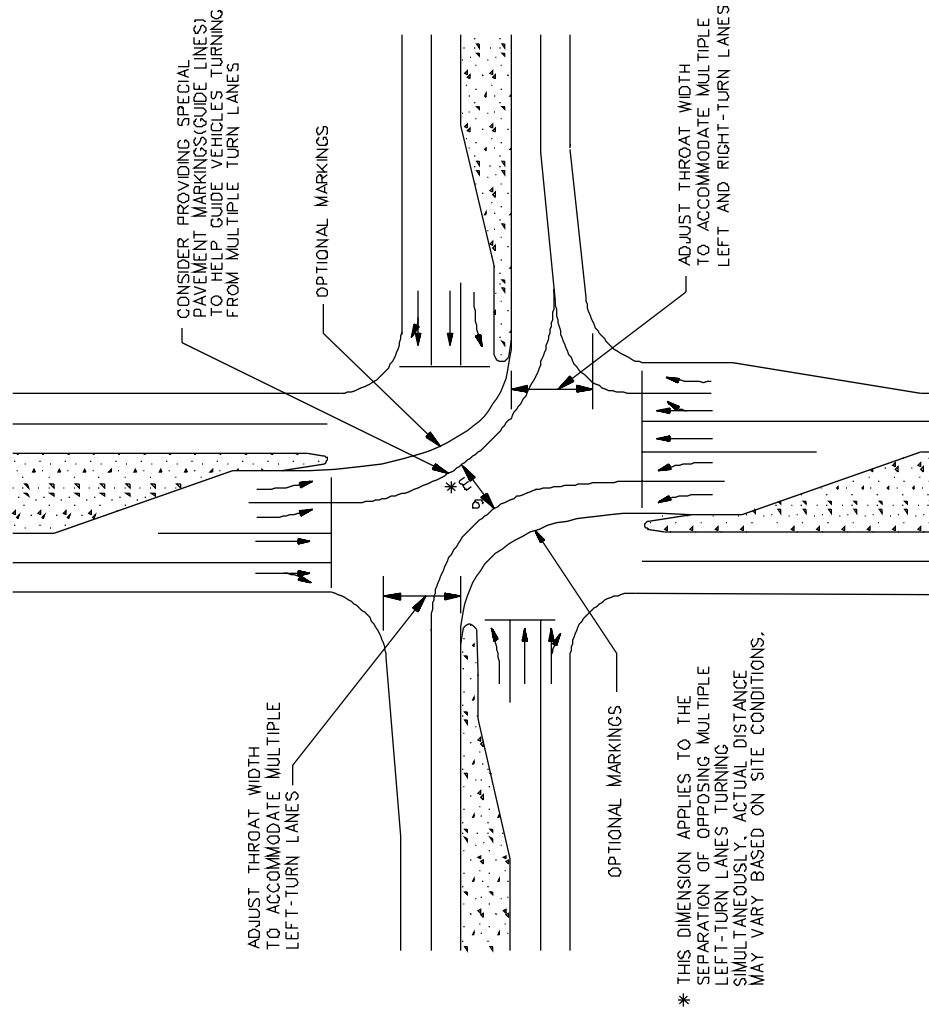
2. Increase length if storage requirements exceed 30 m. See Figure 11-5G.

3. Formula used is based on the posted speed limit. Speed used in formula is 85th percentile speed or design speed

TYPICAL BY-PASS AREA ON A 2-LANE HIGHWAY

Figure 11-5K

MARCH 2000



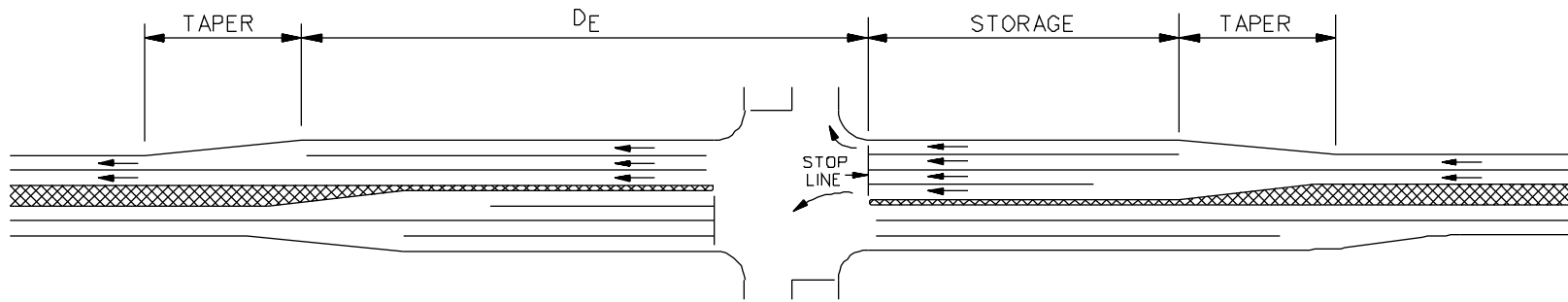
DESIGN OF DUAL TURN LANES

Figure 11-5L

1. Throat Width. Because of the off-tracking characteristics of turning vehicles, the normal width of two travel lanes may be inadequate to properly receive two vehicles turning abreast. Therefore, the receiving throat width may need to be widened. For 90° intersections, the designer can expect that the throat width for dual turn lanes will be approximately 9 m to 10.8 m. If the angle of turn is less than 90°, it may be acceptable to provide a narrower width. When determining the available throat width, the designer can assume that the paved shoulder, if present, will be used to accommodate two-abreast turns.
2. Widening Approaching Through Lanes. If a 9-m or 10.8-m throat width is provided to receive dual-turn lanes, the designer should also consider how this will affect the traffic approaching from the other side. The designer should also ensure that the through lanes line up relatively well to ensure a smooth flow of traffic through the intersection.
3. Special Pavement Markings. As illustrated in Figure 11-5L, these can effectively guide two lines of vehicles turning abreast. The Division of Traffic Engineering will help determine the selection and placement of any special pavement markings.
4. Opposing Left-Turn Traffic. If simultaneous, opposing left turns will be allowed, the designer should ensure that there is sufficient space for all turning movements. This is always a factor, but dual left-turn lanes can cause special problems. If space is unavailable, it may be necessary to alter the signal phasing to allow the two directions of traffic to move through the intersection on separate phases.
5. Turning Templates. All intersection design elements for dual turn lanes must be checked by using the applicable turning templates. The design vehicle will be assumed to be in each lane turning side by side.

11-5.06 Extension of Additional Through Lanes

To meet the level-of-service criteria, it may be necessary to add through lanes approaching the intersection. However, these additional lanes must be extended beyond the intersection to realize the capacity benefits. Figure 11-5M provides criteria for determining how far these lanes should be extended beyond the intersection.



Notes:

1. D_E is that distance required by the vehicle to accelerate from a stop to 10 km/h below the design speed (90 m minimum).

2. The taper distance is calculated from:

$$L = 0.6 WS \text{ (} S > 70 \text{)} \text{ or } L = WS^2 / 155 \text{ (} S \leq 60 \text{)}$$

Where: L = taper length, m
 W = 3.6 m
 S = design speed, km/h

3. These criteria are for preliminary design purposes. See discussion in Section 11-5.06.

Design Speed (km/h)	D_E^* (m)	Taper* (m)
50	90	60
60	90	90
70	110	150
80	160	170
90	240	190
100	330	220
110	460	240

*Rounded for design.

TYPICAL EXTENSION OF ADDITIONAL THROUGH LANES

Figure 11-5M

The designer should recognize that the full-width lengths of the through lane extensions (D_E) are those distances needed for the stopped vehicle to accelerate to 10 km/h below the design speed of the highway. These distances may or may not be sufficient for the vehicle to merge into the "primary" through lane. The merging characteristics will be based on vehicular acceleration, rate of departure through the intersection and headways in the "primary" lane. Therefore, the criteria in Figure 11-5M should be used for preliminary design purposes. For final design, the designer will coordinate with the Division of Traffic Engineering, who will perform a more detailed analysis.

11-6.0 MEDIAN OPENINGS

11-6.01 Guidelines

The designer should consider providing median openings on divided non-freeways at all intersections with public roads and major traffic generators (e.g., shopping centers). The following recommended minimum spacings should be evaluated when determining the need for a median opening:

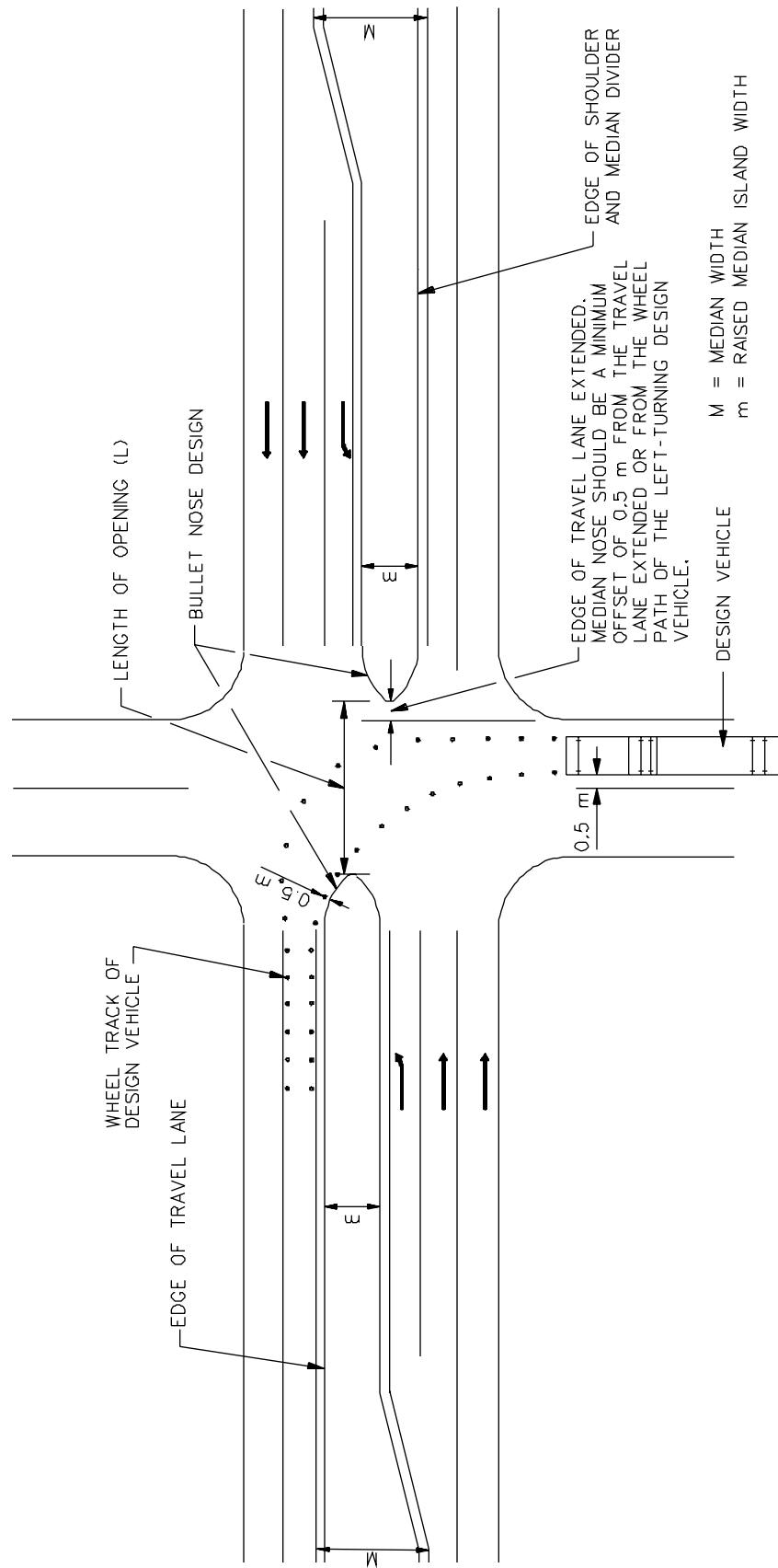
1. Rural Intersections. Openings are generally provided at all public road intersections.
2. Urban Intersections. In general, median openings are typically provided at all intersections. However, to improve capacity and traffic efficiency, the designer may elect not to provide an opening for a traffic generator if there are other points of access within a reasonable distance of the generator.

Median openings should normally be between 400 m and 800 m.

11-6.02 Design

Median openings must be designed to properly accommodate left-turning vehicles, which trace essentially the same path as right-turning vehicles. Figure 11-6A illustrates a typical median opening design. The following criteria will apply to the design of a median opening:

1. Nose Design. The bullet nose design should be used for the median nose. The radius at the nose should be approximately 0.5 m to 1 m. The semicircular design is acceptable, but it requires a greater median width or length of opening to accommodate a given design vehicle.
2. Design Vehicle. The design vehicle for median openings should be the largest vehicle that will be making the turn with some frequency. The process for the selection of the design vehicle is the same as for a right-turning vehicle (see Section 11-3.02).
3. Encroachment. In all cases, the designer should consider providing a design that will allow the selected design vehicle to make the left turn entirely within the inside lane (i.e., there will be no encroachment into the lane adjacent to the inside lane). This will be the minimum design at unsignalized intersections. At signalized intersections, the minimum design will be to allow the selected design vehicle to encroach to the outside edge of the traveled way. For dual left-turn lanes, the designer may assume that the design vehicle will turn from the outer left-turn lane.



MEDIAN OPENING DESIGN

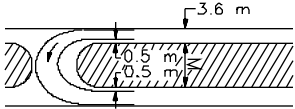
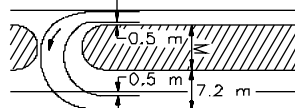
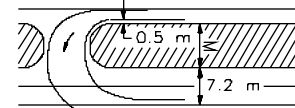
Figure 11-6A

4. Length of Opening. The length of a median opening should properly accommodate the turning path of the design vehicle. The minimum median opening length is 12 m. However, each median opening should be evaluated individually to determine the proper length of opening. The designer should consider the following factors in the evaluation:
 - a. Turning Templates. The designer should check the proposed design with the turning template for the design vehicle most likely to use the intersection. Consideration should be given to the frequency of the turn and to the encroachment onto adjacent travel lanes or shoulders by the turning vehicle.
 - b. Nose Offset. At 4-leg intersections, traffic passing through the median opening (going straight) will pass the nose and the median end (semicircular or bullet nose). To provide a sense of comfort for these drivers, the offset between the nose and the through travel lane (extended) should be at least 0.5 m.
 - c. Lane Alignment. The designer should ensure that lanes line up properly for crossing traffic.
 - d. Location of Crosswalks. Where practical, pedestrian crosswalks should intersect the median nose to provide some refuge for pedestrians. Therefore, the median opening design should be coordinated with the location of crosswalks.
5. U-turns. Median openings are sometimes used only to accommodate U-turns on divided non-freeways. Figure 11-6B provides information on minimum U-turn median opening design.

11-6.03 Median Openings on Freeways

On access-controlled freeways, median crossings are denied to the public. However, occasional median openings or emergency crossovers are needed to accommodate maintenance and emergency vehicles. The following should be considered:

1. Warrants and Location. Emergency crossovers are normally placed away from any mainline conflicts. As a general guide, median openings may be considered when the distance between interchanges exceeds 5 km. Two crossovers may be considered where the distance between interchanges exceed 10 km. In addition, crossovers may be placed at State lines, maintenance section ends and at interchanges for winter maintenance. Locations for median openings are reviewed by the Median Opening Committee. This Committee is chaired by the Director of Maintenance.

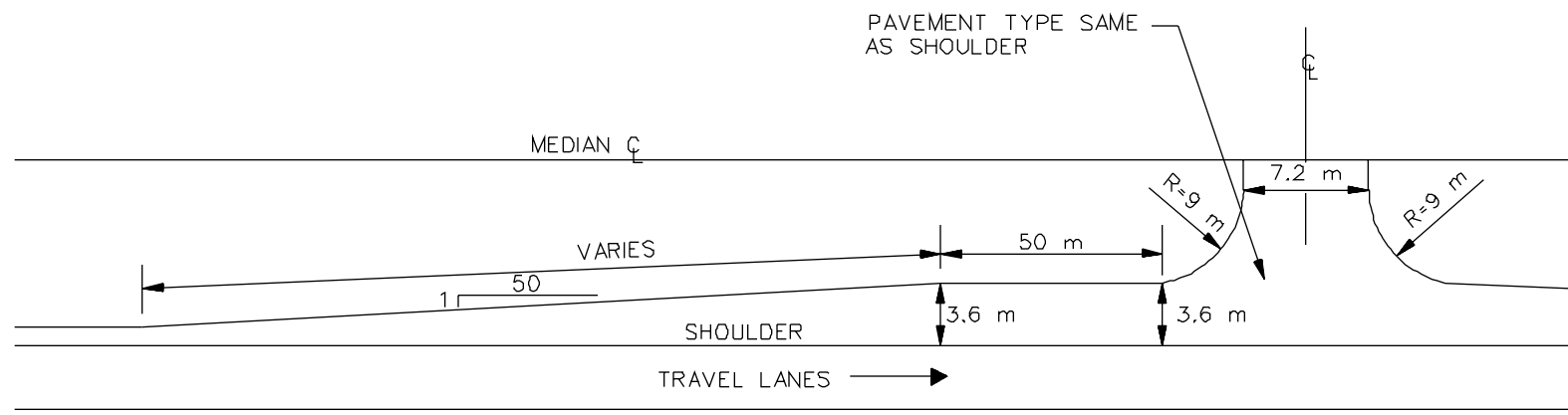
Type of Maneuver		M - Min. width of median (m) for design vehicle				
		P	SU	BUS	WB-12	WB-15
		Length of design vehicle (m)				
		5.8	9.1	12.2	15.2	16.7
Inner Lane to Inner Lane		9	19	19	18	21
Inner Lane to Outer Lane		5	15	15	15	18
Inner Lane to Shoulder		2	12	12	12	15

Note: For freeway median openings, use the SU design vehicle.

MINIMUM DESIGNS FOR U-TURNS

Figure 11-6B

2. Sight Distance. Because of the unexpected U-turn maneuver, sight distances should be large when vehicles make U-turns on freeways. The designer should attempt to select a location that can achieve a sight distance of 600 m to the right of the crossover in both directions. If this cannot be achieved, then intersection sight distance as discussed in Section 11-2.0 may be used.
3. Median Width. The median should be wide enough to accommodate the design vehicle.
4. Median Barriers. Emergency crossovers should be avoided where a median barrier is present. If a crossover must be provided, the barrier should be terminated as described in Section 13-6.0. The width of the opening should be about 7.5 m to 9.0 m. This is wide enough to safely allow a vehicle to turn through, but it is narrow enough to minimize the possibility of a run-off-the-road vehicle passing through.
5. Design. Figure 11-6B provides the minimum width of median for several design vehicles and types of U-turn maneuvers. If practical, the design should allow the inner lane to inner lane design. This design also allows the vehicle to be fully protected within the median, if the driver must stop here. Figure 11-6C provides additional design details for a median opening.



Notes:

- 1. The median opening is symmetrical about the centerline.
- 2. The gradient through the opening should be as flat as practical.
- 3. Curbs should not be used.

TREATMENT OF MEDIAN OPENING ON FREEWAY

Figure 11-6C

11-7.0 CHANNELIZATION

11-7.01 Design Principles

Intersection channelization directs traffic into definite paths of travel. When properly applied, channelization can increase capacity, improve safety and maximize the sense of driver comfort. Improper channelization can greatly confuse drivers and may be worse than no channelization at all. The designer should incorporate the following principles into the channelization design:

1. Motorists should not be confronted with more than one decision at a time.
2. Unnatural paths that require turns greater than 90° or sudden and sharp reverse curves should be avoided.
3. Areas of vehicular conflict should be reduced as much as practical. However, merging and weaving areas should be as long as conditions permit.
4. Traffic streams that cross without merging and weaving should intersect at or near right angles.
5. The angle of intersection between merging streams of traffic should be small.
6. Refuge areas for turning vehicles should be provided clear of through traffic.
7. Prohibited turns should be discouraged wherever practical by the use of, for example, sharp radii curbs.
8. Safe location of essential traffic control devices should be an integral part of the design of a channelized intersection.

11-7.02 Design Details (Islands)

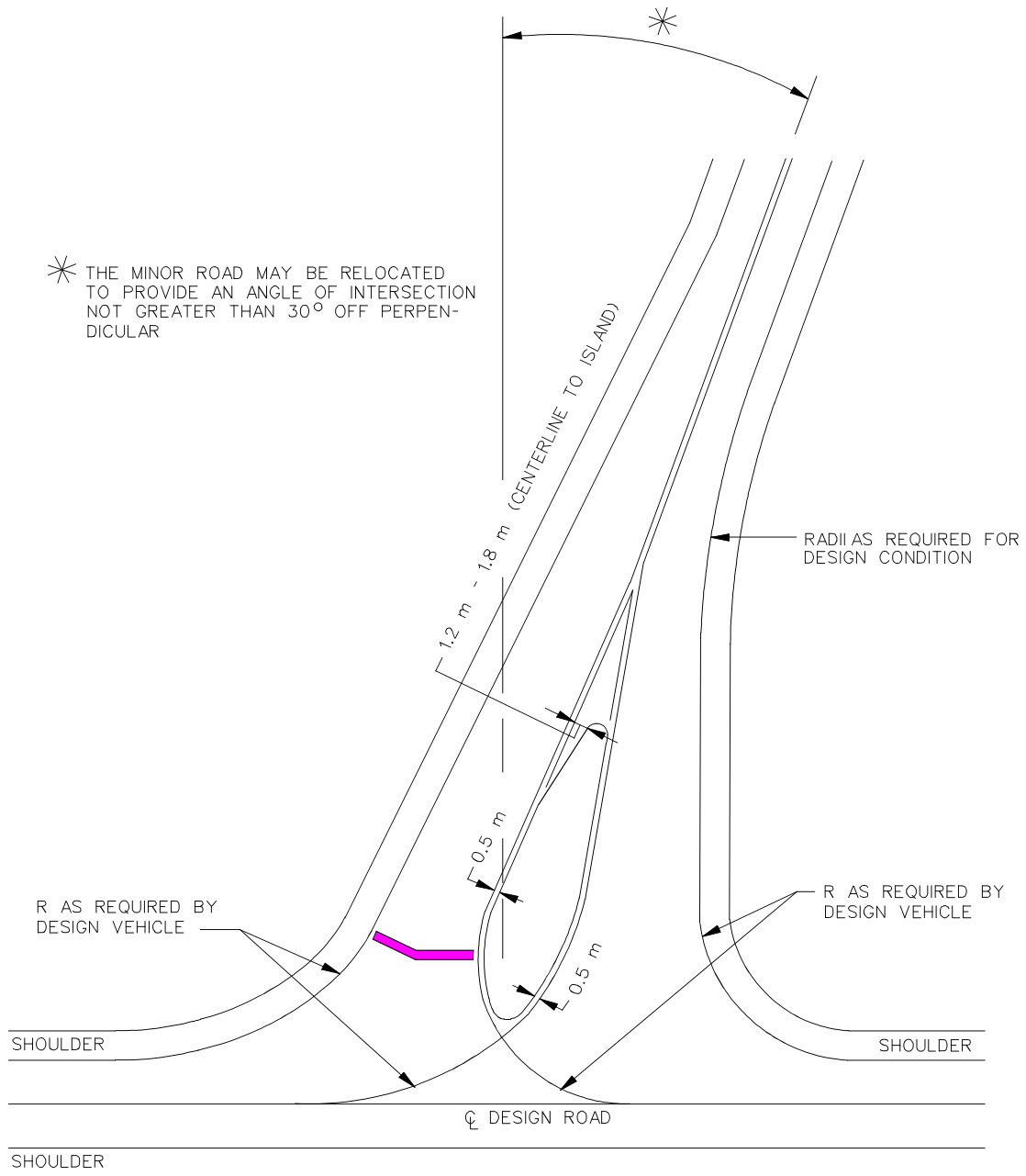
Flush or raised islands are used to create the intersection channelization. The designer should adhere to the following criteria when designing islands:

1. Types. Islands may be flush or raised, paved or turf, and triangular or elongated. Raised islands (with curbs) should be used where pedestrian traffic is significant and where traffic control devices are needed within the island. The designer should consider lighting the intersection where raised islands are used. Flush (painted) islands are appropriate in lightly

developed areas, where approach speeds are above 60 km/h and where the intersection is not lighted. Elongated islands are used to divide two flows of traffic.

2. Size. In general, an island must be large enough to command attention. For triangular islands, the minimum size is 5 m² at urban intersections and 7 m² at rural intersections. Where right-of-way is available, provide a triangular island of at least 9 m². The minimum width of an elongated island should be not less than 1.2 m wide and preferably 1.8 m.
3. Approach Treatment. Islands with curbs are acceptable where the design speed is 80 km/h or less. Flush islands should be used at higher speeds; however, raised islands with the BCLC are acceptable where the "target" value of a raised island is considered desirable. The corners of curbed islands should be constructed with nose radii of 0.5 m to 1.0 m. For good delineation, pavement markings should be placed in advance of the island approach to warn the driver.
4. Island Offset to Through Lanes. Where there are no curbs on the roadway approach, the curbed island should be offset 0.5 m to 1.0 m from the travel lane. This applies to approach roadways without shoulders. Where shoulders are present, the curbed island should be offset a distance equal to the shoulder width. Although the value of the offset is not as critical for flush islands, they should desirably be treated in the same manner as raised islands.

Figure 11-7A provides an illustration of a channelized intersection.



Note: Where island size is either less than 6-m wide or 12-m long, it will be paved to minimize maintenance. Otherwise, it will be loamed and seeded. Positive drainage may be required.

EXAMPLE OF CHANNELIZED INTERSECTION

Figure 11-7A

11-8.0 DRIVEWAYS

11-8.01 Design

11-8.01.01 Detailed Criteria

Figure 11-8A summarizes the Department's recommended criteria for the design of driveways. The designer should also consider the following:

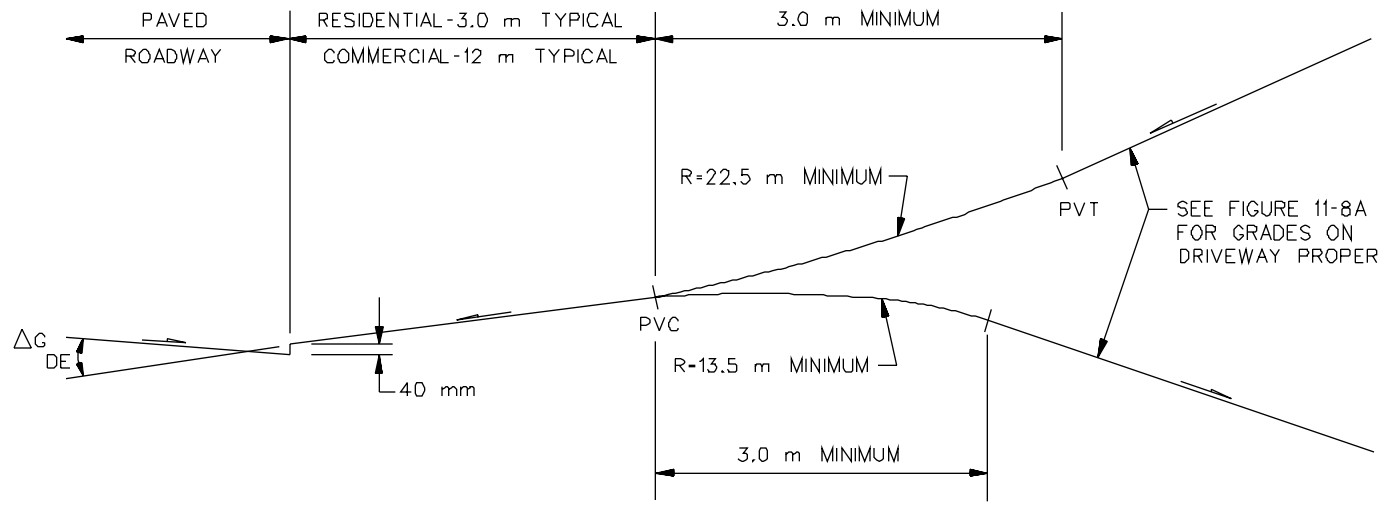
1. Driveway Type. As indicated in Figure 11-8A, the Department has designated three driveway types for the purpose of design. These are residential, minor commercial and major commercial.
2. Vertical Profile. Figures 11-8B, 11-8C and 11-8D present the Department's driveway entrance designs for the vertical profile. The designer should meet these criteria, if practical. However, actual field conditions may make this unattainable.
3. Auxiliary Lanes. Deceleration and acceleration lanes should be considered at high-volume driveway entrances, especially on high-speed, high-volume arterials. Section 11-5.0 further discusses the design and warrants for auxiliary turn lanes. In addition, it may be warranted to provide a right-turn lane if the change in grade is abrupt at the driveway entrance.
4. Turning Template. The designer should check the driveway entrance with the applicable turning template to ensure that the design vehicle can make the turn within the driveway width.
5. Sight Distance. Intersection sight distance should be evaluated at all driveways (see Section 11-2.0). However, only intersection sight distance for major commercial driveways will be considered as a controlling design criteria and will require an exception if the minimum values are not met. Residential and minor commercial driveways will not require an exception if the minimum values are not met.
6. Transverse Slopes. Where the highway mainline intersects a driveway, a slope transverse to the mainline will be present. See Section 13-3.07. If impacted by a run-off-the-road vehicle, the angle of impact will likely be close to 90 degrees. Even for relatively flat side slopes, this will result in vehicular vaulting; for steeper slopes the vehicle bumper may "catch" in the slope resulting in an abrupt stop and high occupant decelerations. For these reasons, transverse slopes should be as flat as practical. For design speeds of 80 km/h or higher, the slope should be 1:10 or flatter. Below 80 km/h, the slope should be 1:6 or flatter.

Driveway Design Element		Driveway Type		
		Residential	Minor Commercial	Major Commercial
Design Vehicle		P	SU * (WB-15 can physically make turn)	WB-15 *
Tolerable Encroachment by Design Vehicle Turning Into/Out of Driveway	Adjacent Lane On Through Road	None into opposing lanes of travel. Acceptable into lanes moving in same direction; however, consider providing a design so that there will be no encroachment.		
	In Driveway	Use all of driveway width if 1-way; no encroachment into driveway entrance or exit lane if 2-way, unless low-volume driveway.		
Width		Based on 1-way or 2-way operation; on selected design vehicle template; on encroachment criteria; and on assumed speed. (Note: Minimum residential driveway width = 3.0 m. Maximum width is 9.0 m.)		
Grades on Driveway Proper		≤ 10% - 12%	≤ 5% - 8%	≤ 5% - 8%
Maximum Change in Grade Without Vertical Curve (%)	Driveway Entrance	See Figures 11-8B, 11-8C and 11-8D		Designed like street intersection
	Driveway Proper	15%	6%	3%

* Where multiple drives are present, only the route to and from the loading area needs to accommodate trucks.

RECOMMENDED DRIVEWAY DESIGN CRITERIA

Figure 11-8A



1. This design applies with or without curbs.
2. As an alternative to providing a vertical curve, the designer may use an angular break which does not exceed the ΔG_{DE} criteria in Figure 11-8A for the driveway proper.

3. The maximum ΔG_{DE} will be as follows:

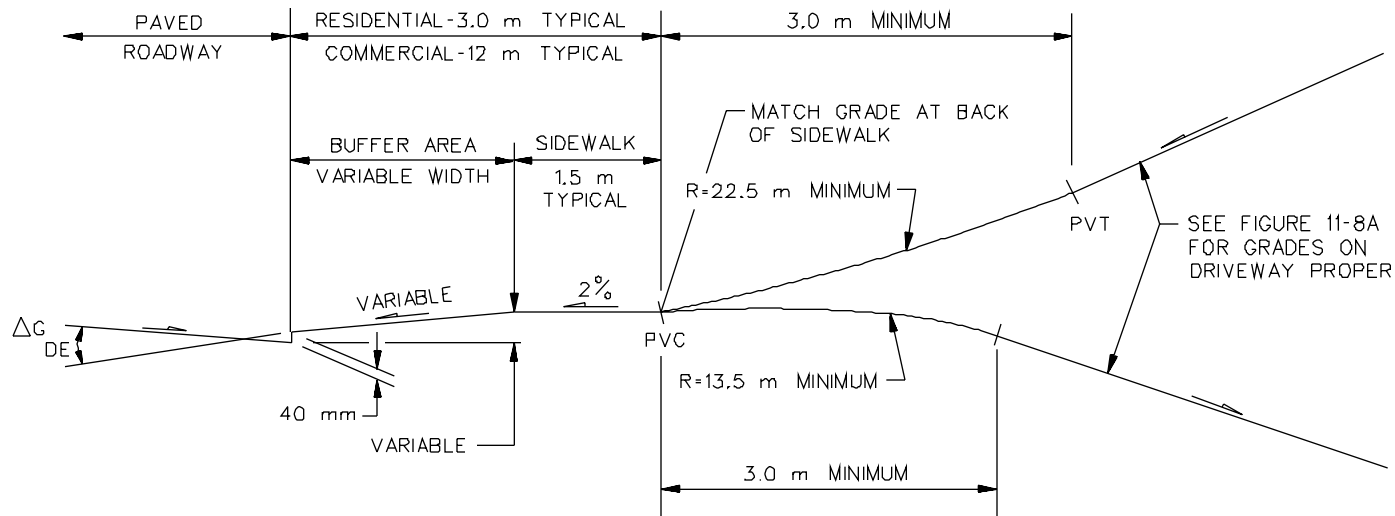
<u>Turn From</u> Travel Lane	<u>Turn From Shoulder</u> or Turn Lane
8%	12%

Note that a shoulder must be at least 2.1 m wide to use the higher ΔG_{DE} values.

4. When determining the appropriate vertical design for the driveway entrance, the designer should also consider the highway design speed, through traffic volumes, driveway volumes, turning speeds allowed by the available curb radius and accident history.
5. See the Department's Standard Drawings for additional details.

**TYPICAL DRIVEWAY ENTRANCE
(No Provision for Sidewalks)**

Figure 11-8B



1. This design applies with or without curbs.
2. As an alternative to providing a vertical curve, the designer may use an angular break which does not exceed the ΔG_{DE} criteria in Figure 11-8A for the driveway proper.
3. The maximum ΔG_{DE} will be as follows:

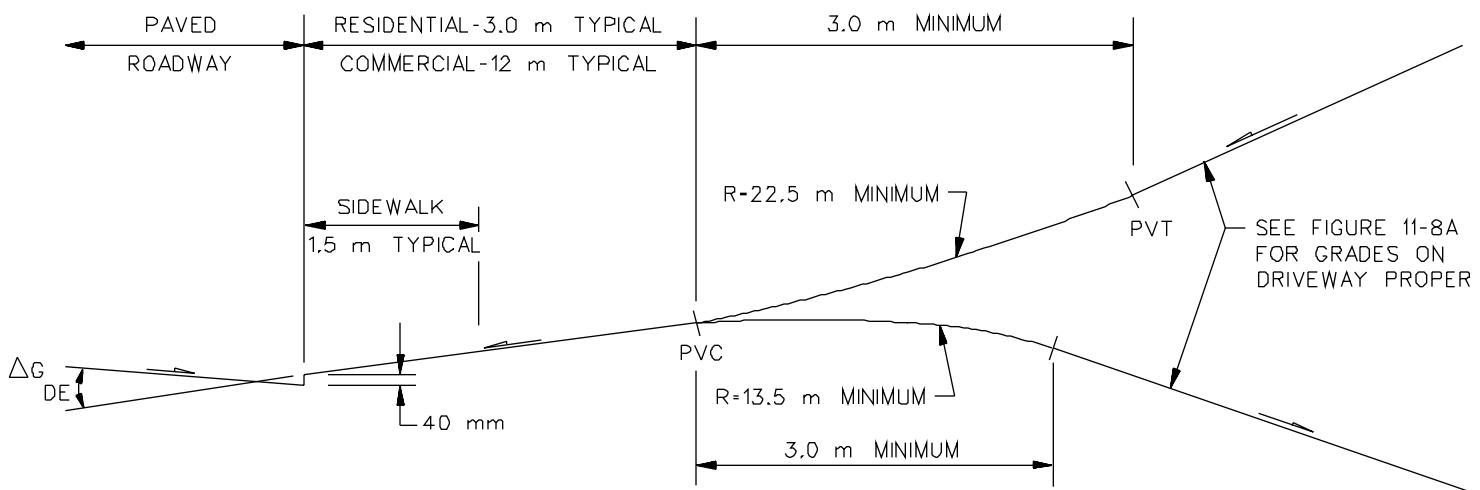
<u>Turn From</u>	<u>Turn From Shoulder</u>
8%	12%

Note that a shoulder must be at least 2.1 m wide to use the higher ΔG_{DE} values.

4. The grade for the driveway portion through the border area should not exceed the grades on the driveway proper in Figure 11-8A.
5. When compromises are necessary, the criteria for the maximum ΔG_{DE} should receive more weight than the 2% sidewalk cross slope (i.e., the sidewalk should be warped as necessary to allow the smallest practical ΔG_{DE}). However, this in effect gives preference to the safety of the vehicular traffic. If the ΔG_{DE} will be made from a travel lane, it will usually be necessary to alter the sidewalk cross slope if curbs are present.
6. When determining the appropriate vertical design for the driveway entrance, the designer should also consider the highway design speed, through traffic volumes, driveway volumes, turning speeds allowed by the available curb radius and accident history.
7. See the Department's Standard Drawings for additional details.

TYPICAL DRIVEWAY ENTRANCE (Sidewalk With Buffer Area)

Figure 11-8C



1. This design applies with or without curbs.
2. As an alternative to providing a vertical curve, the designer may use an angular break which does not exceed the ΔG_{DE} criteria in Figure 11-8A for the driveway proper.

3. The maximum ΔG_{DE} will be as follows:

<u>Turn From</u>	<u>Turn From Shoulder</u>
<u>Travel Lane</u>	<u>or Turn Lane</u>
8%	12%

Note that a shoulder must be at least 2.1 m wide to use the higher ΔG_{DE} values.

4. The typical design assumes that the sidewalk will be warped so that the ΔG_{DE} criteria can be satisfied. However, if the sidewalk is on an accessible route,, the designer must also consider ADA criteria for handicapped individuals (see Section 15-1.0).
5. When determining the appropriate vertical design for the driveway entrance, the designer should also consider the highway design speed, through traffic volumes, driveway volumes, turning speeds allowed by the available curb radius and accident history.
6. See the Department's Standard Drawings for additional details.

**TYPICAL DRIVEWAY ENTRANCE
(Sidewalk Adjacent to Curb)**

7. Curb Returns. Where curbs are used, the curb return should be constructed into the driveway. The radius of the curb return should not be less than 0.6 m nor more than 15 m.

11-8.01.02 Criteria (Existing Driveways)

The following will apply to projects which impact existing driveways:

1. Grades. When an existing driveway is impacted by the project construction, the designer should, whenever practical, ensure that the reconstructed driveway grade will not exceed the grade of the existing driveway. When the grade must be adjusted, the new grade should not exceed the criteria in Figure 11-8A.

If an existing driveway grade exceeds the criteria in Figure 11-8A, the designer should attempt to flatten the grade as part of the project.

2. Procedures. If it is determined during the Preliminary Design review that there will be a substantial increase in the grade of the driveway or if the length of the driveway will be significantly revised, then the words, "Right to construct, reconstruct and/or relocate driveway required," should be noted on the construction plans. This will signify that the property owner must be contacted and permission obtained. It will be the responsibility of the Right-of-Way representative to contact the property owner to explain the proposed construction. This will be done during the acquisition stage of property in the vicinity.

If the proposed reconstruction of a driveway will exceed the Department's driveway design criteria, alternative solutions will be discussed at the Preliminary Design meeting. These solutions will be presented to the property owner during the regular acquisition of property in the vicinity. If neither alternative is acceptable to the owner, the designer may meet with the Right-of-Way project coordinator for the area concerned to review the driveway design.

3. Project Plans. To ensure a clear understanding of the intended driveway construction and, especially, to depict the treatment of the grade to prevent roadway drainage from flowing into the property, the normal indication of proposed driveways on 1:500 scale plans and profiles will be supplemented by a standard sheet, a driveway section or a special detail. The section or detail will contain a scale and will be sufficiently detailed so that there will be no misunderstanding by construction personnel or claim of misrepresentation by the Contractor.

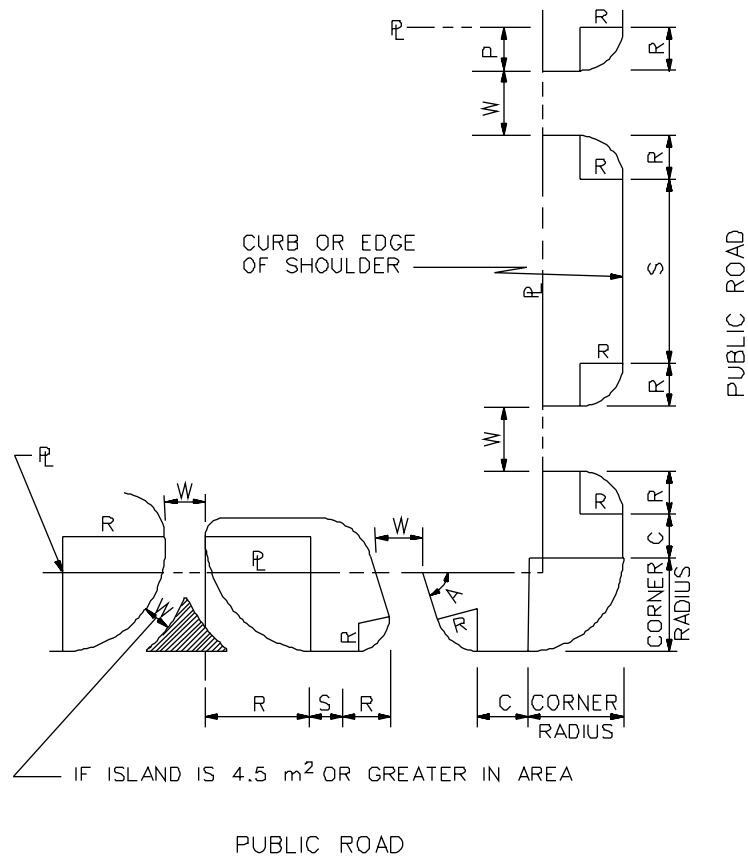
11-8.02 Driveway Spacing and Corner Clearances

Closely spaced driveways can cause operational problems, especially with high-volume roadways and/or high-volume driveways. These problems can also result if driveways are too close to at-grade intersections. The following criteria will apply to driveway spacing and corner clearance:

1. Upper Design Values. Figure 11-8E presents criteria which, where practical, should be met. On new construction and major reconstruction projects, the designer should be able to achieve these criteria. This will help provide good traffic operations for the main facility and for driveways.
2. Minimum. Section 13b-11-15 of the Department's "Highway Encroachment Permit Regulations" discusses criteria for driveway spacing and location. For convenience, Section 13b-11-15 is presented at the end of Section 11-8.0. At a minimum, the designer will ensure that these criteria are met. This will often be applicable on 3R projects. In addition, it will not be permissible to place any part of a driveway (including its entrance radius) within the radius of a public road at an intersection. If this criteria cannot be met for properties in intersection corners, one possible solution is to relocate the driveway entrance from the major road to the minor road, if applicable.

11-8.03 Major Traffic Generators

The State Traffic Commission (STC) is responsible for processing and approving access requests for major traffic generators (e.g., shopping malls). The Department may be requested to review and comment on the engineering aspects of the access requests. Section 14-311 of the General Statutes provides the regulatory basis for the authority of the STC to regulate the access of major traffic generators onto public roads.



- Key:
- R = Driveway radius
 - W = Driveway width
 - PL = Property line
 - C = Corner clearance
 - A = Driveway angle of intersection
 - S = Spacing between two driveway radius points
 - P = Spacing between driveway and property line radius point

Dimension	Term	Type of Driveway		
		Residential	Commercial	Industrial
From Property Line	P	1.5 m	4.5 m	R
From Street Corner	C	1.5 m	3.0 m	3.0 m
Between Driveways	S	1.0 m	1.0 m	3.0 m

DRIVEWAY DIMENSIONS

Figure 11-8E

Note: This excerpt has retained the English units from the 1992 version.

Section 13b-11-15 "Driveways"
from the
Highway Encroachment Permit Regulations

Approval of an application for a permit for a driveway shall be subject to Sec. 13a-143a Driveway Permits, which reads "No person shall construct a new driveway or relocate an existing driveway leading onto a state highway without first obtaining a permit from the Commissioner of Transportation. In determining the advisability of issuing such permit, the Commissioner shall include, in his consideration, the location of the driveway with respect to its effect on highway drainage, highway safety, the width and character of the highways affected, the density of traffic thereon, and the character of such traffic. The person to whom the permit is issued shall comply with the provisions and restrictions contained therein at his own expense."

Such approval shall also be subject to the following conditions:

(1) The applicant is the owner of the property, or owner jointly with the contractor, and any driveway approach constructed is for the bona fide purpose of securing access to the property and not for the purpose of parking or servicing vehicles on the highway right-of-way.

(2) Any driveway, approach or improvement constructed under permit within the right-of-way shall be subject to inspection at any time by the State. The District Maintenance Manager reserves the right to require such changes, additions and relocations thereto as, in the manager's opinion, may be necessary for the relocation, reconstruction, widening or maintenance of the highway or to provide protection to life and property on or adjacent to the highway.

(3) No driveway, approach or other improvement constructed on the right-of-way, under permit, shall be relocated, or its dimensions altered, without written permission of the District Maintenance Manager.

(4) The applicant agrees to comply with all insurance requirements set forth in section 13b-17-9 of these regulations.

(5) The proposed location, design and construction of any driveways under permit shall be evaluated by the State in accordance with the following criteria:

(a) For permit purposes, the priority of use by the abutting land-owner of that portion of the roadside fronting on his/her land shall be confined between lines drawn from the frontage corners of the property to the centerline of the roadway either at right angles to the centerline on tangents or on a radial line on curves.

(b) No more than one combination entrance and exit shall be allowed for any property with frontage of less than 50 feet. Parcels having a frontage from 50 to 100 feet may be permitted two entrances if a minimum of one-third of the total frontage is used to separate driveways. Lots with frontage in excess of 100 feet shall conform to such driveway and channelization layout as the District Maintenance Manager shall prescribe.

(c) The width of any entrance or exit shall not exceed 30 feet, measured parallel to the direction of the State highway at the property line, except as may otherwise be designated by the District Maintenance Manager because of municipal ordinance or other

valid reason. The area within State property between the entrance and exit shall not be improved to facilitate vehicular traffic or parking. This area shall be considered restricted and may be developed on as hereinafter provided in paragraph (1).

(d) The grade of entrances and exits shall conform to current Highway Design Standards for typical treatment of drives.

(e) In rural or suburban regions, no entrance or exit shall be so constructed that any part of such entrance or exit is less than ten feet from the extended common boundary separating adjacent private properties, except for returns, the radius of which shall not exceed 50 feet. In urban areas, or where there is a curb and gutter, the distance from the boundary may be five feet. See paragraph 5(a) above for limitations on radius termini.

(f) The construction of parking areas on the highway right-of-way is prohibited, except as provided for under the regulations governing parking areas under lease within the highway right-of-way. Places of business requiring parking space for their customers shall provide such facilities on their own premises.

(g) Drainage discharged from a State highway or flowing within the right-of-way shall not be altered or impeded and the permittee must provide suitable drainage structures as directed by the District Maintenance Manager.

(h) When a curb and gutter are removed, the entrance and exit shall be constructed so that the curbing along the highway shall be returned into the entrance and exit on a radius of not less than 2 feet or more than 50 feet unless otherwise directed by the District Maintenance Manager.

(i) All entrances and exits shall be so located that vehicle operators approaching or using them shall have adequate sight distances in both directions along the State highway in accordance with current Department of Transportation geometric design standards. All slopes shall be stabilized by the permit applicant by loaming and seeding or other method directed by the Permit Inspector.

(j) All entrances and exits constructed under permit shall be paved on the entire section within the State highway right-of-way with bituminous concrete, portland cement concrete, or as directed by the District Maintenance Manager. The remainder of the area graded to drain to the State highway shall be stabilized to prevent erosion and washing of material onto the State highway. All costs of such paving shall be borne by the permittee. The pavement shall be joined in a straight line at its intersection with the State highway shoulder and shaped as the Inspector shall require to accommodate highway drainage.

(k) No entrance or exit shall be constructed at the intersection of two State highways, town road, or city street within the area lines drawn perpendicular to the centerline of the highway from points on the right-of-way lines, for a distance of 25 feet from the intersection of said right-of-way lines at non-signalized intersections. Driveways at signalized intersections shall be constructed as directed by the District Maintenance Manager.

(l) The area between entrances and exits and those portions of rights-of-way which have been defined herein above in (c) as restricted area may be filled in only when surface drainage is provided, so that all surface water on the improved area is carried away from the highway roadbed and shoulder in a suitable manner, and when the drainage facility installed under any filled area is adequate to carry the water along the State highway. No headwall or other structure so designed as to be a hazard to an errant vehicle shall be

constructed in the highway right-of-way within the clear zone as specified in the Guidelines for Highway Design. The District Maintenance Manager will determine whether or not berms or curbs are to be constructed around this separating island area and also along the edges of any end island area. Driveway side slopes within the highway clear zone should not exceed 1:6 maximum.

(m) At locations of new, single homes being constructed adjacent to and lower than the State highway pavement, the property owner is required to grade the frontage within highway limits so as to confine highway surface water to the gutter or construct a bituminous concrete berm. These berms, either grassed earth or bituminous concrete, are maintained by the State upon satisfactory completion by the permittee. Particular care must be exercised to see that the permittee constructs driveway entrances so as to confine surface drainage to the highway gutter.

(n) At new housing developments, shopping centers, industrial parks, and similar developments, the owner shall be required to construct a bituminous concrete lip curb adjacent to the gutter along the entire frontage of the property being developed unless otherwise directed by the District Maintenance Manager.

(o) In instances where the property abutting a State highway is already developed and it becomes necessary to construct a bituminous concrete berm to confine the highway surface drainage, the total cost of constructing the berm is the obligation of the Department.

11-9.0 REFERENCES

1. *A Policy on Geometric Design of Highways and Streets*, AASHTO, 1994.
2. *Highway Capacity Manual*, TRB, 1994.
3. NCHRP Synthesis 225, *Left-Turn Treatments at Intersections*, TRB, 1996.
4. *Manual on Uniform Traffic Control Devices*, FHWA, 1988.
5. NCHRP 279, *Intersection Channelization Design Guide*, TRB, 1985.
6. *Guidelines for Driveway Location and Design*, ITE, 1987.
7. "Volume Warrants for Left-Turn Storage Lanes at Unsignalized Grade Intersections," M.D. Harmelink, Highway Research Record 211, 1967.
8. "Parameters Affecting Intersection Sight Distance", Special Studies Unit, Connecticut Department of Transportation, October, 1985.
9. NCHRP 375, *Median Intersection Design*, TRB, 1995.
10. *Highway Encroachment Permit Regulations*, Connecticut Department of Transportation, 1992.
11. "Major Traffic Generators Procedure for Engineering and Preparation of State Traffic Commission Report", Connecticut State Traffic Commission, January, 1977.

Chapter Twelve
INTERCHANGES
Table of Contents

		<u>Page</u>
12-1.0	GENERAL	12-1(1)
	12-1.01 <u>Warrants</u>	12-1(1)
	12-1.01.01 <u>Guidelines</u>	12-1(1)
	12-1.01.02 <u>New/Revised Interchanges on the Interstate System</u> ..	12-1(2)
	12-1.02 <u>Interchange Type Selection</u>	12-1(4)
	12-1.02.01 <u>General Evaluation</u>	12-1(4)
	12-1.02.02 <u>Types</u>	12-1(4)
12-2.0	TRAFFIC OPERATIONAL FACTORS	12-2(1)
	12-2.01 <u>Basic Number of Lanes and Lane Balance</u>	12-2(1)
	12-2.02 <u>Lane Reductions</u>	12-2(1)
	12-2.03 <u>Distance Between Successive Freeway/Ramp Junctions</u>	12-2(5)
	12-2.04 <u>Safety Considerations</u>	12-2(5)
	12-2.05 <u>Capacity and Level of Service</u>	12-2(10)
	12-2.06 <u>Collector-Distributor Roads</u>	12-2(10)
12-3.0	FREEWAY/RAMP JUNCTIONS	12-3(1)
	12-3.01 <u>Exit Ramps</u>	12-3(1)
	12-3.01.01 <u>Deceleration Lanes</u>	12-3(1)
	12-3.01.02 <u>Sight Distance</u>	12-3(1)
	12-3.01.03 <u>Superelevation</u>	12-3(5)
	12-3.01.04 <u>Gore Area</u>	12-3(5)
	12-3.01.05 <u>Cross Slope Rollover</u>	12-3(6)
	12-3.02 <u>Entrance Ramps</u>	12-3(6)
	12-3.02.01 <u>Acceleration Lanes</u>	12-3(6)
	12-3.02.02 <u>Sight Distance</u>	12-3(10)
	12-3.02.03 <u>Superelevation</u>	12-3(10)
	12-3.03 <u>Critical Design Elements</u>	12-3(10)

Table of Contents
(Continued)

	Page
12-4.0	RAMP DESIGN 12-4(1)
12-4.01	<u>Design Speed</u> 12-4(1)
12-4.02	<u>Cross Section</u> 12-4(2)
12-4.03	<u>Horizontal Alignment</u> 12-4(3)
12-4.04	<u>Vertical Alignment</u> 12-4(6)
12-5.0	RAMP/CROSSING ROAD INTERSECTION 12-5(1)
12-5.01	<u>Design of At-Grade Intersections</u> 12-5(1)
12-5.02	<u>Frontage Road Intersection</u> 12-5(4)
12-5.03	<u>Access Control</u> 12-5(4)
12-6.0	REFERENCES 12-6(1)

Chapter Twelve

INTERCHANGES

12-1.0 GENERAL

12-1.01 Warrants

12-1.01.01 Guidelines

Although an interchange is a high-level compromise for intersection problems, its high cost and environmental impact require that interchanges only be used after careful consideration of its costs and benefits. Because of the great variance in specific site conditions, ConnDOT has not adopted specific interchange warrants. When determining the need for an interchange or grade separation, the following guidelines should be considered:

1. Design Designation. Once it has been decided to provide a fully access-controlled facility, each intersecting highway must be terminated, rerouted, provided a grade separation or provided an interchange. The importance of the continuity of the crossing road and the feasibility of an alternative route will determine the need for a grade separation or interchange. An interchange should be provided on the basis of the anticipated demand for access to the minor road.

On facilities with partial control of access, intersections with public roads will be accommodated by an interchange or with an at-grade intersection; grade separations alone are not normally provided. Typically, an interchange will be selected for the higher-volume intersecting roads. Therefore, on a facility with partial control of access, the decision to provide an interchange will be, in general, based on the criteria in the following comments.

2. Functional Classification. Interchanges will be provided at all freeway-to-freeway crossings. On fully access-controlled facilities, interchanges should be provided with all major highways, unless this is determined inappropriate for other reasons. Interchanges to other highways may be provided if practical.
3. Congestion. An interchange may be considered where the level of service (LOS) at an at-grade intersection is unacceptable, and the intersection cannot be redesigned at-grade to operate at an acceptable LOS. Although LOS criteria is the most tangible of any interchange

guideline, ConnDOT has not adopted any specific levels which, when exceeded, would demand an interchange.

4. Safety. The accident reduction benefits of an interchange should be considered at an existing at-grade intersection which has a high accident rate. Section 12-2.04 provides additional information on various safety considerations relative to interchange selection.
5. Site Topography. At some sites the topography may be more adaptable to an interchange than an at-grade intersection.
6. Road-User Benefits. Interchanges significantly reduce the travel time when compared to at-grade intersections but may increase the travel distances. If an analysis reveals that road-user benefits over the service life of the interchange will exceed costs, then an interchange may be considered.
7. Traffic Volumes. A traffic volume warrant is the most tangible of any interchange warrant. Although the Department has not adopted specific numbers which, when exceeded, would demand an interchange, it is still an important factor. For example, the point at which volumes for an at-grade intersection exceed capacity may warrant an interchange, if the at-grade intersection cannot be practically upgraded. In addition, other factors, such as costs, right-of-way and environmental concerns, need to be considered.
8. Interchange Spacing. When interchanges are spaced farther apart, freeway operations are improved. Spacing of urban interchanges between interchange crossroads should not be less than 1.5 km. This should allow for adequate distance for an entering driver to adjust to the freeway environment, to allow for proper weaving maneuvers between entrance and exit ramps, and to allow for adequate advance and exit signing. In urban areas, a spacing of less than 1.5 km may be developed by grade-separated ramps or by collector-distributor roads. In rural areas, interchanges should not be spaced less than 5 km apart on the Interstate system or 3 km on other systems.

12-1.01(02) New/Revised Interchanges on the Interstate System

The Department's goal is to maintain the highest practical level of service, safety and mobility on its Interstate System. Among other design features, this is accomplished by controlling access onto the system. In general, new access points on existing fully access-controlled facilities are discouraged. Proposals for new or revised access points on an existing Interstate must fully address the following considerations:

1. Traffic Volumes. The proposal must demonstrate that existing interchanges and/or local roads and streets within the corridor cannot satisfactorily accommodate, nor can the existing network be feasibly improved to accommodate, the expected design-year traffic volumes.
2. Alternatives. The proposal must demonstrate that all reasonable alternatives for design options, locations and transportation system management type improvements (e.g., ramp metering, mass transit, HOV facilities) have been evaluated, provided for, and/or provision made for future incorporation.
3. Impacts. The proposed new access point should not have a significant adverse impact on the safety and operation of the Interstate facility based on an analysis of current and future traffic (e.g., 20 years in the future). The operational analysis for existing conditions should include:
 - a. an analysis of Interstate sections to, and including, at least the first adjacent existing or proposed interchange on either side; and
 - b. an analysis of crossroads and other roads/streets to ensure their ability to collect and distribute traffic to and from the proposed interchange.
4. Connections. The proposed new interchange will only be connected to a public road, and it will provide for all traffic movements. Less than "full interchanges" for special purpose access for transit vehicles, for HOV entrances or to park-and-ride lots may be considered on a case-by-case basis.
5. Land Use. The proposal must address the consistency of the interchange with local and regional development plans and transportation system improvements. For possible multiple interchange additions, the proposal must be supported by a comprehensive Interstate network study which should address all proposed and desired access within the context of a long-term plan.
6. New/Expanded Development. Where new or revised access is requested, due to a proposed or expanded development, document that the appropriate coordination has taken place with the developer in conjunction with other transportation system improvements.
7. Design. The Department's design criteria for interchanges as presented in this chapter must be met or adequately addressed.

All proposed new or revised access points on the Interstate System will require formal approval from the FHWA. See Federal Register, Vol. 55, No. 204, Monday, 10-22-90.

Each entrance and exit point on the mainline, including "locked gate" access (e.g., utility opening), is defined as an access point (e.g., diamond interchanges have four access points). A revised access is considered to be a change in the interchange configuration even though the number of access points may not change (e.g., replacing a diamond interchange ramp with a loop).

12-1.02 Interchange Type Selection

12-1.02.01 General Evaluation

The AASHTO *A Policy on Geometric Design of Highways and Streets* presents the various interchange types which may be used at a given site. The Office of Intermodal Project Planning normally determines the type of interchange for the site. Typically, the Office will evaluate several types for potential application considering:

1. compatibility with the surrounding highway system;
2. route continuity;
3. level of service for each interchange element (e.g., freeway/ramp junction, ramp proper);
4. operational characteristics (e.g., single versus double exits, weaving, signing);
5. road user impacts (e.g., travel distance and time, safety, convenience, comfort);
6. driver expectancy;
7. geometric design;
8. construction and maintenance costs;
9. potential for stage construction;
10. right-of-way impacts and availability;
11. environmental impacts; and
12. potential growth of surrounding area.

All interchanges should provide for all movements, even when the anticipated turning volume is low. An omitted movement may cause confusion to those drivers searching for the exit or entrance. In addition, unanticipated future developments may increase the demand for that movement.

12-1.02.02 Types

This section presents the basic types of interchanges in Connecticut. The AASHTO *A Policy on Geometric Design of Highways and Streets* discusses the advantages and disadvantages for each interchange type. Each interchange must be custom-designed to fit the individual site considerations. The final design may be a minor or major modification of one of the basic types or may be a combination of two or more basic types. The following are the basic types of interchanges used in Connecticut:

1. Three-Leg. Three-leg interchanges, also known as T- or Y-interchanges, are provided at intersections with three legs.
2. Diamond. The diamond is the simplest and perhaps the most common type of interchange. One-way diagonal ramps are provided in each quadrant with two at-grade intersections provided at the minor road. If these two intersections can be properly designed, the diamond is usually the best choice of interchange where the intersecting road is not access controlled.
3. Single Point Urban Interchange. The single point urban interchange is a special type of diamond interchange. With this interchange, all legs of the interchange meet at a single point. It can significantly increase the interchange capacity, alleviate the operational problems of having two closely spaced at-grade intersections on the minor road, and overcome the left-turn lane storage problem for drivers wishing to enter the freeway.
4. Full Cloverleafs. Cloverleaf interchanges are used at 4-leg intersections and employ loop ramps to accommodate left-turn movements. Loops may be provided in any number of quadrants. Full cloverleaf interchanges are those with loops in all four quadrants; all others are partial cloverleafs.
5. Partial Cloverleafs. Partial cloverleaf interchanges are those with loops in one, two or three quadrants. They are appropriate where right-of-way restrictions preclude ramps in one or more quadrants. They are also advantageous where a left-turn movement can be provided onto the major road by a loop without the immediate presence of an entrance loop from the minor road.
6. Directional and Semi-Directional. Directional or semi-directional interchanges are used for heavy left-turn movements to reduce travel distance, to increase speed and capacity and to eliminate weaving. These types of connections allow an interchange to operate at a better level of service than is possible with cloverleaf interchanges.

12-2.0 TRAFFIC OPERATIONAL FACTORS

Several traffic operational factors are important in the design of an interchange. Adhering to these factors will minimize confusion, operational problems and the number of accidents. The designer must work closely with the Design Development Team to ensure that all operational factors are properly considered.

12-2.01 Basic Number of Lanes and Lane Balance

The basic number of lanes is the minimum number of lanes over a significant length of highway based on the overall capacity needs of that section. The number of lanes should remain constant over short distances. For example, a lane should not be dropped at the exit of a diamond interchange and then added at the downstream entrance simply because the traffic volume between the exit and entrance drops significantly. A basic lane should also not be dropped between closely spaced interchanges simply because the estimated traffic volume in that short section of highway does not warrant the higher number of lanes.

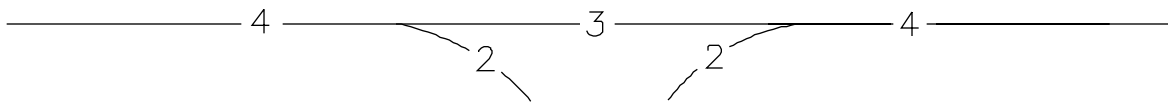
The number of lanes on the freeway mainline should not be reduced by more than one lane at an exit or increased by more than one lane at an entrance. This principle is lane balance. It would prohibit, for example, dropping two lanes at a 2-lane exit ramp. One lane must provide the option of remaining on the freeway.

Figure 12-2A illustrates how to coordinate lane balance and the basic number of lanes at an interchange. Figure 12-2B illustrates how to achieve lane balance at the merging and diverging points of branch connections.

12-2.02 Lane Reductions

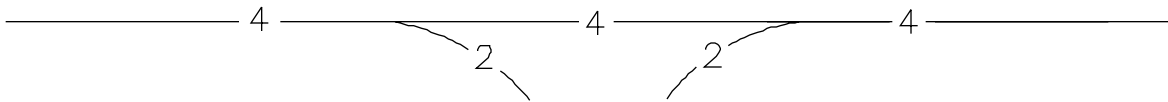
Freeway lane drops, where the basic number of lanes is decreased, must be carefully designed. They should occur on the freeway mainline away from any other turbulence, such as interchange exits and entrances. Figure 12-2C illustrates the recommended design of a lane drop beyond an interchange. The following criteria are important when designing a freeway lane drop:

1. Location. The lane drop should occur 600 m to 900 m beyond the previous interchange. This distance allows adequate signing and driver adjustments from the interchange, but yet is not so far downstream that drivers become accustomed to the number of lanes and are surprised by the lane drop. In addition, a lane should not be dropped on a horizontal curve or where other signing is required, such as for an upcoming exit.



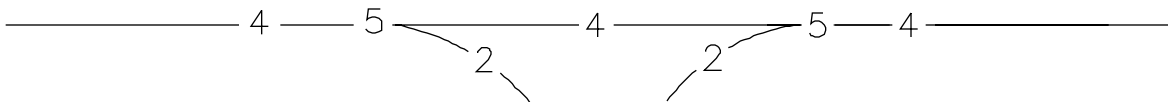
LANE BALANCE BUT NO COMPLIANCE WITH BASIC NUMBER OF LANES

-A-



NO LANE BALANCE BUT COMPLIANCE WITH BASIC NUMBER OF LANES

-B-

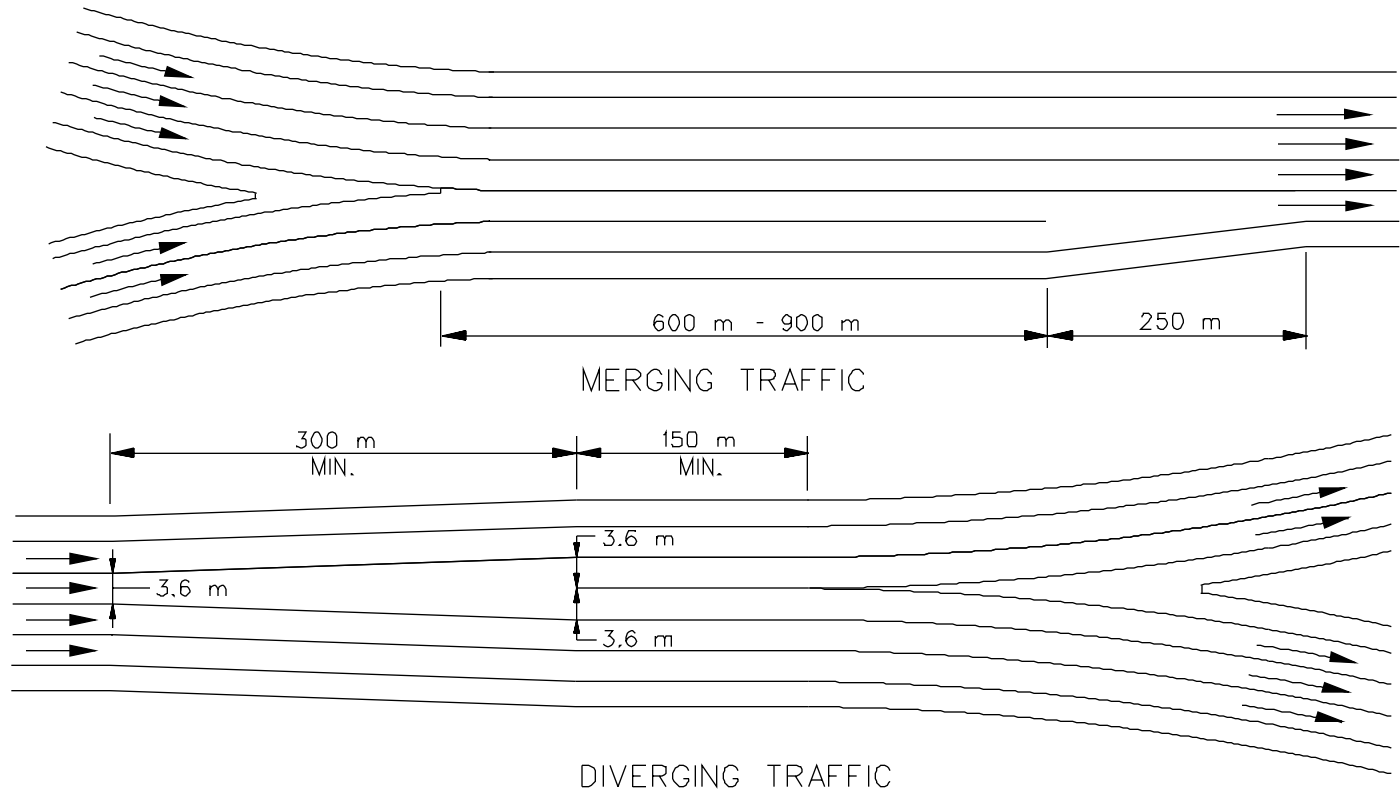


COMPLIANCE WITH BOTH LANE BALANCE AND BASIC NUMBER OF LANES

-C-

COORDINATION OF LANE BALANCE AND BASIC NUMBER OF LANES

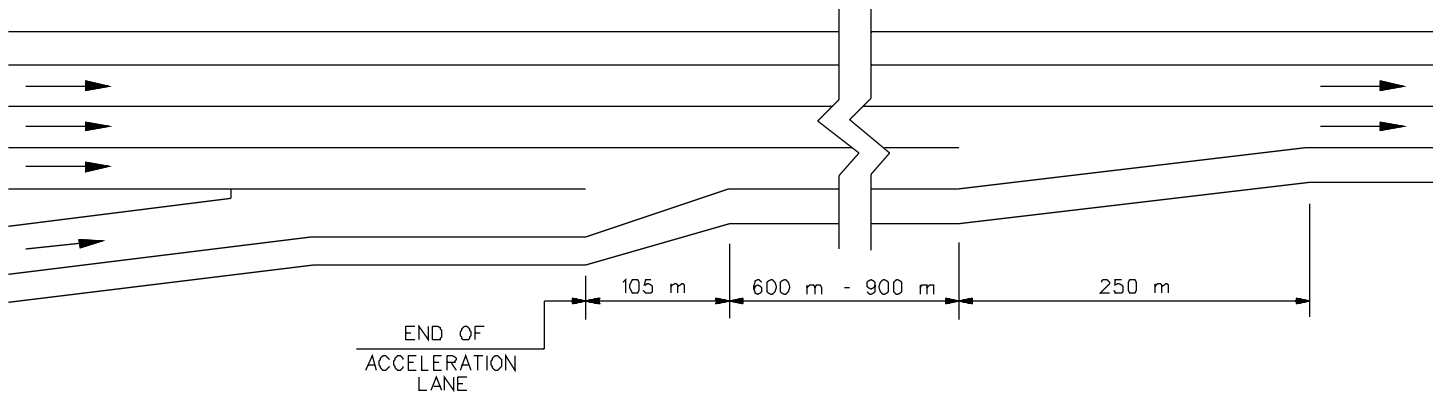
Figure 12-2A



- Notes:
1. Branch connections should be designed to avoid compound merging or diverging movements.
 2. Each merge and diverge will be treated individually, considering traffic operations and geometric features upstream and downstream and in the immediate area of the merge.
 3. The preferred arrangement will provide a reduction, if any is required, of no more than one lane for merging movements and an addition of no more than one lane for diverging movements.
 4. The number of lanes approaching and leaving the merging or diverging area should be determined by traffic volumes and/or operational requirements.

LANE BALANCE AT BRANCH CONNECTIONS

Figure 12-2B



FREWAY LANE DROP BEYOND INTERCHANGE

Figure 12-2C

2. Transition. The length of transition is 250 m, which is based on a 70:1 taper rate.
3. Sight Distance. Where practical, decision sight distance (DSD) should be available to any point within the entire lane transition (250 m). See Figure 7-2A for applicable DSD values. When determining the availability of DSD, the height of object should be 0.0 mm (the roadway surface); however, it is acceptable to use 150 mm. This criteria would favor, for example, placing a freeway lane drop within a sag vertical curve rather than just beyond a crest.
4. Right-Side versus Left-Side Drop. All freeway lane drops should be on the right side, unless specific site conditions greatly favor a left-side lane reduction.

In urban areas, interchanges may be closely spaced for considerable lengths of highway. In these cases, it may be necessary to drop a freeway lane at an exit. Figure 12-2D illustrates the recommended design. One key design feature is the "escape lane" provided just beyond the exit gore. Some drivers may miss the signs which notify them that the mainline lane is being dropped at the exit. The escape lane provides these drivers with an opportunity to merge left into the remaining through lanes. As discussed in Section 12-2.01 on basic number of lanes, this design should not be used unless there is a large decrease in traffic demand for a significant length of freeway.

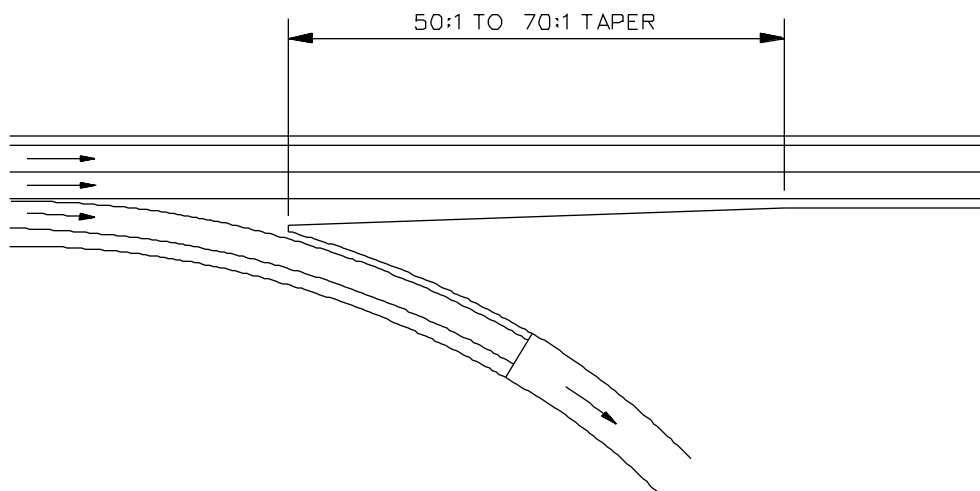
12-2.03 Distance Between Successive Freeway/Ramp Junctions

Frequently, successive freeway/ramp junctions must be placed relatively close to each other, especially in urban areas. The distance between the junction must be sufficient for vehicular maneuvering, signing and capacity. Figures 12-2E and 12-2F provide recommended minimum distances for spacing for freeway/ramp junctions.

In addition, the *Highway Capacity Manual* provides a detailed methodology for calculating the level of service for many combinations of freeway/ramp junctions. This will be a major factor in determining appropriate distances between these junctions. The Design Development Team will review the analysis to determine the applicable spacing for a specified level of service. The greater of the distances from Figures 12-2E and 12-2F or from the capacity analysis will govern.

12-2.04 Safety Considerations

The following summarizes significant safety considerations which should be evaluated in the design of an interchange:

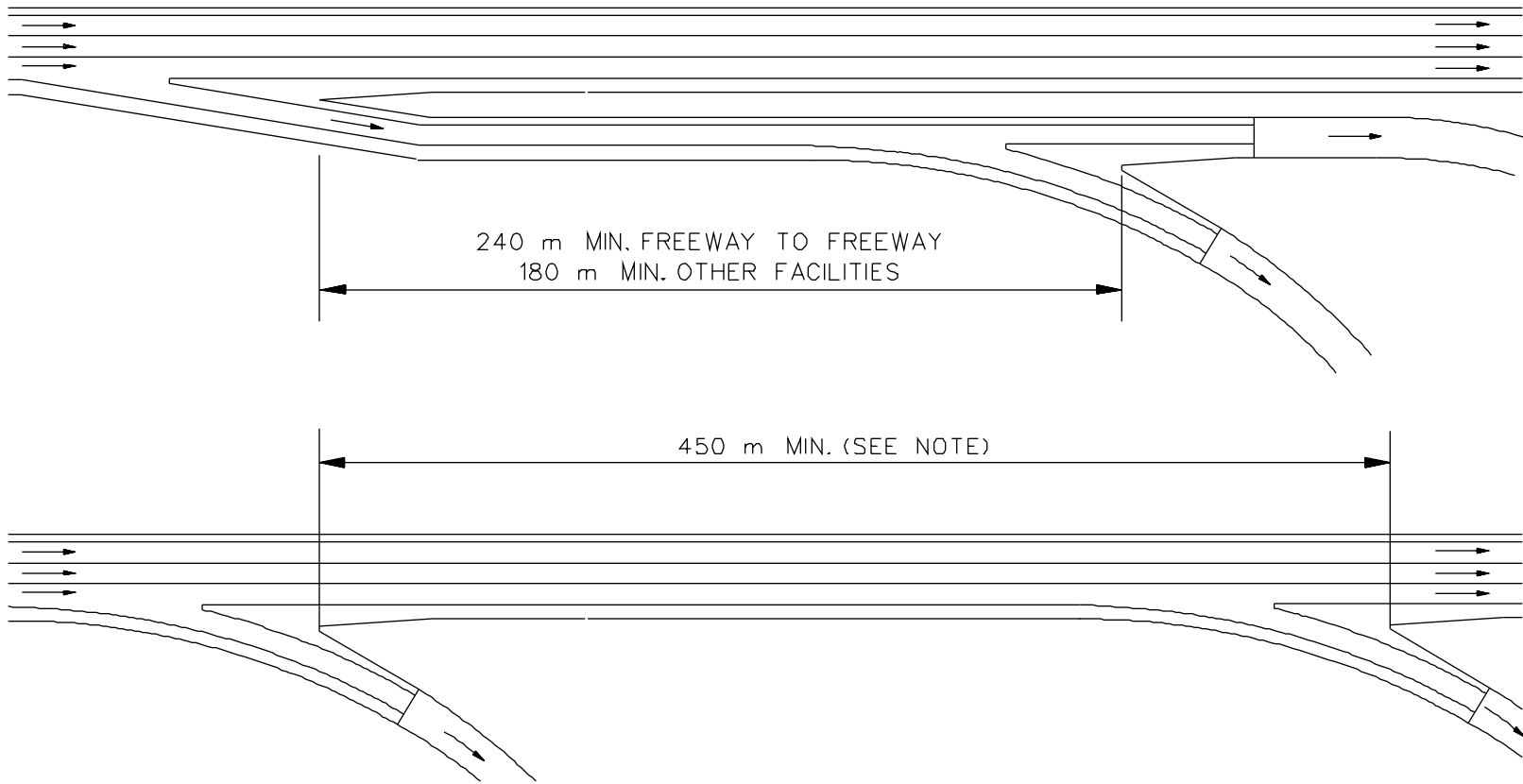


Note:

A reduction in the number of lanes at an interchange is an appropriate layout only where the traffic warrants for a considerable section of the freeway beyond the interchange do not require the greater number of lanes. Because of the difficulty of predicting the daily and hourly fluctuations of traffic on low-volume ramp movements, the number of lanes should not be reduced within the interchange area, such as between successive "off" and "on" ramps.

REDUCTION IN NUMBER OF TRAFFIC LANES AT INTERCHANGE

Figure 12-2D

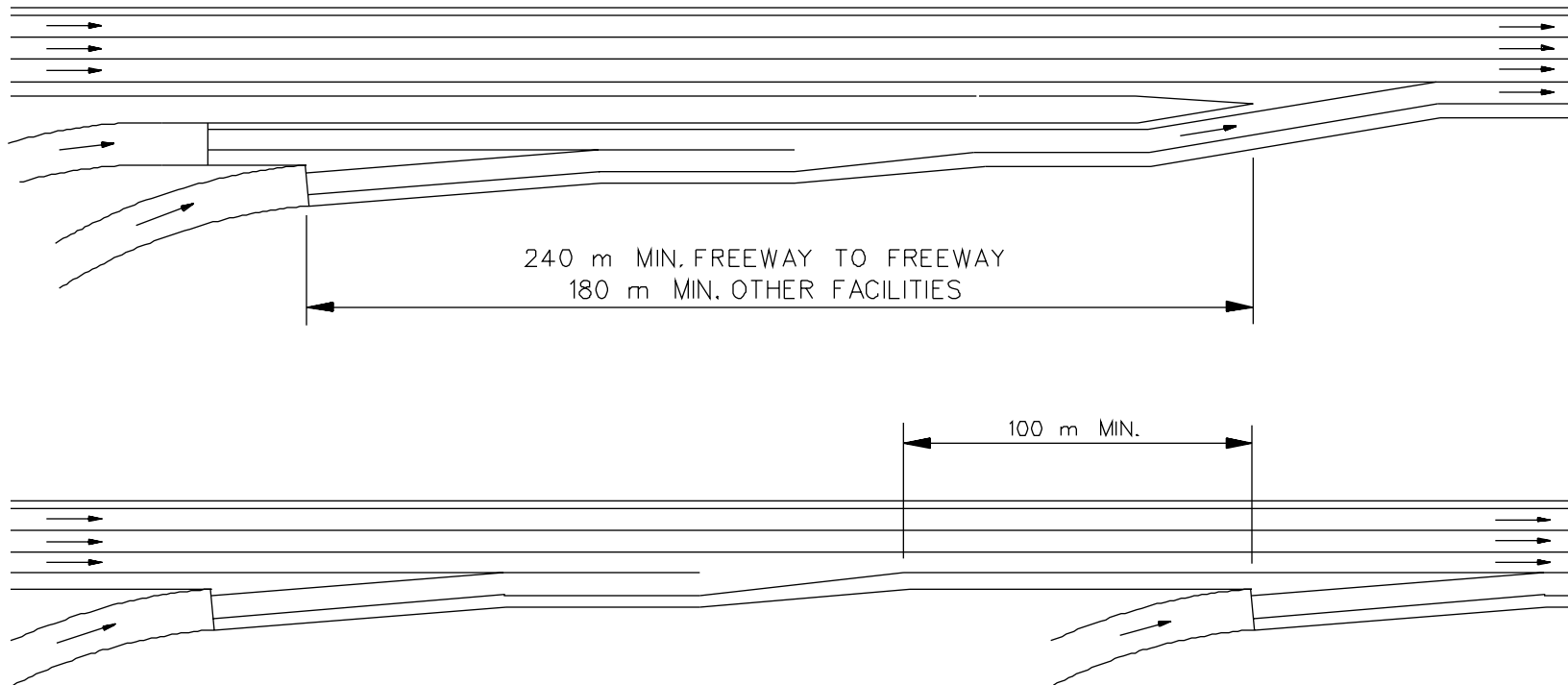


Note:

The spacing of exit terminals should be based upon considerations of signing to permit the driver adequate time to make decisions. Exit terminals should not be spaced closer than 1.5 km except where conditions, such as ramp or local terminal capacity, may make it necessary to reduce this distance. 450 m is considered the minimum distance between exit terminals which will provide safe and efficient operation. Closer spacings should only be used under the lower speed situation provided by the distributor road arrangement shown in the upper sketch. In addition, the Highway Capacity Manual should be used to determine the actual distance based on a specified level of service.

SUCCESSIVE EXIT TERMINAL SPACINGS

Figure 12-2E



Note:

The spacing of entrance terminals should be based upon considerations of maintaining smooth operations on the through traffic lanes. Entrance terminals often cause turbulence which should not extend through successive entrance areas. 100 m is considered the minimum distance of normal cross section necessary for the turbulence associated with lane changing to subside. Where closer spacing of entrance terminals is required, the collector road detail shown in the upper sketch may be employed. In addition, the Highway Capacity Manual should be used to determine the actual distance based on a specified level of service.

SUCCESSIVE ENTRANCE TERMINAL SPACINGS

Figure 12-2F

1. Exit Points. Where practical, provide decision sight distance at freeway exits, and use the pavement surface for the height of object (0.0 mm). A 150-mm height of object is acceptable. See Section 12-3.01 for the application of decision sight distance to freeway exits. Proper advance signing of exits is also essential.
2. Exit Speed Changes. The design should provide enough distance to allow safe deceleration from the freeway design speed to the design speed of the first governing geometric feature on the ramp, typically the horizontal exit curve. See Section 12-3.01 for applicable values for deceleration length.
3. Merges. Rear-end collisions on entrance merges onto a freeway may result from a driver attempting the complicated maneuver of simultaneously searching for a gap in the mainline traffic stream and watching for vehicles in front. An acceleration distance of sufficient length should be provided to allow a merging vehicle to attain speed and find a sufficient gap to merge into.
4. Fixed-Object Accidents. A number of fixed objects may be located within interchanges, such as signs at exit gores or bridge piers. These should be removed where practical, made breakaway, or shielded with barriers or crash cushions. See Chapter Thirteen for a detailed discussion on roadside safety.
5. Wrong-Way Entrances. In almost all cases, wrong-way maneuvers originate at interchanges. Some cannot be avoided, but many result from driver confusion due to poor visibility, deceiving ramp arrangement or inadequate signing. The interchange design must attempt to minimize wrong-way possibilities. The designer should coordinate with the Division of Traffic Engineering to achieve this objective.
6. Incomplete Interchanges. If practical, the designer should ensure that all movements are provided at an interchange, even if projected turning volumes are low. A missing movement may cause confusion for those drivers seeking that movement. In addition, if future demand for the movement increases, it may be relatively expensive and disruptive to provide the connection.
7. Driver Expectancy. Interchanges can be significant sources of driver confusion; therefore, they should be designed to conform to the principles of driver expectancy. Several of these principles are discussed below:
 - a. Avoid using left-hand exits and entrances. It is difficult for a driver entering from a ramp to safely merge with the high-speed left lane on the mainline. Therefore, left exits and entrances should not be used, because they are not consistent with the

concept of driver expectancy when they are mixed with right-hand entrances and exits.

- b. Do not place exits in line with the freeway tangent section at the point of mainline curvature to the left.
- c. Avoid placing exits beyond structures.

12-2.05 Capacity and Level of Service

The capacity of an interchange will depend upon the operation of its individual elements:

1. basic freeway section where interchanges are not present,
2. freeway/ramp junctions,
3. weaving areas,
4. ramp proper, and
5. ramp/crossing road intersection.

The basic capacity reference is the *Highway Capacity Manual* (HCM). The HCM provides the analytical tools to analyze the level of service for each element listed above.

The interchange should operate at an acceptable level of service. The level of service values presented in Figures 4A and 5A for freeways will also apply to interchanges. The level of service of each interchange element should be as good as the level of service provided on the basic freeway section. At a minimum, interchange elements should not operate at more than one level of service below that of the basic freeway section. In addition, the operation of the ramp/crossing road intersection in urban areas should not impair the operation of the mainline. This will likely involve a consideration of the operational characteristics on the minor road for some distance in either direction from the interchange. The Design Development Team is responsible for conducting the capacity analyses for all interchange elements. However, coordinate the capacity analyses at ramp/crossing road intersections with the Division of Traffic Engineering.

12-2.06 Collector-Distributor Roads

Collector-distributor (C-D) roads are sometimes provided within an interchange to improve its operational characteristics. C-D roads will:

1. remove weaving maneuvers from the mainline,
2. provide single exits and entrances from the mainline, and
3. provide all mainline exits in advance of the structure.

C-D roads are most often warranted when traffic volumes are so high that the interchange without them cannot operate at an acceptable level of service, especially in weaving sections. C-D roads may be one or two lanes, depending upon the traffic volumes and weaving conditions. Lane balance should be maintained at the exit and entrance points of the C-D road. The design speed should be the same as the mainline, but not more than 20 km/h below the mainline. The separation between the C-D road and mainline should be as wide as practical, but not less than that required to provide the applicable shoulder widths and a longitudinal barrier between the two.

12-3.0 FREEWAY/RAMP JUNCTIONS

12-3.01 Exit Ramps

12-3.01.01 Deceleration Lanes

Sufficient deceleration distance is needed to safely and comfortably allow an exiting vehicle to leave the freeway mainline. All deceleration should occur within the full width of the deceleration lane. The length of the deceleration lane will depend upon the design speed of the mainline and the design speed of the first governing geometric control on the exit ramp. This will most often be a horizontal curve but could be, for example, stopping sight distance on a vertical curve. Figure 12-3A provides the deceleration distances for various combinations of highway design speeds and ramp design speeds. Greater distances should be provided if practical. If the deceleration lane is on a grade of 3% or more, the length of the lane should be adjusted according to the criteria in Figure 12-3B.

The specific use of the deceleration criteria to horizontal curves warrants some elaboration. The following will apply:

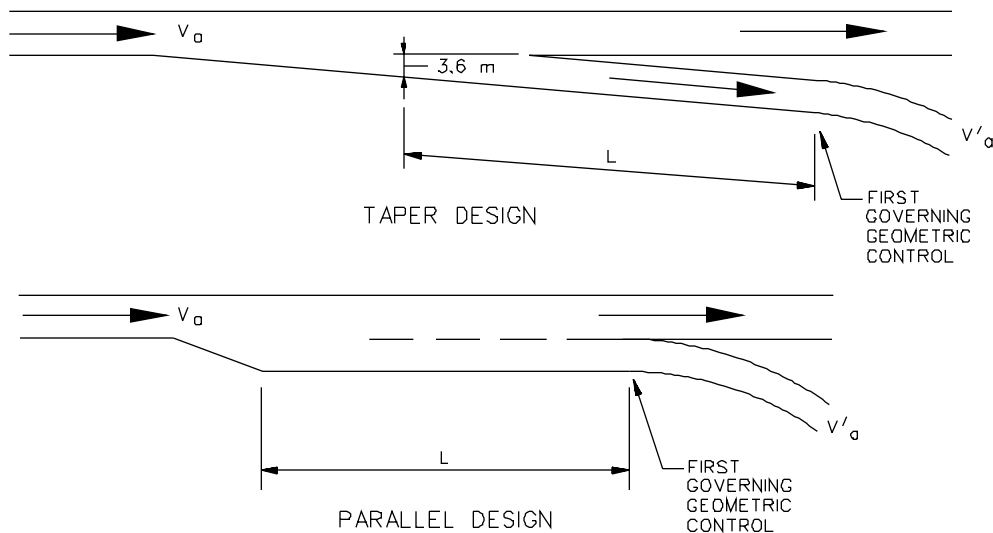
1. Based on the highway design speed and the design speed of the first curve on the exit ramp, Figure 12-3A will yield the required length of the deceleration lane. This will apply from the point where the deceleration lane becomes 3.6 m to the PC of the horizontal curve.
2. For compound curves on the ramp, the minimum length of the entering flatter curve should allow for safe deceleration to the design speed of the sharper curve. Figure 12-3A provides the criteria to determine the minimum distance between the PC and PCC or between the PCC and PCC.

Department policy is that taper ramps will be used for all freeway exits. Figure 12-3C illustrates the typical design for a freeway taper exit. However, at restrictive sites where a taper design cannot provide the needed deceleration for sharp curvature, a parallel lane may be considered. If used, it should be introduced with a taper of 25:1. The AASHTO *A Policy on Geometric Design of Highways and Streets* provides the design criteria for parallel lane designs.

12-3.01.02 Sight Distance

Where practical, decision sight distance should be provided for drivers approaching an exit. This sight distance is particularly important for exit loops immediately beyond the structure. Vertical curvature or bridge piers can obstruct the exit points if not carefully designed. When measuring for

Highway Design Speed (km/h) (V)	Speed Reached (km/h) (V _a)	L = Deceleration Length (m)							
		For Design Speed of First Governing Geometric Control (km/h) (V')							
		Stop	20	30	40	50	60	70	80
		For Average Running Speed on Exit Curve (km/h) (V _a ')							
		0	20	28	35	42	51	63	70
50	47	75	70	60	45	-	-	-	-
60	55	95	90	80	65	55	-	-	-
70	63	110	105	95	85	70	55	-	-
80	70	130	125	115	100	90	80	55	-
90	77	145	140	135	120	110	100	75	60
100	85	170	165	155	145	135	120	100	85
110	91	180	180	170	160	150	140	120	105



Notes:

1. The deceleration lengths are calculated from the distance needed for a passenger car to decelerate from the average running speed of the highway mainline to the average running speed of the first governing geometric control.
2. These values are for grades less than 3%. See Figure 12-3B for steeper upgrades or downgrades.

MINIMUM LENGTH OF DECELERATION LANES

Figure 12-3A

Direction of Grade	Ratio of Deceleration Lane Length on Grade to Length on Level			
	< 3%	$3\% \leq G < 5\%$	$5\% \leq G < 7\%$	$G \geq 7\%$
Upgrade	1.0	0.9	0.8	0.7
Downgrade	1.0	1.2	1.35	1.5

- Notes:
1. Table applies to all highway design speeds.
 2. The "grade" in the table is the average grade over the distance used for measuring the length of the deceleration lane. See Figure 12-3C.

Example

Given:

Highway Design Speed	-	110 km/h
First Exit Curve Design Speed	-	70 km/h
Average Grade	-	5% downgrade

Problem: Determine length of deceleration lane.

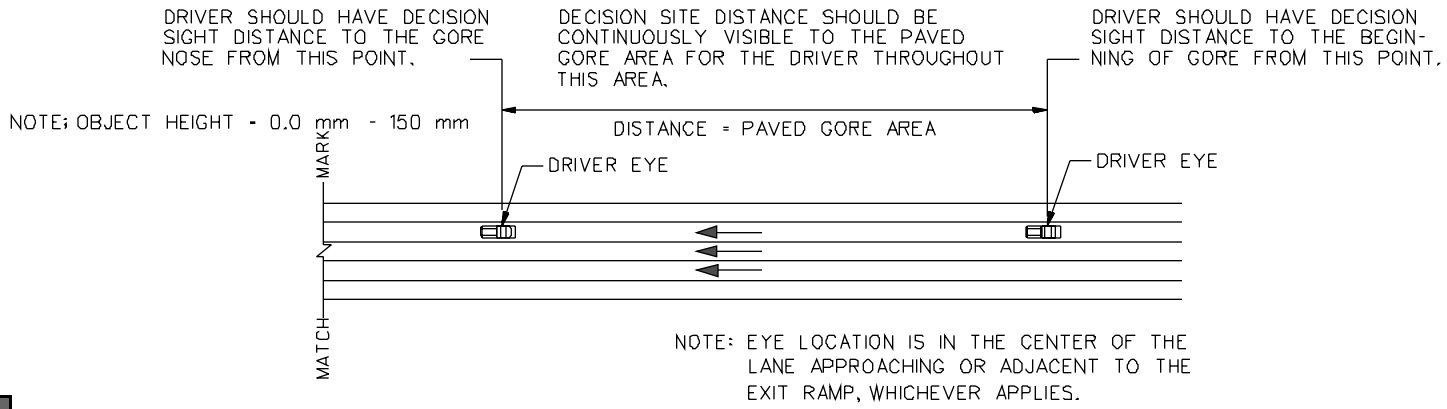
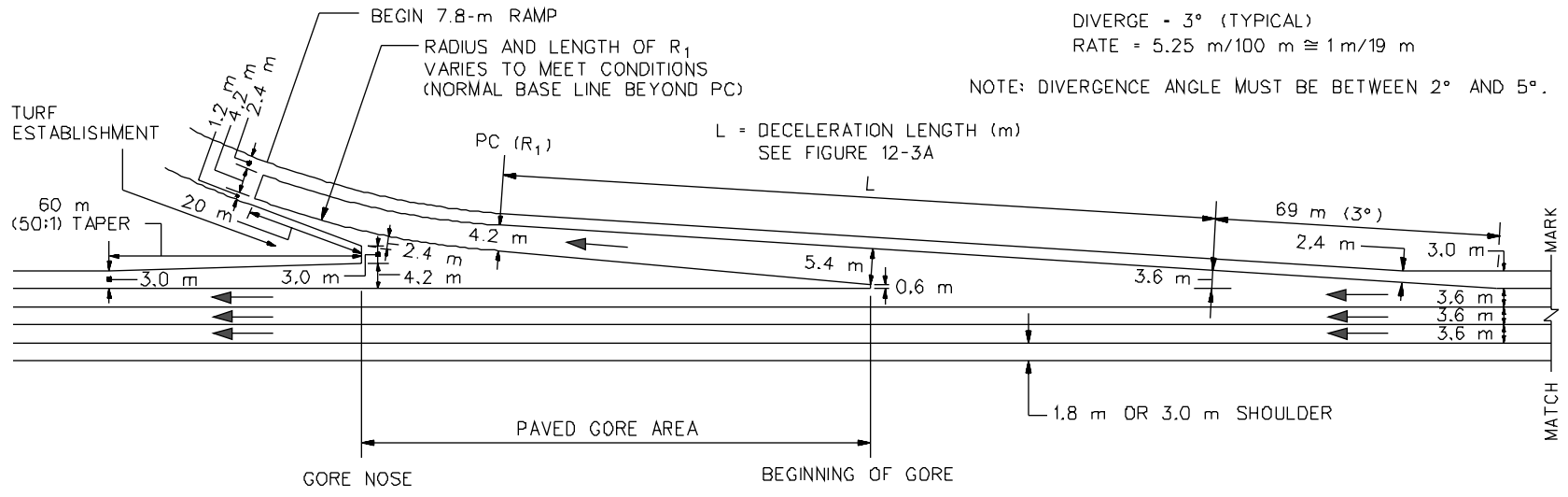
Solution: Figure 12-3A yields a minimum deceleration lane of 120 m on the level. According to Figure 12-3B, this should be increased by 1.35.

$$\begin{aligned} \text{Therefore: } L &= 120 \times 1.35 \\ L &= 162 \text{ m} \end{aligned}$$

A 162-m deceleration lane would be provided from the full width of the lane to the PC of the first exit curve.

GRADE ADJUSTMENTS ON DECELERATION LANES

Figure 12-3B



**TYPICAL EXIT RAMP DESIGN
 (3° Divergence)**

Figure 12-3C

MARCH 2000

adequate sight distance, the height of object should be 0.0 mm (the roadway surface); however, it is acceptable to use 150 mm. Figure 12-3C illustrates the application of the decision sight distance to freeway exits.

12-3.01.03 Superelevation

The superelevation at an exit ramp must be developed to properly transition the driver from the mainline to the curvature at the exit. The principles of superelevation for rural highways and high-speed urban facilities, as discussed in Section 8-2.0, should be applied to the exit ramp design.

The maximum superelevation rate is 6%. Figure 8-2A presents the design superelevation rate for various combinations of radii and design speed. Typically, the exit lane should be transitioned so that 0.67 of the design superelevation is reached at the PC of the first exit curve. At a minimum, the length of runoff should be based on the distances provided in Figure 8-2A.

12-3.01.04 Gore Area

The gore area is normally considered to be both the paved triangular area between the through lane and the exit lane, plus the graded area which may extend 100 m or more downstream beyond the gore nose. The following should be considered when designing the gore:

1. Traffic Control Devices. If practical, the area beyond the gore nose should be free of signs and luminaire supports for approximately 100 m beyond the gore nose. If they must be present, they must be yielding or breakaway or shielded by guide rail or a crash cushion. (See Chapter Thirteen).
2. Grading. The graded area beyond the gore nose should be as flat as practical. If the elevation between the exit ramp or loop and the mainline increases rapidly, this may not be practical. These areas will likely be non-traversable and the gore design must shield these areas from the motorist. At some sites, the vertical divergence of the ramp and mainline will warrant protection for both roadways beyond the gore.
3. Paved Gore. The paved triangular gore area between the through lane and exit lane should be safely traversable. The effects of snow storage and melt in the gore area design must be carefully considered. The typical gore grading design will collect the highway runoff in a swale section and direct it off the highway into the earth gore or collect it in a subsurface drainage system. This will minimize icing problems during winter maintenance activities. The maximum break in pavement cross slopes through the swale area should not exceed 8% at any point. Where this treatment is not practical, a straight cross slope may be used provided drainage and snow melt issues are adequately addressed. In no case should the cross slope

of gore be steeper than the adjacent travel lane cross slope. To ensure adequate consideration is given to the combination of drainage and geometric factors, careful evaluation will be necessary early in the design process.

4. **Signing.** Signing in advance of the exit and at the divergence should be according to current ConnDOT practices. This also applies to the pavement markings in the triangular area upstream from the gore nose. Signing and pavement markings should be coordinated with the Division of Traffic Engineering.

12-3.01.05 Cross Slope Rollover

The cross slope rollover is the algebraic difference between the slope of the through lane and the slope of the exit lane, when these two are adjacent to each other (i.e., before the gore begins). The maximum algebraic difference is 4% to 5%.

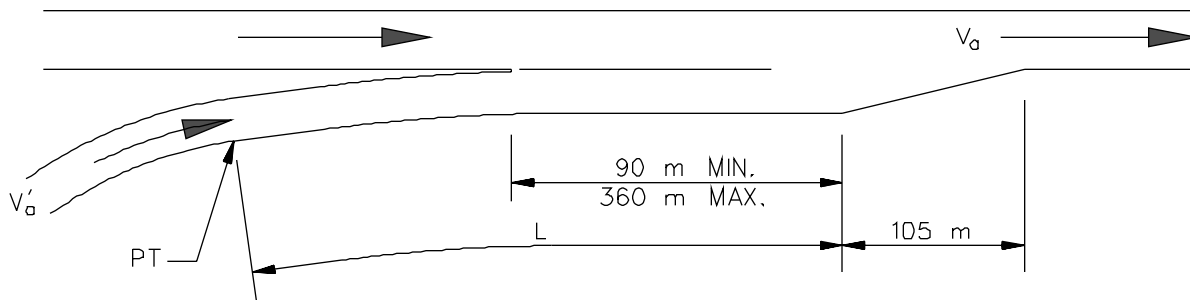
12-3.02 Entrance Ramps

12-3.02.01 Acceleration Lanes

A properly designed acceleration lane will facilitate driver comfort, traffic operations and safety. The length of the acceleration lane will primarily depend upon the design speed of the last (or controlling) curve on the entrance ramp and the design speed of the mainline. Figure 12-3D provides the criteria for minimum lengths of acceleration lanes. These lengths are for the full width of the acceleration lane; taper lengths, typically 105 m, are in addition to the table lengths. However, in restrictive locations, up to 15 m of the taper length may be used to meet the criteria for the acceleration distance. Where grades of 3 percent or more occur on the acceleration lane, adjustments should be made in its length according to Figure 12-3E. Figure 12-3F illustrates the typical design for entrance ramps. The designer should coordinate with the Design Development Team to determine the actual length of the acceleration lane.

The values in Figure 12-3D provide sufficient distance for vehicular acceleration; they may not safely allow a vehicle to merge into the mainline if traffic volumes are high. Where the mainline and ramp will carry traffic volumes approaching the design capacity of the merging area, the parallel portion of the acceleration lane should be increased to a maximum of 360 m in length.

Highway Design Speed (km/h) (V)	Speed Reached (km/h) (V _a)	L = Acceleration Length (m)								
		For Entrance Curve Design Speed (km/h)								
		Stop	20	30	40	50	60	70	80	
		And Initial Speed (km/h) (V' _a)								
		0	20	28	35	42	51	63	70	
50	37	60	-	-	-	-	-	-	-	
60	45	100	85	70	-	-	-	-	-	
70	53	145	125	110	85	50	-	-	-	
80	60	195	180	165	135	100	55	-	-	
90	67	275	260	240	210	175	130	50	-	
100	75	370	345	330	300	265	220	145	55	
110	81	430	405	390	360	330	285	210	120	



Notes:

1. The acceleration lengths are calculated from the distance needed for a passenger car to accelerate from the average running speed of the entrance curve to a speed of 10 km/h below the average running speed on the mainline.
2. These values are for grades less than 3%. See Figure 12-3E for steeper upgrades or downgrades.
3. Use the value of L or 90 m beyond the 0.6-m nose, whichever is greater.

MINIMUM LENGTH OF ACCELERATION LANES

Figure 12-3D

Design Speed of Highway (km/h)	Acceleration Lanes					
	Ratio of Length on Grade to Length for Design Speed of Entrance Ramp Curve (km/h)					
	40	50	60	70	80	All Speeds
	3% to 4% upgrade					3% to 4% downgrade
60	1.3	1.4	1.4	-	-	0.7
70	1.3	1.4	1.4	1.5	-	0.65
80	1.4	1.5	1.5	1.5	1.6	0.65
90	1.4	1.5	1.5	1.5	1.6	0.6
100	1.5	1.6	1.7	1.7	1.8	0.6
110	1.5	1.6	1.7	1.7	1.8	0.6
120	1.5	1.6	1.7	1.7	1.8	0.6
	5% to 6% upgrade					5% to 6% downgrade
60	1.5	1.5	-	-	-	0.6
70	1.5	1.6	1.7	-	-	0.6
80	1.5	1.7	1.9	1.8	-	0.55
90	1.6	1.8	2.0	2.1	2.2	0.55
100	1.7	1.9	2.2	2.4	2.5	0.5
110	2.0	2.2	2.6	2.8	3.0	0.5
120	2.3	2.5	3.0	3.2	3.5	0.5

- Notes:
1. No adjustment is needed on grades less than 3%.
 2. The "grade" in the table is the average grade measured over the distance for which the acceleration length applies. See Figure 12-3F.

Example

Given: Highway Design Speed - 110 km/h
Entrance Ramp Curve Design Speed - 60 km/h
Average Grade - 5% upgrade

Problem: Determine length of acceleration lane.

Solution: Figure 12-3D yields an acceleration lane of 285 m on the level. According to the above, this should be increased by a factor of 2.6.

$$\text{Therefore: } L = 285 \times 2.6$$

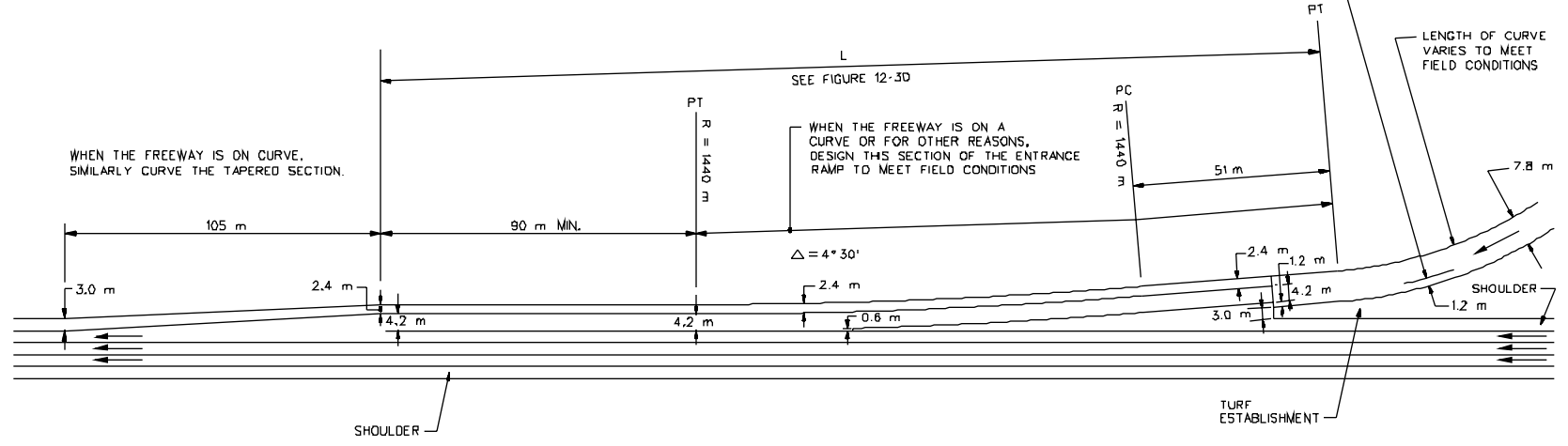
$$L = 741 \text{ m}$$

A 741-m acceleration lane should be provided from the PT of the entrance ramp curve to the beginning of the taper.

GRADE ADJUSTMENTS ON ACCELERATION LANES

Figure 12-3E

RAMP TYPE	R Min.
DIAMOND	270 m
CLOVERLEAF - OUTER CONNECTION	135 m
CLOVERLEAF - INNER LOOP	50 m
(NORMAL BASE LINE)	



TYPICAL ENTRANCE RAMP DESIGN

Figure 12-3F

12-3.02.02 Sight Distance

Where practical, decision sight distance should be provided for drivers on the mainline approaching an entrance terminal. They need sufficient distance to see the merging traffic so they can adjust their speed or change lanes to allow the merging traffic to enter the freeway. Likewise, drivers on the entrance ramp need to see a sufficient distance upstream from the entrance to locate gaps in the traffic stream for merging.

12-3.02.03 Superelevation

The ramp superelevation should be gradually transitioned to meet the normal cross slope of the mainline. The principles of superelevation for rural highways, as discussed in Section 8-2.0, should be applied to the entrance design. The following criteria should be used:

1. The maximum superelevation rate is 6%.
2. The maximum algebraic difference between the slopes of the acceleration lane and through lane is 4% to 5%, when these two lanes are adjacent to each other.
3. At a minimum the superelevation runoff length should be based on the distance provided in Figure 8-2A.

12-3.03 Critical Design Elements

The designer should provide a freeway/ramp junction design which meets all criteria presented in Section 12-3.0. However, the following elements are especially important to the safety and proper operation of the junction:

1. the minimum length of deceleration for an exit ramp (Figure 12-3A),
2. the deflection (taper) angle for a taper exit ramp (Figure 12-3C),
3. the minimum length of acceleration for an entrance ramp (Figure 12-3D), and
4. the parallel portion of the acceleration lane for an entrance ramp (360 m minimum).

12-4.0 RAMP DESIGN

12-4.01 Design Speed

Figure 12-4A provides the acceptable ranges of ramp design speed based on the design speed of the mainline. In addition, the designer should consider the following:

1. Freeway/Ramp Junctions. The design speeds in Figure 12-4A apply to the ramp proper and not to the freeway/ramp junction. Freeway/ramp junctions are designed using the freeway mainline design speed.
2. At-Grade Terminals. If a ramp will be terminated at an at-grade intersection with a stop or signal control, the design speeds in the figure may not be applicable to the ramp portion near the intersection.
3. Variable Speeds. The ramp design speed may vary based on the two design speeds of the intersecting roadways. Higher design speeds should be used on the portion of the ramp near the higher-speed facility while lower design speeds may be selected near the lower-speed facility. The designer needs to ensure that sufficient deceleration distance is available between design elements with varying design speeds (e.g., two horizontal curves).
4. Ramps for Right Turns. Design speeds for right-turn ramps are typically in the mid to high range. This includes, for example, a diagonal ramp of a diamond interchange.
5. Loop Ramps. Design speeds in the high range are generally not attainable for loop ramps. For mainline design speeds greater than 80 km/h, the loop design speed should not be less than 40 km/h. However, design speeds greater than 50 km/h will require significantly more right-of-way and may not be practical in urban areas.
6. Semidirect Connections. Design speeds between the mid and high ranges should be used for semidirect connections. Design speeds less than 50 km/h should not be used. Design speeds greater than 80 km/h are generally not practical for short, single-lane ramps. For 2-lane ramps, values in the mid to high ranges should be used.
7. Direct Connections. For direct connections, the design speed should be in the mid to high range. The design speed should not be less than 60 km/h.

Mainline Design Speed (km/h)	70	80	90	100	110
Ramp Design Speed (km/h)					
High Range	60	70	80	90	100
Mid Range	50	60	60	70	80
Low Range	40	40	50	50	60

RAMP DESIGN SPEEDS

Figure 12-4A

12-4.02 Cross Section

Figure 12-4B presents the typical cross section for ramps. The following will also apply to the ramp cross section:

1. Width. The minimum paved width of a one-way, one-lane ramp will be 7.8 m. For pavement marking purposes, this will normally be distributed as 1.2 m - 4.2 m - 2.4 m (i.e., 1.2-m left shoulder, 4.2-m traveled way, 2.4-m right shoulder when viewed in the direction of travel). This arrangement is illustrated on Figures 12-3C and 12-3F for exit and entrance ramp designs.

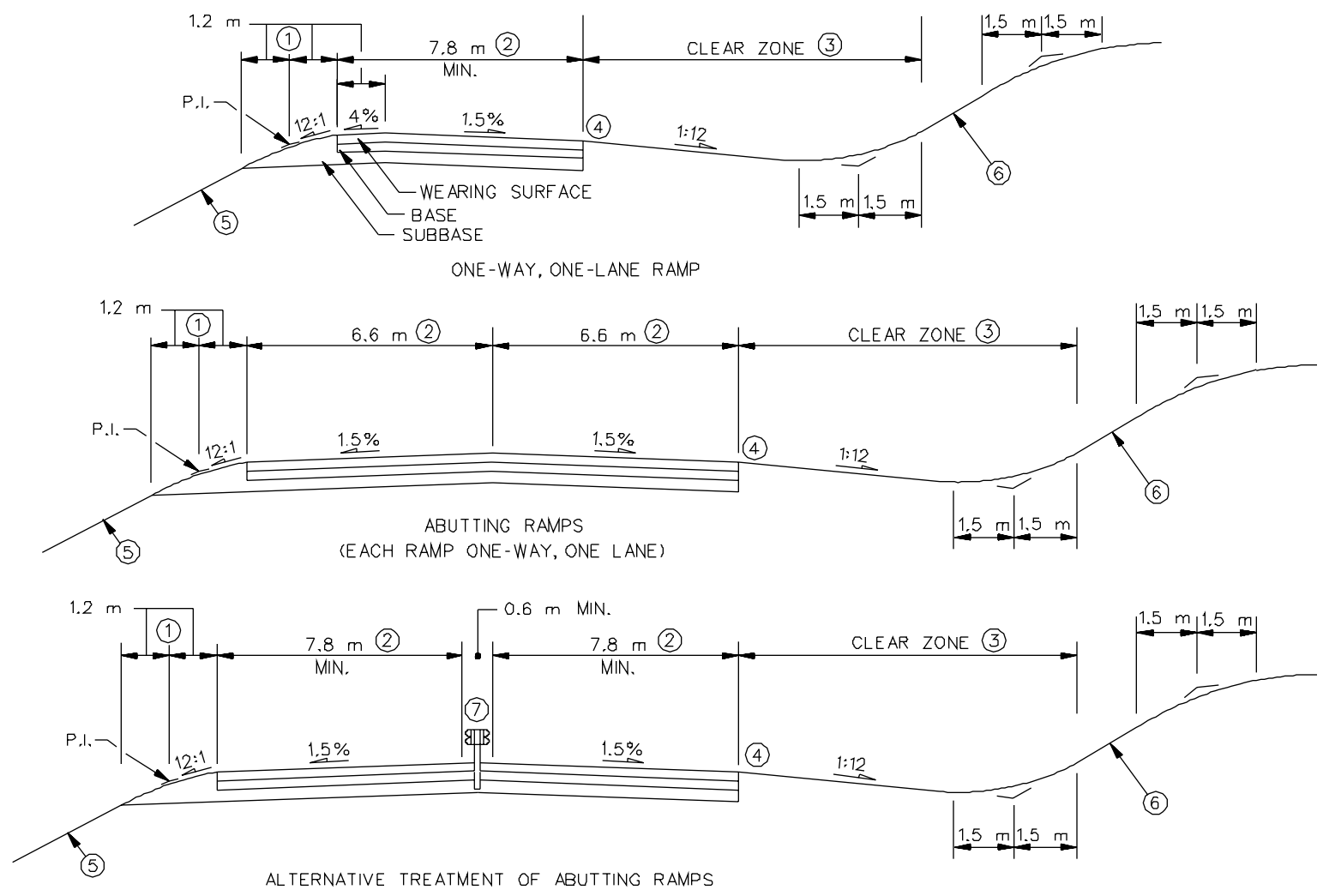
The minimum width of a one-way, two-lane ramp will be 12 m. This width yields two 4.2-m ramp lanes, a 1.2-m left shoulder and a 2.4-m right shoulder.

2. Bridges and Underpasses. The full width of the ramp or loop should be carried over a bridge or beneath an underpass.
3. Side Slopes. Fill and cut slopes should be as flat as practical. Consider providing slopes flat enough so that they do not warrant guide rail (see Section 13-3.0).
4. Lateral Clearances to Obstructions. The lateral clearance from the edge of the ramp traveled way will be equal to its clear zone as calculated from Section 13-2.0.
5. Right-of-Way. The right-of-way/non-access line adjacent to the ramp will be the same as that determined for the freeway mainline in the vicinity of the interchange.

12-4.03 Horizontal Alignment

Flexibility must be applied when determining the horizontal alignment on ramps. This recognizes their unique character. In general, horizontal alignment will be determined by the design speed and type of ramp. The following should be considered:

1. Minimum Radius. The criteria in Figure 8-2A for rural highways also apply to the minimum radius on all ramps, except for loop ramps. Because of the normally restrictive condition for loop ramps, it is typically impractical to use rural criteria. Therefore, the criteria in Figure 11-4D for turning roadways may be used on loop ramps. The design speed or the anticipated operating speed at the curve should be selected to determine the minimum radius.
2. Outer Connection. The outer connection at cloverleaf interchanges should be as directional as practical. However, if site conditions are restrictive, it may be warranted to follow a reverse-path alignment around the inner loop.
3. Loops. Loop ramps should be on a continuously curved alignment in a compound curve arrangement. The radius of the flatter curve should be no more than twice the radius of the sharper curve. Figure 11-4D presents minimum curve lengths for turning roadways at intersections. These also apply to ramp loops.
4. Compound Curves. Where compound curves are used in the vicinity of an exit ramp, the designer should ensure that the length of the flatter curve provides a sufficient distance to decelerate to the design speed of the sharper curve. The deceleration criteria in Figure 12-3A should be used to determine the minimum lengths of curves in a compound curvature arrangement. In addition, the designer should provide a ratio of 1.5:1 between the radius of the flatter curve and that of the succeeding sharper curve. However, in restricted locations, it may be 2:1.
5. Superelevation. The following applies:
 - a. The maximum superelevation rate is 6%.
 - b. The criteria for rural highways and high-speed urban highways discussed in Section 8-2.0 also apply to ramps for transitioning to and from the needed superelevation. This includes the superelevation runoff lengths presented in Figure 8-2A. However, because of the restrictive nature of some ramps, this may not be practical. The minimum longitudinal slope should not exceed 1 percent, which corresponds to a "P" of 100. This value should be used in the following equation to calculate the superelevation transition length:



TYPICAL RAMP CROSS SECTIONS

Figure 12-4B

TYPICAL RAMP CROSS SECTIONS

Notes to Figure 12-4B

- ① Slope Rounding: This is the recommended treatment and, when used, the slope rounding should be 2.4 m. Rounding is not necessary on fill slopes protected by guide rail. See Figure 4H for detail if guide rail is used.
- ② Ramp Width: For 2-lane, 1-way ramps, minimum width is 12 m.
- ③ Clear Zone: The outside limit of rounding for the backslope should be outside of the clear zone as determined in Section 13-2.0. If this is within the clear zone, the backslope should be safely traversable (see Section 13-3.0).
- ④ Curb Sections: If curbing is required for drainage, see Figure 4H for typical section.
- ⑤ Fill Slope: These should be as flat as practical. The following criteria are typical:

<u>Fill Height</u>	<u>Fill Slope</u>	<u>Guide Rail</u>
0 - 3.0 m	1:6	No
3.0 m - 7.5 m	1:4	No (without curb) Yes (with curb)
>7.5 m	1:2	Yes

Also, see Figure 4H for treatment at bottom of fill slope. If a curb is used, see Figure 4H for treatment of guide rail and curb used in combination.

- ⑥ Cut Slope: These should be as flat as practical, but should not exceed 1:2. Also, see the clear zone discussion in Note ③. A uniform rate of slope should be maintained throughout a cut section. Where site conditions dictate a change from one rate of slope to another within a cut section, the length of transition should be as long as practical to effect a natural appearing contour. Figure 4J contains detailed information on earth and rock cuts.
- ⑦ Barrier: The metal-beam rail is preferred, but the CMB is acceptable.
- ⑧ Superelevated Section: The axis of rotation will be about a line 1.2 m from the left edge of pavement in the direction of travel. This means that, on a 7.8-m ramp, 6.6 m will be superelevated at the design "e" and 1.2 m will slope away from the 6.6 m. The break in the slope will be rounded according to the detail on Figure 4H. This criteria applies to curves in both the left and right directions; applies to both 1-lane and 2-lane ramps; and applies regardless of the pavement markings on the ramp.
- ⑨ Abutting Ramps: See Figure 12-5B for pavement striping details for abutting ramps at an at-grade intersection.

$$L = (e) (W) (P)$$

where: L = superelevation transition length (m)
P = 100
e = superelevation rate (expressed as a decimal)
W = width of pavement rotation (m)

- c. The axis of rotation will be about a line 1.2 m from the inside edge of pavement. This means that, on a 7.8-m ramp, 6.6 m will be superelevated at the design "e" and 1.2 m will slope away from the 6.6-m section. The break in the slope will be rounded according to the detail on Figures 4H and 5J. This criteria applies to curves in both the left and right directions and applies regardless of the pavement markings on the ramp.
 - d. The designer should not superelevate curves on ramps such that the design "e" is maintained on the curve for a very short distance. No specific minimum length is provided; these will be evaluated on a case-by-case basis.
 - e. If the ramp will be terminated at an at-grade intersection with stop or signal control, it is not appropriate to fully superelevate curves near the terminal.
6. Sight Distance. Section 8-2.04 describes how to determine the middle ordinate to provide stopping sight distance at horizontal curves.

12-4.04 Vertical Alignment

Maximum grades for vertical alignment cannot be as definitively expressed as those for the highway mainline. General values of limiting gradient are shown in Figure 12-4C, but for any one ramp the selected gradient is dependent upon a number of factors. These factors include the following:

1. The flatter the gradient on the ramp relative to the freeway grade, the longer it will be. At restricted sites, it may be necessary to provide a steeper grade for the purpose of shortening the length of ramp.
2. The steepest gradients should be designed for the center part of the ramp. Landing areas or storage platforms at at-grade intersections should be as flat as practical.
3. Downgrades on ramps should follow the same guidelines as upgrades. They may, however, safely exceed these values by 2%, with 8% considered a recommended maximum.

4. Practical ramp gradients and lengths can be significantly impacted by the angle of intersection between the two highways. The direction and grade on the two mainlines may also have a significant impact.
5. Stopping sight distance will be the minimum design for vertical curves. See Section 9-3.0.

Ramp Design Speed (km/h)	40	50	60	70	80
Maximum Grade Range (%)	6-8	5-7	4-6	3-5	3-5

Note: Downgrades may exceed the table values by 2% but should not exceed 8%

RAMP GRADIENT GUIDELINES

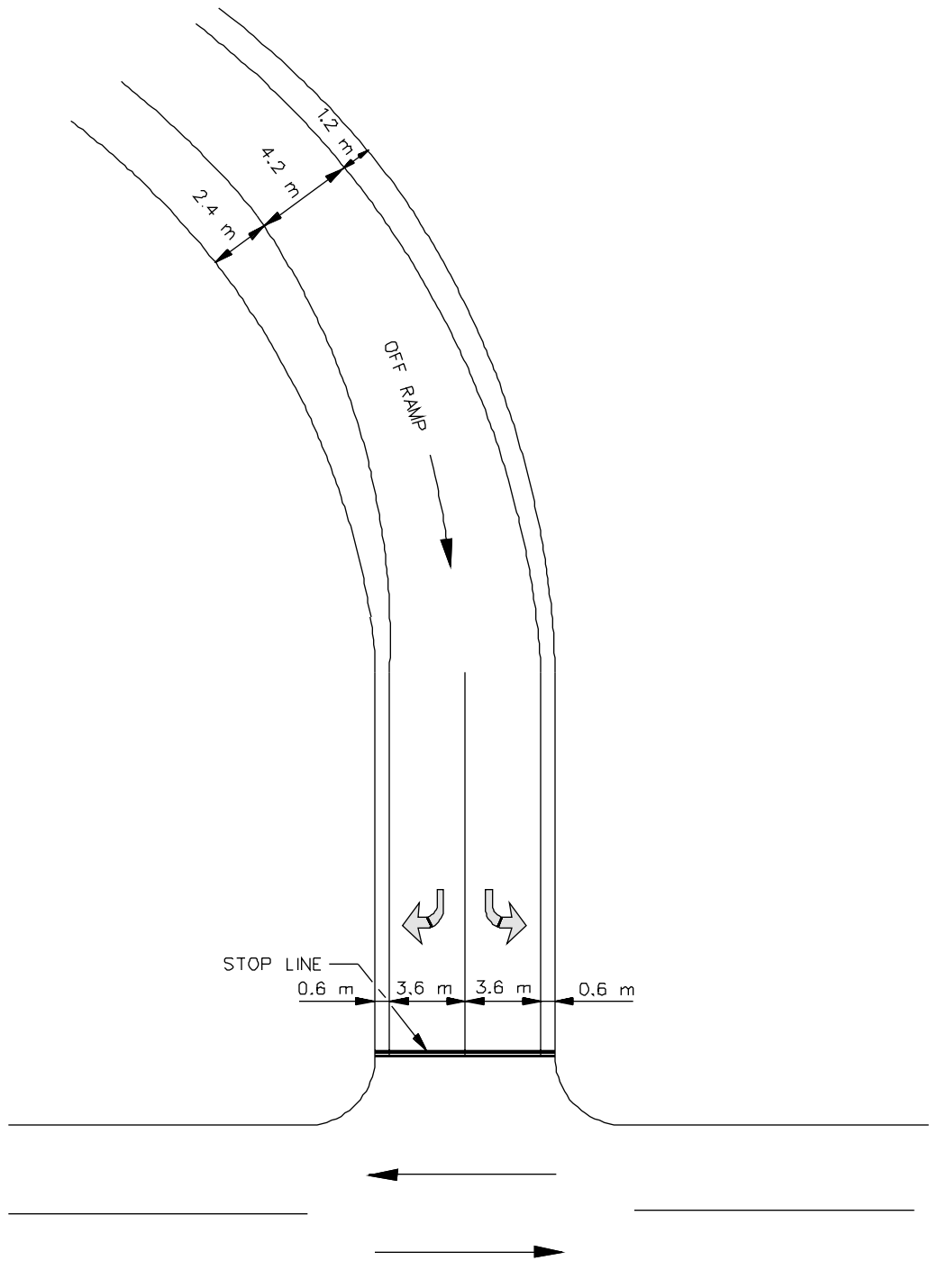
Figure 12-4C

12-5.0 RAMP/CROSSING ROAD INTERSECTION

12-5.01 Design of At-Grade Intersections

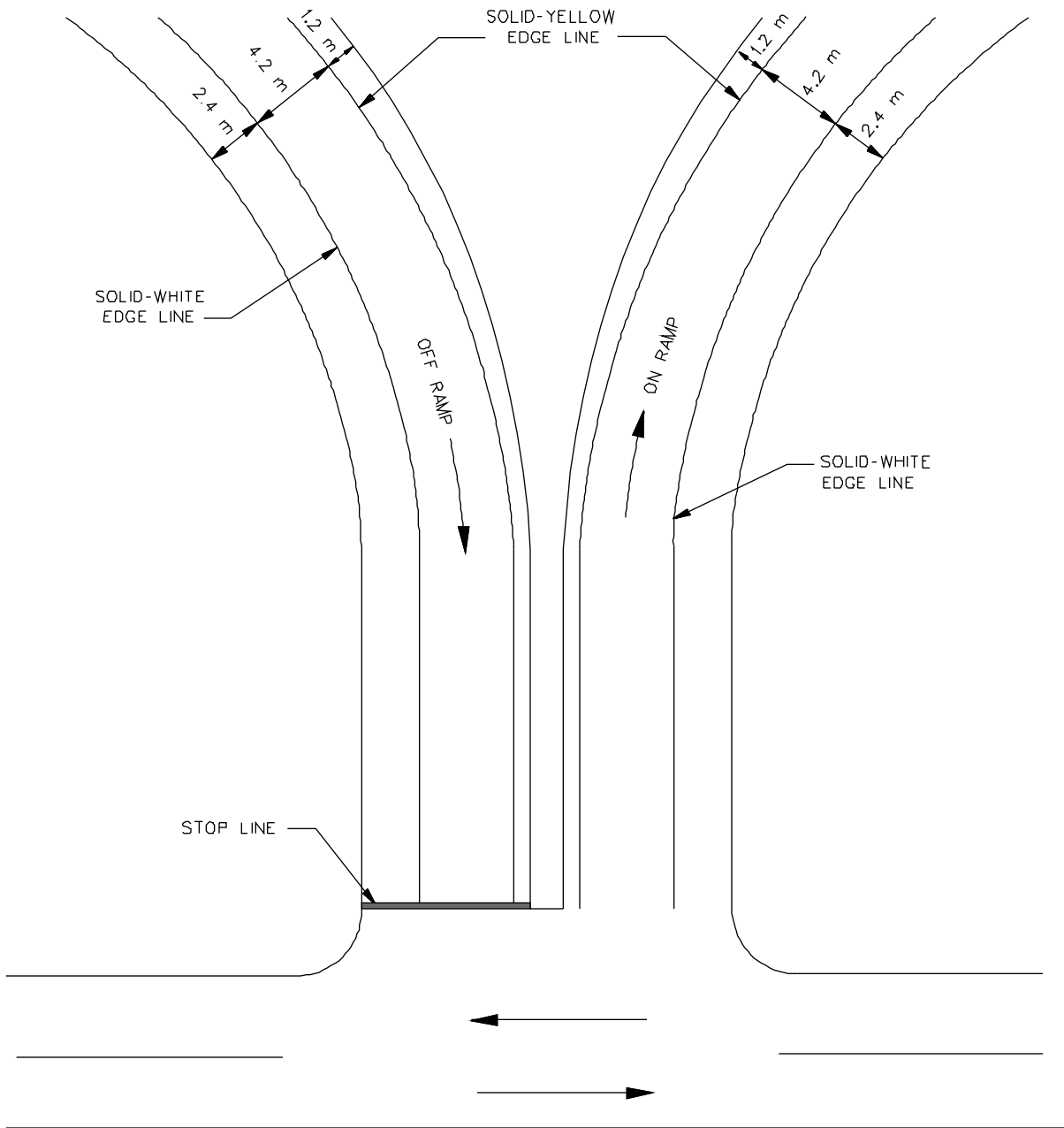
Where the ramp will intersect the minor road at-grade, this intersection should be treated as described in Chapter Eleven. This will involve a consideration of capacity and the physical geometric design elements such as design vehicle, sight distance, angle of intersection, acceleration lanes, grade, channelization and turning lanes. However, several points warrant special attention in the design of the ramp/crossing road intersection:

1. Capacity. In urban areas where traffic volumes are often high, inadequate capacity of the ramp/crossing road intersection can adversely affect the operation of the ramp/freeway junction. In a worst case situation the safety and operation of the mainline itself may be impaired by a backup onto the freeway. Therefore, special attention should be given to providing sufficient capacity and storage for an at-grade intersection or merge with the crossing road. This could lead to the addition of lanes at the intersection or on the ramp proper (see Figure 12-5A), or it could involve traffic signalization where the ramp traffic will be given priority. The analysis must also consider the operational impacts of the traffic characteristics in either direction on the intersecting road. Coordinate this analysis with the Division of Traffic Engineering. See Chapter 11 for additional information.
2. Sight Distance. Section 11-2.0 discusses the criteria for intersection sight distance. These criteria also apply to a ramp/crossing road intersection. Special attention must be given to the location of the bridge pier or abutment because these will present major sight distance obstacles. The bridge obstruction and the required intersection sight distance may result in the need to relocate the ramp/crossing road intersection.
3. Wrong-Way Movements. Most wrong-way movements originate at the ramp/crossing road intersection. This intersection must be properly signed and designed to minimize the potential for a wrong-way movement.
4. Abutting Ramps. Figure 12-4B illustrates the use of a metal-beam rail to divide abutting ramps. This provides a physical separation and discourages wrong-way entry. Where the ramp intersects the crossing road, the median barrier should be terminated with an approved end terminal. Where a median barrier is not used, the abutting ramps should intersect the minor road as shown in Figure 12-5B.



MULTIPLE-LANE RAMP AT MINOR ROAD INTERSECTION

Figure 12-5A



ABUTTING RAMPS AT MINOR ROAD INTERSECTION

Figure 12-5B

12-5.02 Frontage Road Intersection

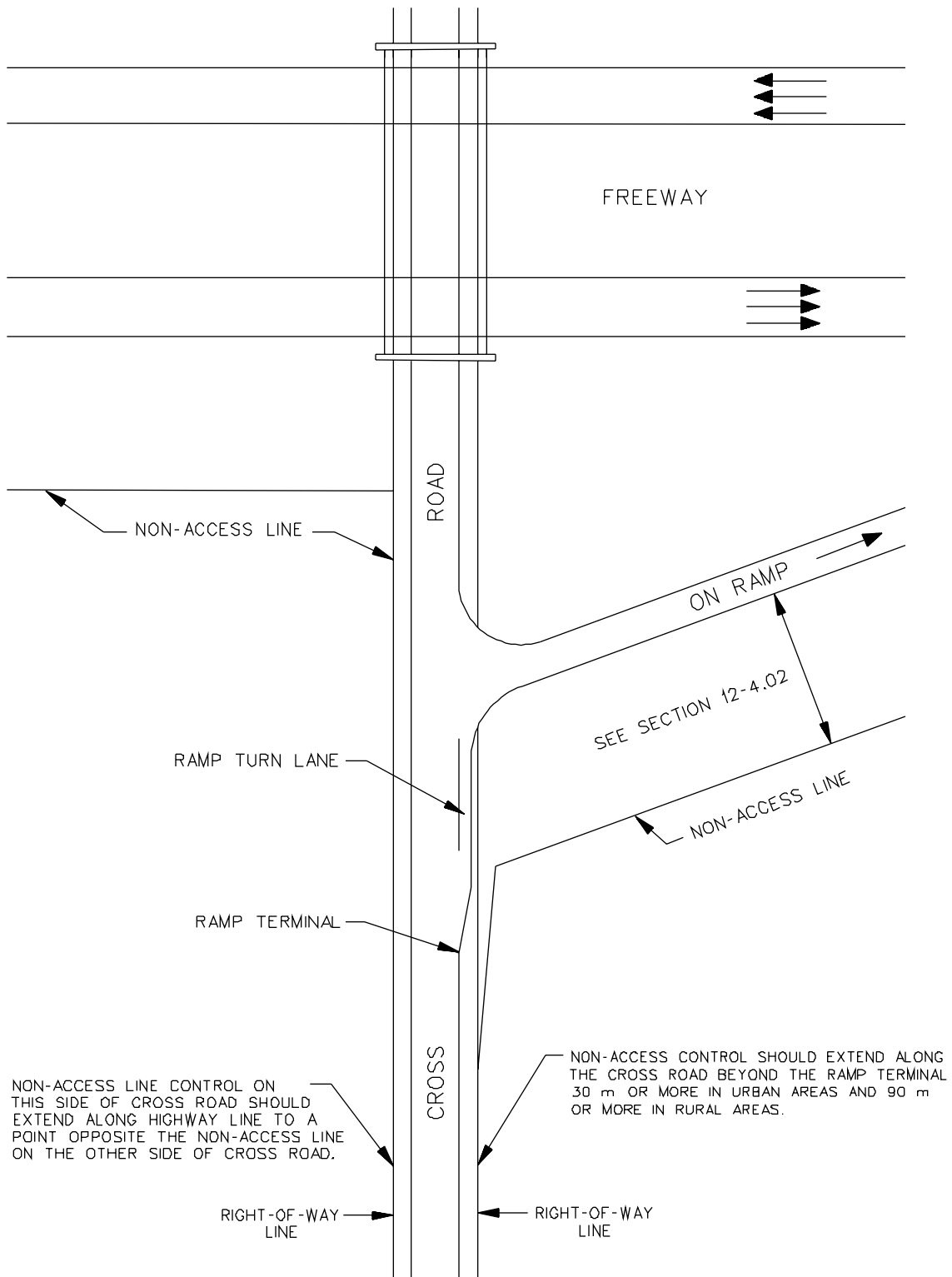
Where frontage roads are present adjacent to freeways, the ramp/crossing road intersection is greatly complicated. If practical, the frontage road should be curved away from the interchange and allowed to intersect the minor road a sufficient distance from the ramp intersection. If the ramp intersects the crossing road at approximately 90°, this distance should be at least 90 m. If the ramp traffic merges with the crossing road, the distance should be 90 m beyond where the taper of the acceleration lane ends. This treatment allows the two intersections to operate independently, and it eliminates the operational and signing problems of providing the same point of exit and entrance for the frontage road and freeway ramp.

At some interchanges, it may be impractical to separate the intersections of the ramp and frontage road with the crossing road. In these cases, the only alternative is to combine the ramp and frontage road before the intersection with the crossing road. This can apply to either the exit or entrance ramp. A detailed analysis will be necessary to establish the needed distance to properly accommodate traffic volumes and speeds, weaving, stopping and intersection storage. Coordinate this analysis with the Division of Traffic Engineering.

12-5.03 Access Control

Proper access control must be provided along the crossing road in the vicinity of the ramp/crossing road intersection. This will ensure that the intersection has approximately the same degree of freedom and absence of conflict as the freeway itself. Figure 12-5C illustrates the Department's policy for the location of the non-access line at ramp/crossing road intersections. Any proposals which do not meet these criteria will require an exception to the controlling design criteria. See Section 6-6.0. This applies to all of the access control criteria in Figure 12-5C. This also applies both to new interchanges and to existing non-access lines at existing interchanges.

One situation warrants a special discussion. Many interchanges were initially constructed in Connecticut when the surrounding area was rural in character. Since that time, the area may have become suburban or urban. As indicated in Figure 12-5C, the Department has adopted different criteria for the access control at urban and rural interchanges. However, the change in area character alone is not a sufficient justification to alter the location of the non-access line.



NON-ACCESS LINE TREATMENT IN VICINITY OF RAMP TERMINAL

Figure 12-5C

12-6.0 REFERENCES

1. *A Policy on Geometric Design of Highways and Streets*, AASHTO, 1994.
2. *Highway Capacity Manual*, TRB, 1994.
3. NCHRP 345, *Single Point Urban Interchange Design and Operations Analysis*, TRB, 1991.
4. NCHRP 175, *Freeway Lane Drops*, TRB, 1976.

Chapter Thirteen

ROADSIDE SAFETY

Table of Contents

	<u>Page</u>
13-1.01	DEFINITIONS 13-1(1)
13-2.0	CLEAR ZONES 13-2(1)
13-2.01	<u>Background</u> 13-2(1)
13-2.02	<u>Application</u> 13-2(1)
13-2.03	<u>Rock Removal</u> 13-2(6)
13-2.04	<u>Utility Setback and Design Exceptions Procedures</u> 13-2(7)
13-3.0	GUIDE RAIL WARRANTS 13-3(1)
13-3.01	<u>Embankments</u> 13-3(1)
13-3.02	<u>Roadside Hazards</u> 13-3(1)
13-3.03	<u>Bridge Rails and Approaches</u> 13-3(3)
13-3.04	<u>Bridge Piers & Abutments</u> 13-3(3)
13-3.05	<u>Vertical Drop-offs</u> 13-3(3)
13-3.06	<u>Roadside Ditches, Channels and Swales</u> 13-3(6)
13-3.07	<u>Transverse Slopes</u> 13-3(6)
13-3.08	<u>High Tension Lines and Reservoirs</u> 13-3(9)
13-4.0	ROADSIDE BARRIERS 13-4(1)
13-4.01	<u>Guide Rail Types</u> 13-4(1)
13-4.01.01	Three Cable Guide Railing (I-Beam Posts) 13-4(1)
13-4.01.02	Metal Beam Rail (Type R-I) 13-4(3)
13-4.01.03	Metal Beam Rail (Type R-B) 13-4(3)
13-4.01.04	Metal Beam Rail (Type R-B 350) 13-4(3)
13-4.01.05	Thrie Beam 350 13-4(4)
13-4.01.06	Metal Beam Rail (Box Beam) 13-4(4)
13-4.01.07	Single-Faced Precast Concrete Barrier Curb (PCBC) 13-4(4)
13-4.01.08	Merritt Parkway Timber Rail 13-4(4)

Table of Contents
(Continued)

		<u>Page</u>
13-4.02	<u>Deflection Distance</u>	13-4(5)
13-4.03	<u>Disposition of Existing Guide Rail</u>	13-4(8)
	13-4.03.01 NHS Facilities	13-4(8)
	13-4.03.02 All Other Facilities	13-4(8)
13-5.0	MEDIAN BARRIERS	13-5(1)
13-5.01	<u>Warrants</u>	13-5(1)
13-5.02	<u>Median Barrier Types</u>	13-5(1)
	13-5.02.01 Metal Beam Rail (Type MD-I)	13-5(1)
	13-5.02.02 Metal Beam Rail (Type MD-B)	13-5(3)
	13-5.02.03 Metal Beam Rail (Type MD-B 350)	13-5(3)
	13-5.02.04 Double-Faced F-Shape PCBC	13-5(3)
	13-5.02.05 Merritt Parkway Median Barrier	13-5(3)
13-5.03	<u>Median Barrier Placement</u>	13-5(4)
	13-5.03.01 Divided Median Barriers	13-5(6)
13-5.04	<u>Glare Screens</u>	13-5(6)
13-5.05	<u>Disposition of Existing Median Barriers</u>	13-5(7)
	13-5.05.01 NHS Facilities	13-5(7)
	13-5.05.02 All Other Facilities	13-5(7)
13-6.0	GUIDE RAIL LAYOUT	13-6(1)
13-6.01	<u>Length of Need</u>	13-6(1)
13-6.02	<u>Flare Rate</u>	13-6(1)
13-6.03	<u>Lateral Placement</u>	13-6(1)
13-6.04	<u>Curbs and Curb/Barrier Combinations</u>	13-6(3)
13-6.05	<u>Placement on Slopes</u>	13-6(4)
13-6.06	<u>Minimum Length and Guide Rail Gaps</u>	13-6(5)
13-6.07	<u>Treatment at Intersecting Roads and Driveways</u>	13-6(5)
13-6.08	<u>Guide Rail Curvature Criteria</u>	13-6(7)

Table of Contents
(Continued)

		<u>Page</u>
13-6.09	<u>Transitions</u>	13-6(7)
	13-6.09.01 Transitions Within Same Type System	13-6(7)
	13-6.09.02 Transitions Between Systems	13-6(8)
13-6.10	<u>Pavement for Railing</u>	13-6(8)
13-6.11	<u>Placement on High Fills with Sidewalk and Utility Pole Lines</u> .	13-6(10)
13-7.0	IMPACT ATTENUATORS	13-7(1)
13-7.01	<u>General</u>	13-7(1)
	13-7.01.01 Definitions	13-7(1)
	13-7.01.02 Crash Cushion and End Terminal Types	13-7(2)
	13-7.01.03 Crash Cushion Selection	13-7(2)
	13-7.01.04 Crash Cushion Design	13-7(2)
13-7.02	<u>End Treatment Selection</u>	13-7(4)
	13-7.02.01 End Treatment Design	13-7(4)
	13-7.02.02 Three Cable Guide Rail	13-7(6)
	13-7.02.03 Merritt Parkway	13-7(6)
	13-7.02.04 Metal Beam Rail Median Barrier (Type MD-B350)	13-7(6)
	13-7.02.05 Concrete Median Barrier	13-7(6)
13-8.0	REFERENCES	13-8(1)

APPENDIX

Guide Rail Procedure

FHWA Technical Advisory T5040.32 “Curved W-Beam Guardrail Installations at Minor Roadway Intersections”

Chapter Thirteen

ROADSIDE SAFETY

This Chapter provides the designer with guidance on measures to reduce the number and/or severity of accidents when vehicles leave the traveled way.

The "forgiving roadside" concept, developed in the 1960's, has been a long-standing philosophy in Connecticut. As a result, many of ConnDOT's State highways have been constructed to meet this design philosophy. In addition, guidance for installing roadside safety hardware has gradually evolved to reflect the results of crash test programs.

The American Association of State Highway and Transportation Officials (AASHTO) has incorporated many of the crash test results and roadside safety design concepts into the *Roadside Design Guide (RDG)*. ConnDOT's *Manual for Selecting, Locating and Designing Guide Railing and Traffic Barriers* has been replaced by the *RDG*.

Chapter Thirteen is a supplement to the *RDG*. Where there is a discrepancy between the two, Chapter Thirteen will take precedence.

13-1.0 DEFINITIONS

1. Recoverable Parallel Slope. Slopes which can be safely traversed and upon which the driver of an errant vehicle has a reasonable opportunity to stop and return to the roadway. The Department considers slopes flatter than 1:4 and slopes of 1:4 without curbing at their top recoverable.
2. Non-Recoverable Parallel Slope. Slopes which are steeper than 1:4. Most drivers will not be able to recover and return to the highway. The Department has decided to treat this range of cross slopes as critical.
3. Critical Parallel Slope. Slopes upon which a vehicle is likely to overturn. Under the Department's roadside criteria, slopes steeper than 1:4 and slopes of 1:4 with curbing at the top are critical.

These definitions vary slightly from those in the *RDG*.

13-2.0 CLEAR ZONES

13-2.01 Background

The clear zone concept was first established in the 1967 AASHTO report entitled *Highway Design and Operational Practices Related to Highway Safety*, known as the *Yellow Book* and revised in 1974. It provided the designer with a numerical value of 9 m as the lateral extent needed for 80-85% of run-off-the-road vehicles to recover. The 9-m clear zone was predicated on the following set of conditions:

1. 100-km/h vehicular speed,
2. tangent section, and
3. flat side slope.

If these conditions vary, the 9-m clear zone should be adjusted accordingly. For example, at higher speeds, vehicles will travel farther before recovering and, at lower speeds, vehicles will travel less before recovering.

Section 13-2.02 presents clear zone distances for various roadway conditions. The overall objective of these clear zone values is to achieve the 80-85% target recovery area for run-off-the-road vehicles on any given roadway.

13-2.02 Application

The calculated clear zone widths presented in Figure 13-2A are recommended values and need not be achieved at all costs. The methodology used to determine the values in this chart are valid and provide the designer with a good frame of reference for making decisions to design safer roadside recovery areas. However, the designer must exercise judgment when applying the distances because they do not apply to every conceivable set of highway conditions. Each application of the clear zone distance must be evaluated individually.

When applying the clear zone distance, the designer must consider right-of-way availability, environmental concerns, economic factors, identification of potential hazards, safety needs and accident histories. The following items further describe the proper usage of the clear zone distances presented in Figure 13-2A.

Design Speed	Design Year of ADT	Cuts or Fills (Negative Shelf)		Cuts or Fills (Positive Shelf)	
		1:6 or flatter	1:4	1:4	1:6 or flatter
60 km/h or less	Under 750	2.0	2.0	2.0	2.0
	750-1500	3.0	3.5	3.0	3.0
	1500-6000	3.5	4.5	3.5	3.5
	Over 6000	4.5	5.0	4.5	4.5
70-80 km/h	Under 750	3.0	3.5	2.5	3.0
	750-1500	4.5	5.0	3.5	4.5
	1500-6000	5.0	6.0	4.5	5.0
	Over 6000	6.0	7.5	5.5	6.0
90 km/h	Under 750	3.5	4.5	3.0	3.0
	750-1500	5.0	6.0	4.5	5.0
	1500-6000	6.0	7.5	5.0	6.0
	Over 6000	6.5	8.0	6.0	6.5
100 km/h	Under 750	5.0	6.0	3.5	4.5
	750-1500	6.0	8.0	5.0	6.0
	1500-6000	8.0	9.0	5.5	7.5
	Over 6000	9.0	9.0	7.5	8.0
110 km/h	Under 750	5.5	6.0	4.5	4.5
	750-1500	7.5	8.5	5.5	6.0
	1500-6000	8.5	9.0	6.5	8.0
	Over 6000	9.0	9.0	8.0	8.5

- Notes:
1. All distances are measured from the edge of traveled way. See Section 13-2.02, Comment #5.
 2. See Section 13-2.02, Comment #2, for application of clear zone criteria on fill slopes.
 3. See Figure 5H for illustration of a cut section with a positive shelf. See Section 13-2.02, Comment #3, on cut slopes and ditch sections.
 4. For clear zones, the "Design Year ADT" will be the total ADT on dual direction roadways and half the "Design Year ADT" on one-way roadways (e.g., interchange ramps and one direction of a divided highway unless noted otherwise).
 5. The values in the table apply to all facilities both urban and rural. See Section 13-2.02, Comment #4, for utility poles in urban areas.

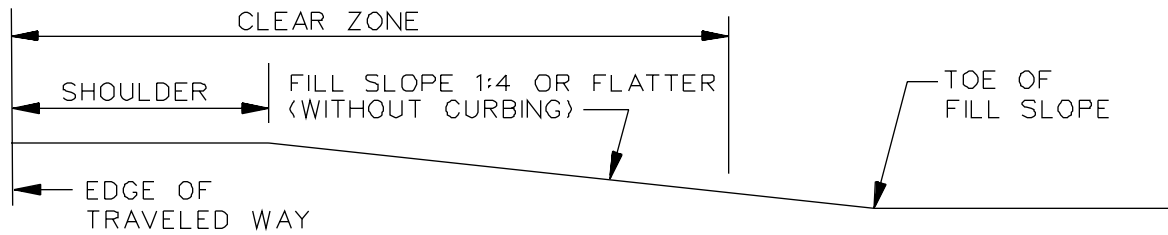
RECOMMENDED CLEAR ZONE DISTANCES (m)

Figure 13-2A

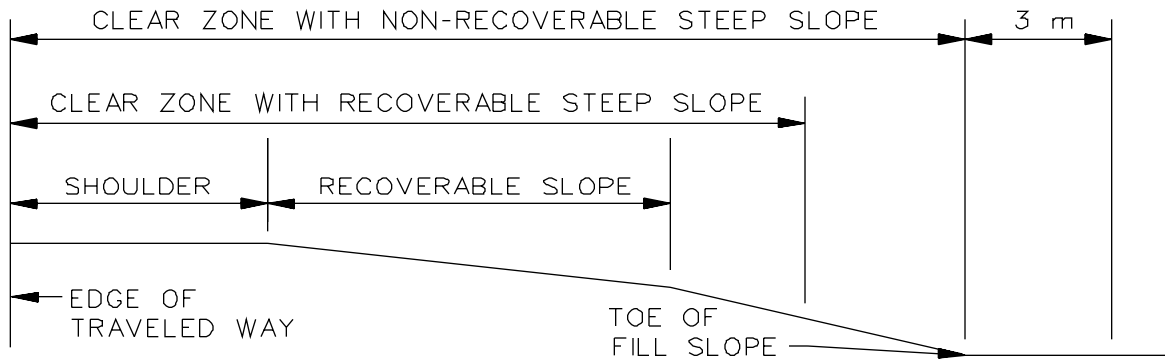
1. Boundaries. The designer should not use the clear zone distances as boundaries for introducing roadside hazards such as bridge piers, non-breakaway sign supports or utility poles. These should be placed as far from the roadway as practical. Where roadside hazards must be placed along the highway, at a minimum they should be placed at the clear zone boundary and possibly shielded.
2. Fill Slopes. Figure 13-2A provides clear zone values as a function of design speed, traffic volume, and the rate of fill slopes with a positive or negative shelf. Figure 13-2B illustrates the clear zone application on fill slopes with a negative shelf. Barn-roof fill slopes may be designed with two slope rates where the second slope is steeper than the slope adjacent to the shoulder. See Figure 13-2B(b). This design requires less right-of-way and embankment material than a continuous, flatter slope. Although a “weighted” average of the slopes may be used, a simple average of the clear zone distances for each slope is sufficiently accurate if the variable slopes are approximately the same width. If one slope is significantly wider, the clear zone computation based on that slope alone may be used.
3. Cut Slopes. Figure 13-2A also provides clear zone values as a function of design speed, traffic volume, and the rate of cut slopes with a positive or negative shelf. Figure 13-2C illustrates the clear zone application in a cut section. The designer must also reference Section 13-3.06 for guidance on the proper treatment of drainage features encountered within the clear zone.

The outside limit of rounding for the backslope should be outside of the clear zone. This is illustrated in the typical section figures in Chapters Four and Five. When this is not achievable, the following approach should be used to calculate the clear zone for a ditch section:

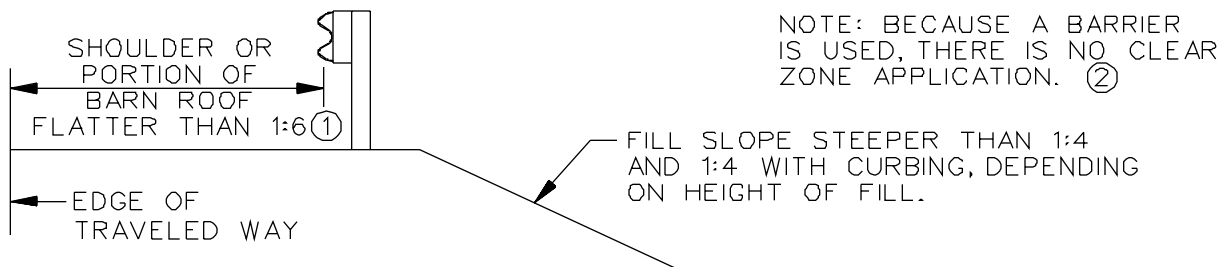
- a. When the backslope is 1:6 or flatter, treat the backslope as level and use the clear zone for the front slope.
- b. When the backslope is between 1:6 and 1:4, assume the vehicle cannot make it up to the top of the backslope, if the slope is at least 3-m wide. The initial 3 m beyond the toe of the backslope or the distance in Step #3a, whichever is less, should be clear of roadside hazards. Any obstacles beyond this point would be considered outside of the clear zone.
- c. When the backslope is steeper than 1:4, assume the vehicle cannot make it up the backslope. However, the initial 1.5 m beyond the outside limit of rounding for the backslope should be clear of roadside hazards. Any obstacles beyond 1.5 m would be considered outside of the clear zone.



RECOVERABLE PARALLEL SLOPE (a)



BARN-ROOF PARALLEL SLOPE (b)



CRITICAL PARALLEL SLOPE (c)

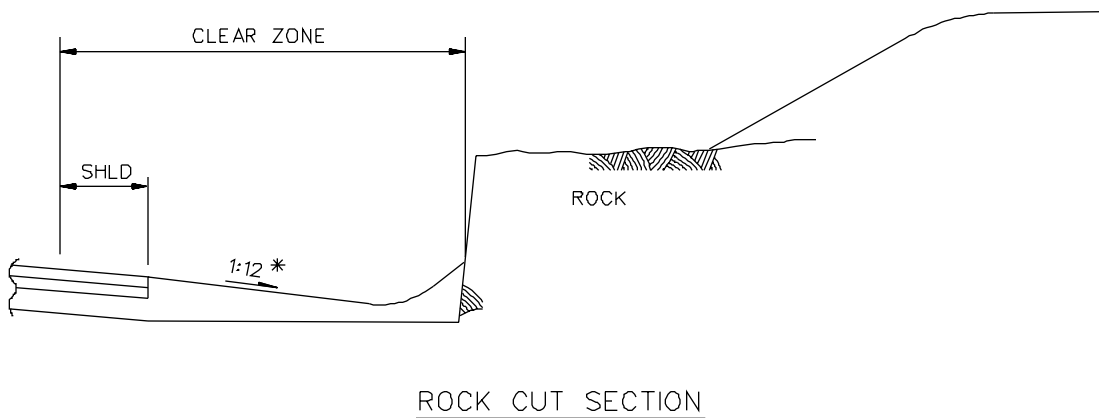
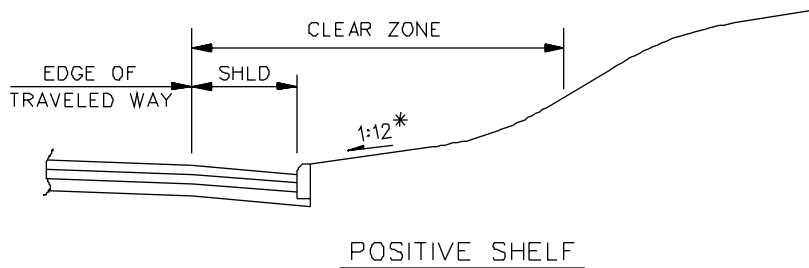
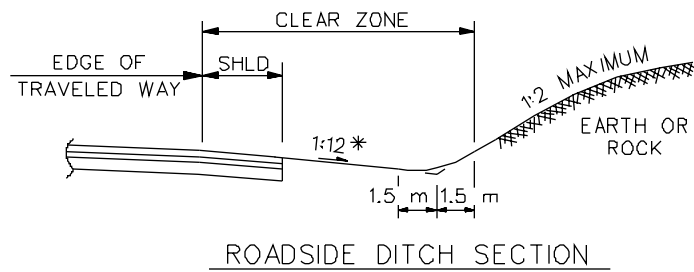
NOTE: BECAUSE A BARRIER IS USED, THERE IS NO CLEAR ZONE APPLICATION. ②

① WHEN GUIDE RAIL IS NOT USED AND THE CLEAR ZONE EXTENDS BEYOND THE TOP OF THE SLOPE, A MINIMUM DISTANCE OF 3.0 m WILL BE CLEARED AT THE TOE OF SLOPE.

② SEE FIGURE 13-3A TO DETERMINE BARRIER NEED.

**CLEAR ZONE APPLICATION FOR FILL SLOPES
(Negative Shelf)**

Figure 13-2B



CLEAR ZONE * 1:12 TYPICAL, 1:10 MAXIMUM

**R
A**

APPLICATION FOR CUT SLOPES

Figure 13-2C

4. Urban Facilities. A minimum horizontal obstruction-free clearance of 500 mm should be provided as measured from the gutter line to any utility pole, sign or traffic signal pole. Clear zones to other fixed objects such as buildings should conform to Figure 13-2A. Refer to the Utility Setback and Design Exceptions Procedure in Section 13-2.04.
5. Auxiliary Lanes. For auxiliary lanes, such as climbing lanes, passing lanes, etc., the clear zone will be the same as for the mainline and will be measured from the outside edge of the auxiliary lane. The clear zone will not normally apply to left- and right-turning lanes at intersections. When evaluating cross-over accident potential for undivided roadways, the clear zone will be measured from the left edge of the through travelway.
6. Horizontal Curves. Additional clear zone may be provided on the outside of horizontal curves by the use of curve correction factors that are included in the *RDG*. These increases should be considered only where accident histories indicate a need or where specific investigations indicate a high potential for accidents and where the increase to the clear zone is cost effective.

13-2.03 Rock Removal

Because of the often considerable expense in removing rock to meet roadside clear zone criteria, the Department adopted a policy specifically for rock removal. If the costs and associated impacts with removing rock to meet the clear zone criteria in Figure 13-2A are reasonable, the designer should meet these criteria. If, however, there are significant negative impacts and/or the costs are major, the designer should evaluate the following factors:

1. Other Benefits. The rock removal may generate benefits other than those for roadside safety. These include:
 - a. improving intersection sight distance;
 - b. improving sight distance around horizontal curves; or
 - c. improving any rock stability, ground water and/or icing problems.

Any additional benefits should be considered when determining the extent of the rock removal.

2. Alternative Improvements. Where the designer determines that retaining the rock within the clear zone presents a significant roadside hazard, the designer should consider alternative improvements to rock removal. These include:

- a. installing a single-faced concrete barrier or guide rail, and
 - b. providing a positive slope (with rounding at its toe) up to the face of the rock (1:4 or steeper) to provide limited vehicular redirection.
3. Application. If rock is within the clear zone and more than 5.5 m from the edge of traveled way, the ConnDOT Design Exception Committee will review the case and will either:
- a. determine that rock removal is appropriate because of its accident potential, or
 - b. grant a waiver of the clear zone criteria.

Designers should also discern whether or not the rock is in a condition that may imperil the traveling public by flaking, falling or icing. If so, the designer should evaluate the need for and proper type of roadside barrier protection. This should be documented in the project file and verification sought from the Design Exception Committee.

13-2.04 Utility Setback and Design Exceptions Procedures

There will be many sites where it will be impractical to locate utility poles outside the clear zone for a project. This is especially prevalent in urban projects but could apply to any project, depending upon the circumstances.

This discussion provides the requirements for blanket design exceptions for utility poles located within the clear zone. Provided the criteria noted below is complied with and the utility company has justified, to the satisfaction of the Department, that its poles have been set back to the maximum extent practical, waivers will not have to be approved through the Design Exception Committee.

The project correspondence file should provide sufficient documentation that utility poles are set back in accordance with the criteria. It is suggested that the request for design approval include the following information:

1. Utility poles should be positioned outside the clear zone whenever practical.
2. A maximum utility pole setback of 3.0 m (measured from the outside edge of the shoulder or the gutter line), irrespective of the clear zone, is permissible. This setback dimension is consistent with the capabilities of the utility company's installation and maintenance equipment. The maximum 3.0-m setback is also consistent with the utility company's corporate strategy of providing a quick response to power outages, etc.

3. The Department may require a setback greater than 3.0 m up to a maximum of 9.0 m if conditions such as, but not limited to, a higher incidence of accidents related to the presence of utility poles exist.
4. Along urban highways, the Department will require poles to be placed as close to the right-of-way line as practical. Where sufficient space is available, poles must be placed in back of the sidewalk. If insufficient space is available, the Department may allow poles to be placed between the curb and sidewalk or as far from the curb as practical when there are no sidewalk considerations (minimum 500 mm behind the face of curb).
5. Design exceptions for utility poles within the clear zone are still required when it is the Department's position that the utility company is not locating its poles in accordance with these criteria.

13-3.0 GUIDE RAIL WARRANTS

Determining the need for guide rail can be difficult and time consuming. Existing conditions may limit the designer's options thus increasing project cost, environmental impacts and right-of-way acquisitions. However, when economically and practically feasible, the designer should always attempt to eliminate the need for guide rail.

Section 1.2 of the *RDG* provides the designer with six design options, in order of priority, for redesigning the roadside to eliminate the need for guide rail. These steps should become an integral part of the preliminary design phase of all Department projects where applicable.

The following sections illustrate where guide rail may be warranted.

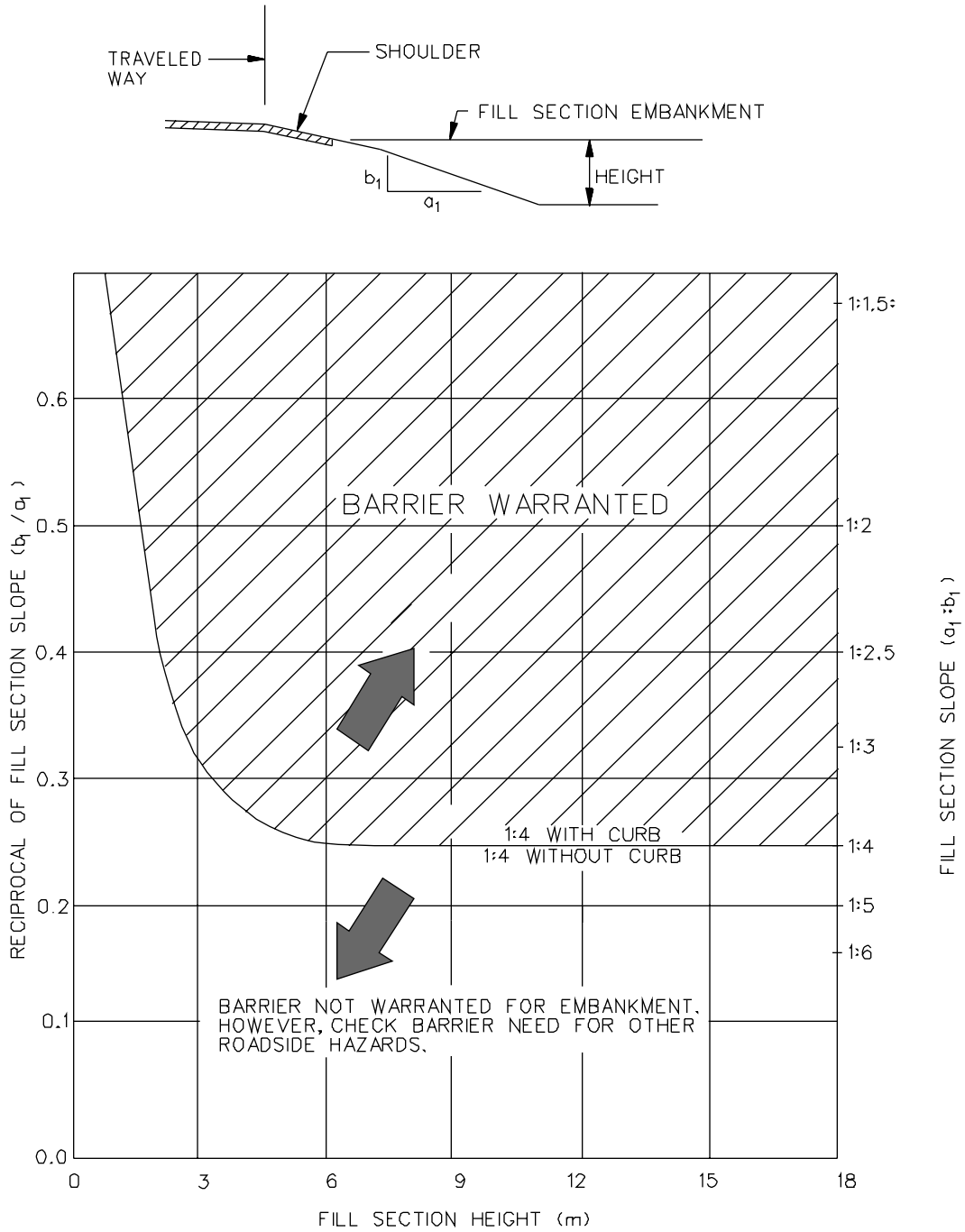
13-3.01 Embankments

The severity of the roadside condition depends upon the rate and height of the fill slope. Refer to Figure 13-3A for Comparative Risk Warrants for Embankments. This figure is revised from Figure 5.1 of the *RDG*. Depending on the height of fill slope, guide rail may be needed to shield a fill slope steeper than 1:4 and slopes of 1:4 with curbing. See section 13-6.04 for curb and curb/barrier combinations. Guide rail is not required on fill slopes flatter than 1:4 if there are no roadside hazards within the clear zone as calculated from Section 13-2.0.

13-3.02 Roadside Hazards

The recommended clear zone distances for various roadway conditions presented in Section 13-2.0 should be free of any fixed objects and non-traversable hazards. Roadside hazards that may warrant guide rail include but are not limited to the following:

1. non-breakaway sign and luminaire supports,
2. concrete bases extending more than 100 mm above the ground,
3. bridge piers and abutments at underpasses,
4. retaining walls and culvert end-walls,
5. trees with diameter greater than 150 mm (at maturity),
6. rough rock cuts,
7. large boulders,
8. streams or permanent bodies of water,
9. stone fences, and
10. utility poles. *Note: It is not Department policy to design guide rail to protect the traveling public from utility poles.*



NOTE: POINTS WHICH FALL ON THE SOLID LINE DO NOT WARRANT A BARRIER.

COMPARATIVE RISK WARRANTS FOR EMBANKMENTS

Figure 13-3A

These hazards in some instances may not warrant guide rail depending on their location. For example, to install guide rail to protect an errant vehicle from an isolated tree at the edge of a 9-m clear zone may not be practical.

The designer should recognize that even barriers installed to deflect errant vehicles away from fixed objects may be hazards themselves. Preference should therefore be given to eliminating or relocating the fixed object or potential hazard rather than placing guide rail in front of it whenever possible.

13-3.03 Bridge Rails and Approaches

The leading and trailing ends of bridge rails normally warrant protection. The highway designer is responsible for determining the need for and design of the guide rail leading up to and trailing from the bridge rail; the bridge designer is responsible for the design of the bridge rail and details for guide rail attachment to bridge parapets. Figure 13-3B illustrates warrants for providing guide rail approaching a bridge rail. Refer to the Department's Guide Rail Procedure for the disposition of existing leading end transitions to bridge parapets. Section 13-6.09.02 provides additional information on transitions.

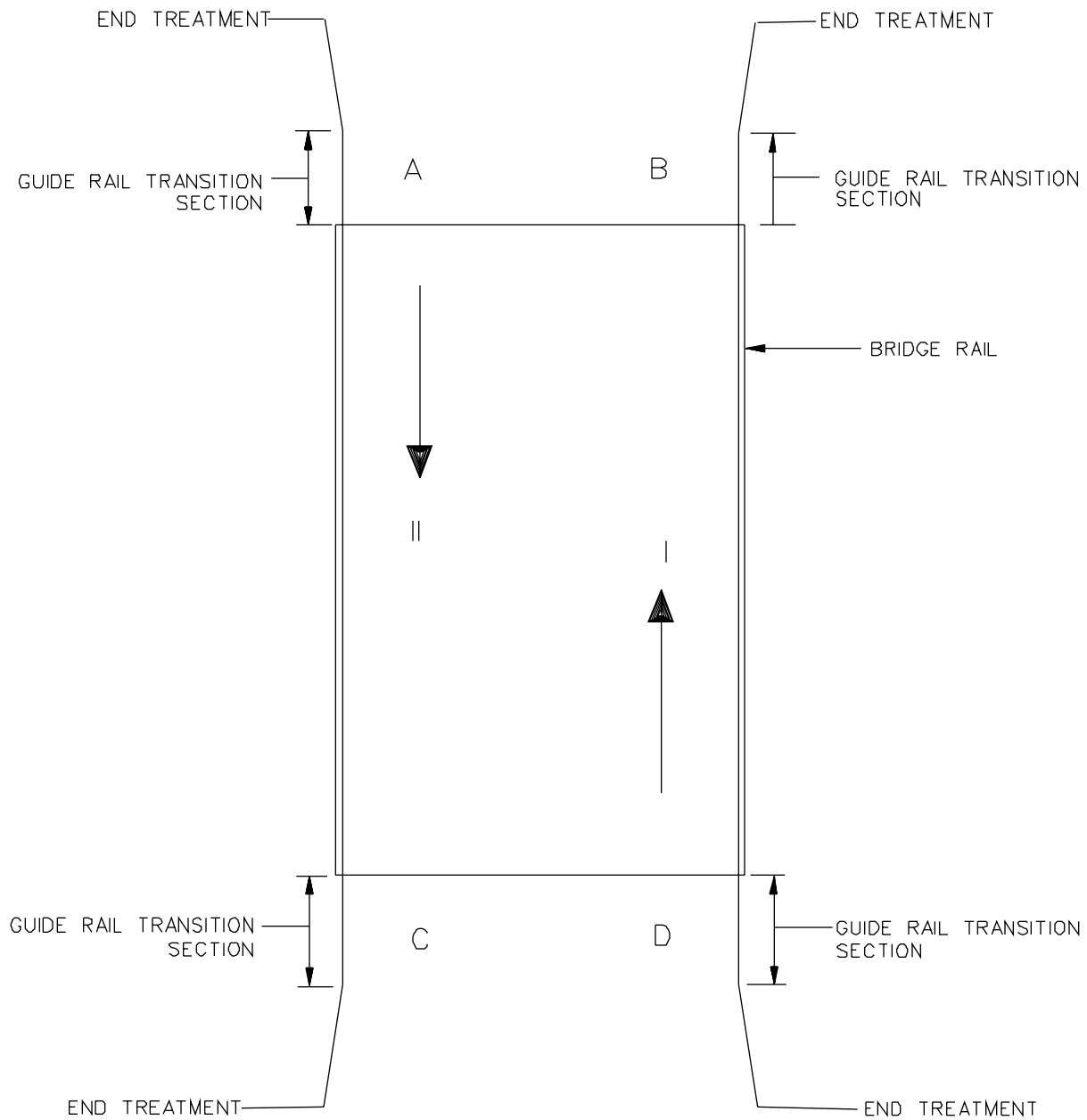
13-3.04 Bridge Piers & Abutments

Bridge piers and abutments should normally be placed outside the clear zone. However, many of Connecticut's existing bridge piers and abutments are within the design clear zone and can not be relocated and, therefore, warrant guide rail protection. Where full-height abutments are immediately outside the clear zone, a leading end guide rail treatment may often be warranted.

When the face of existing bridge piers and abutments are less than or equal to 1 m from the edge of roadway, the selected system must meet appropriate deflection requirements. Section 13-4.02 provides more information on the deflection parameters for various guide rail types.

13-3.05 Vertical Drop-Offs

An extended length of vertical drop-off, either along a fill slope or at the shoulder edge (e.g., retaining wall), typically warrants the installation of an unyielding barrier (e.g., concrete median barrier) when the height of the vertical drop-off is 800 mm or greater. The single-faced, pre-cast concrete barrier curb should not be used unless the area behind it can be backfilled. Normally, either the full-section pre-cast concrete barrier curb or a cast-in-place retaining wall is used. Figure 13-3C provides additional details on where an unyielding barrier may be required.

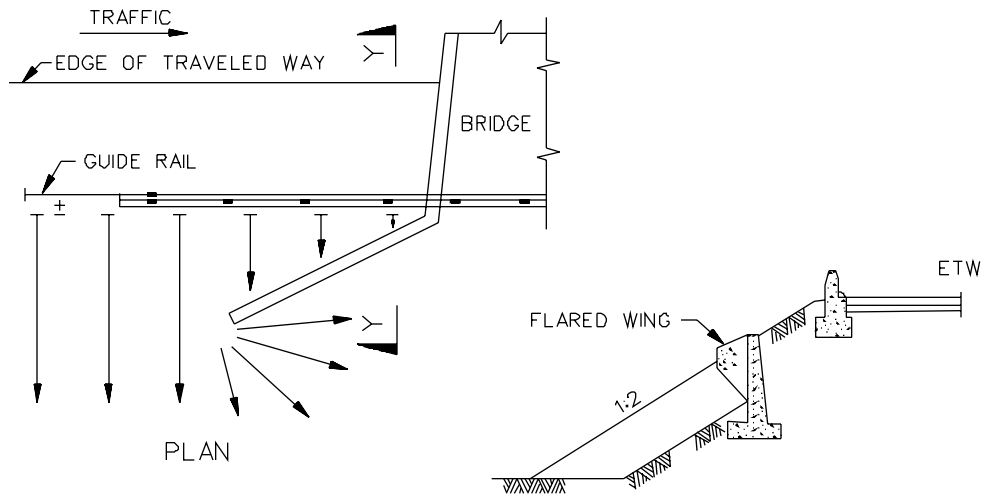


TRAFFIC DIRECTION
 I and II
 II Only
 I Only

BRIDGE APPROACH SECTION REQUIRED AT
 A B C D
 A B
 C D

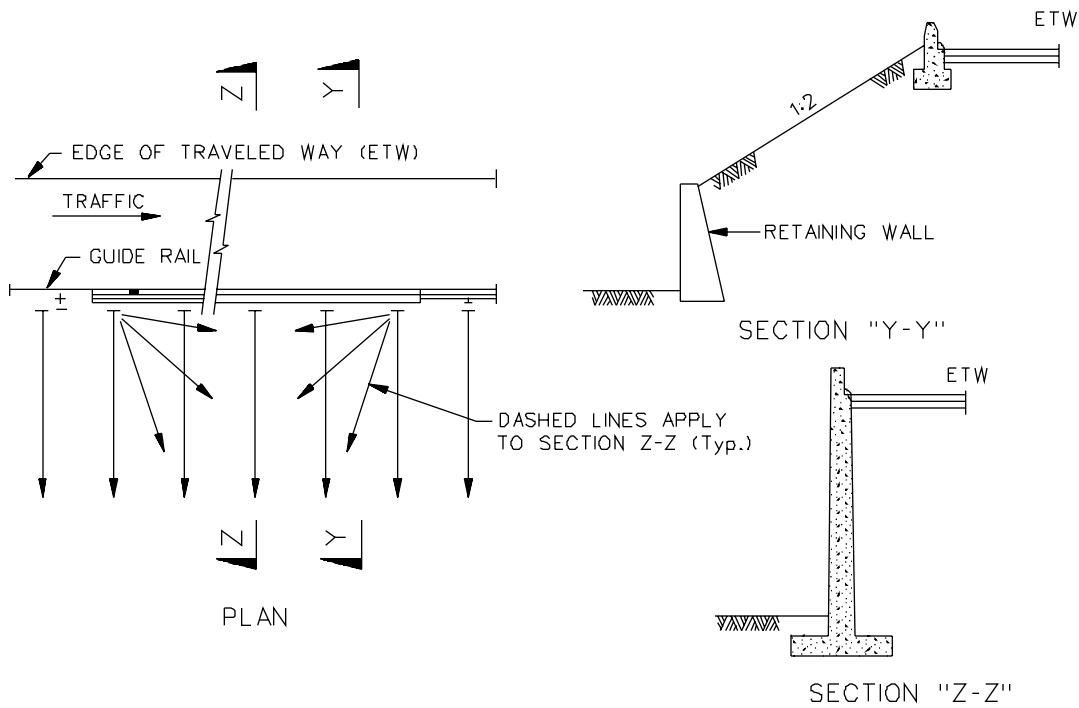
WARRANTS FOR GUIDE RAIL APPROACH TO BRIDGE RAIL

Figure 13-3B



SECTION "Y-Y"

TREATMENT OF PROTECTION AT FLARED WINGS



TREATMENT OF PROTECTION AT EMBANKMENT RETAINING WALLS

Not

unyielding barrier is warranted for vertical drop-offs which exceed 800 mm.

e: An

BARRIER WARRANTS FOR VERTICAL DROP-OFFS

Figure 13-3C

13-3.06 Roadside Ditches, Channels and Swales

If a vehicle departs the roadway and encounters ditches, channels or swales, the roadside configuration may introduce abrupt changes in vehicular direction which can result in destabilization of the vehicle. Figure 13-3D illustrates the relative traversability of various combinations of front slopes, ditch widths and backslopes for roadside channels, ditches and swales.

The typical section figures in Chapters Four and Five and Figure 13-2C illustrate the standard roadside swales in a cut section. For highways without curbs, the front slope is 1:12, the rounded ditch width is 3 m and the backslope is variable but not to exceed 1:2. The typical sections also show that the outside limit of rounding for the backslope should be outside the clear zone distance determined from Section 13-2.0. Where this limit is within the clear zone, the designer should attempt to relocate the outside limit of rounding to beyond the clear zone.

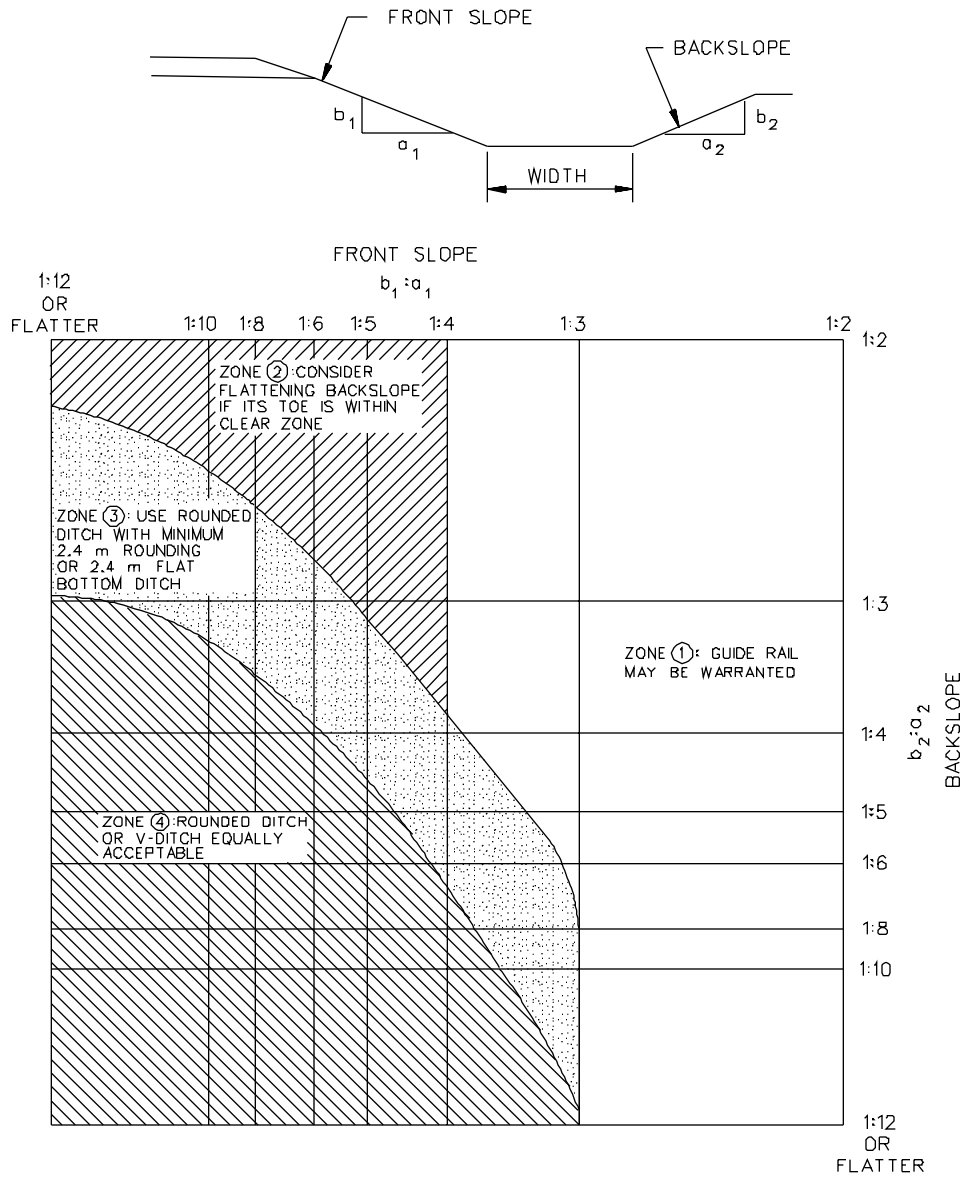
Ditch sections that fall within Zone 1 in Figure 13-3D may warrant guide rail. However, the designer should consider the cost effectiveness of installing lengthy sections of guide rail to shield a ditch. This is not always desirable and may warrant revising the ditch cross section to eliminate the need for guide rail.

If the dimensions of an existing or proposed ditch section fall within Zone 2 in Figure 13-3D, the backslope should be flattened if practical. If this is not feasible, guide rail is not warranted because of the ditch cross section alone. In this Zone, guide rail is considered more of a hazard than the ditch itself and, therefore, may not be warranted.

13-3.07 Transverse Slopes

Where the highway mainline intersects a driveway, side road or median crossing, a slope transverse to the mainline will be present. See Figure 13-3E. If the guide rail is impacted by a run-off-the-road vehicle at this location, the angle of impact will likely be close to 90 degrees. Even for relatively flat side slopes, this may result in vehicular vaulting; for steeper slopes the vehicular bumper may "catch" in the slope resulting in an abrupt stop and high occupant accelerations.

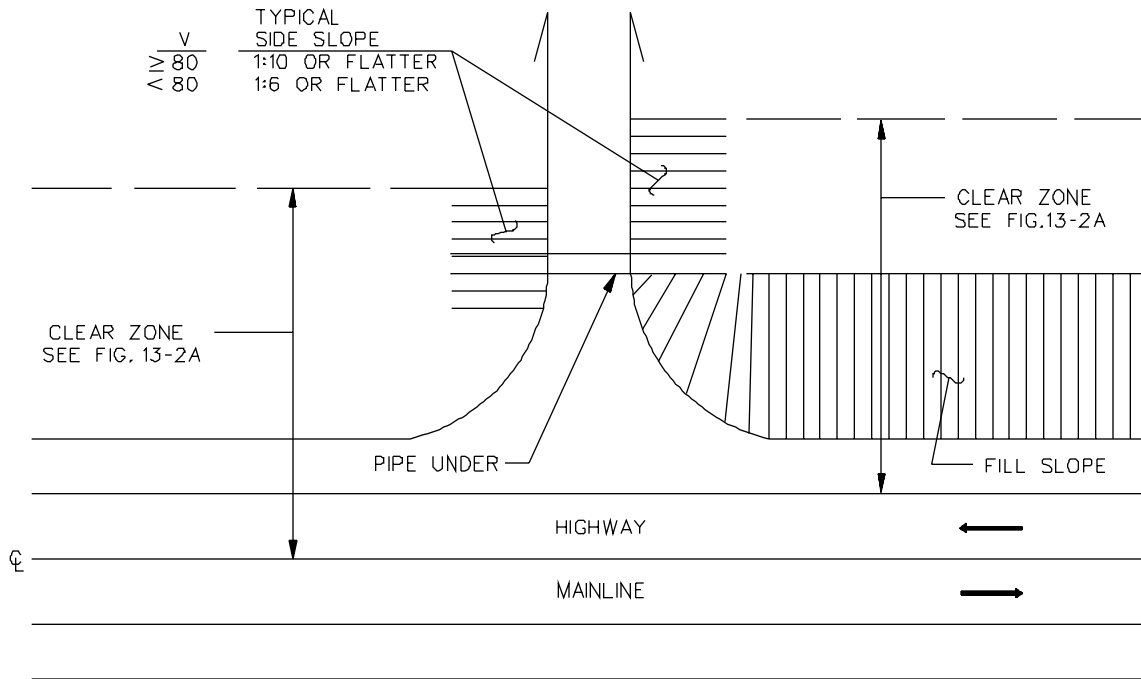
For these reasons, transverse slopes should be as flat as practical. For design speeds of 80 km/h or higher, the slope should be 1:12 typical or 1:10 maximum or flatter. Below 80 km/h, the slope should be 1:6 or flatter. If this criteria cannot be met practically, guide rail may be considered. The decision to use guide rail should be made on a case-by-case basis considering costs, traffic volumes, severity of the proposed transverse slope and other relevant factors. If guide rail is needed around the corners of intersecting roads or driveways, see Figure 13-6D for placement criteria on radii and Appendix A for design criteria of the "Washington Curved Guide rail Treatment".



- Notes:
1. Figure is based on impacts at 100 km/h and 25 degrees.
 2. Zones in figure are numbered indicating their relative hazard with Zone ④ being the most hazardous.

TRAVERSABILITY OF ROADSIDE DITCHES, CHANNELS AND SWALES

Figure 13-3D



TRANSVERSE SLOPES

Figure 13-3E

13-3.08 High Tension Lines and Reservoirs

A 1145-mm precast or cast-in-place concrete barrier curb with the F-shape or box beam are the preferred means of shielding high tension line towers and water supply reservoirs. See Section 13-4.0 for a description of the box beam and Section 13-5.0 for a description of the F-shape roadside barrier.

13-4.0 ROADSIDE BARRIERS

FHWA has mandated that as of October 1, 1998 all new installations of roadside safety hardware on the National Highway System (NHS) must meet, at a minimum, Test Level 3 (TL-3) crash testing criteria in National Cooperative Highway Research Program (NCHRP) Report 350 *Recommended Procedures for the Safety Performance Evaluation of Highway Features*. This applies to roadside barriers (i.e., guide rail), impact attenuators, end treatments, bridge rails and guide rail-to-bridge-rail transitions. The Department has adopted the TL-3 criteria as the minimum acceptable for new installations on all State-owned highways, whether on or off the NHS. Unless indicated otherwise, all guide rail types in Section 13-4.01 have met the TL-3 criteria in NCHRP Report 350.

13-4.01 Guide Rail Types

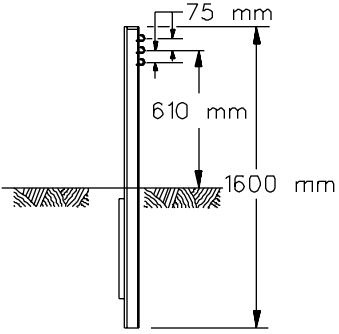
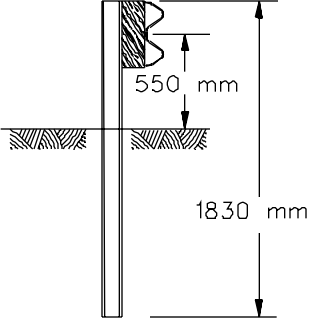
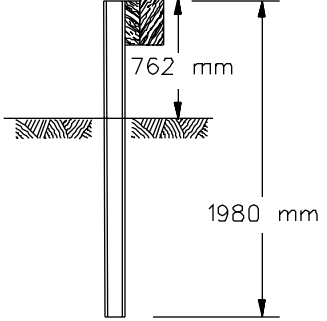
Figure 13-4A presents the Department's preferred guide rail systems. The figure summarizes the hardware requirements for each system. The designer should reference the *Connecticut Standard Sheets* for detailed information on each system. The following sections describe each system and its typical usage. In addition, several special roadside guide rails are described.

13-4.01.01 Three Cable Guide Railing (I-Beam Posts)

Three cable guide railing is a weak-post flexible system with a large dynamic deflection. Most of the resistance to impact is supplied by the tensile forces developed in the cable strands. Upon impact, the cables break away from the posts, and the vehicle is able to knock down the posts as it is redirected by the cables. The detached posts do not contribute to controlling the lateral deflection. However, the posts which remain in place do provide a substantial part of the lateral resistance to the impacting vehicle and are therefore critical to proper performance.

Three cable guide railing is the most forgiving of the available systems because of its large dynamic deflection. It should only be used where considerable lengths of the proper deflection distance is available behind the guide rail. Its use should be tempered by the following considerations:

1. Transitions. Do not use three cable guide railing for leading end transitions into bridge rails.
2. Slopes. Do not use three cable guide railing on fill slopes steeper than 1:2, unless the distance between the back of the posts and the break in the fill slope is at least 2.4 m.

			
Type	Three Cable Guide Rail	Metal Beam Rail (Type R-B 350)	Merritt Parkway Guide Rail
AASHTO Designation	SGR01a	SGR04a (Modified)	N/A
General Type	Weak-post (flexible)	Strong-post (semi-rigid)	Strong-post (semi-rigid)
Standard Post Spacing	4900 mm	1905 mm	3050 mm
Max. Dynamic Deflection	3.3 m	1.305 m	1.305 m
Post Type	S75 x 8.5 Steel	W150 x 13.5 Steel	W150 x 22.5 Steel
Beam Type	Three 19-mm dia. Steel Cables	Steel W. Section	150 mm x 300 mm Rough Sawn Timber
Offset Brackets	None	150 mm x 200 mm x 330 mm Recycled Plastic Block Out	100 mm x 200 mm x 275 mm Timber Block Out

Note: Recycled plastic block outs approved by FHWA per NCHRP Report 350 TL-3 criteria shall be used with R-B 350 guide rail systems. See Connecticut Standard Sheets. The Merritt Parkway Guide Rail is approved for use solely on the Merritt Parkway (see Section 13-4.01.08).

3. Minimum Radius. Three cable guide railing shall not be used on radii less than or equal to 135 m. See Figure 13-6E for guide rail curvature criteria.
4. Cable Tension. For three cable guide rail to provide full impact performance, the cables must be tensioned properly. Therefore, maintenance forces should ensure that the cable strands are tensioned properly at all times.

13-4.01.02 Metal Beam Rail (Type R-I)

Like three cable guide railing, the metal beam rail (Type R-I) is a weak-post flexible system. The tensile strength in the longitudinal W-beam will provide most of the resistance to the lateral forces of the impacting vehicle.

The Type R-I guide rail failed the TL-3 crash testing criteria in NCHRP Report 350. As a result, Department policy is that no new installations of this system will be allowed on any State-owned roadway. See Appendix A for latest Guide Rail Procedure.

13-4.01.03 Metal Beam Rail (Type R-B)

The metal beam rail (Type R-B) is a strong post semi-rigid system with steel posts and steel block outs. The Type R-B guide rail failed the TL-3 crash testing criteria in NCHRP Report 350. As a result, Department policy is that no new installations of this system will be allowed on any State-owned roadway. See Appendix A for latest Guide Rail Procedure.

13-4.01.04 Metal Beam Rail (Type R-B 350)

After the failure of metal beam rail (Type R-B) with steel block outs, FHWA tested a similar system with timber block outs that passed TL-3. Further tests were performed using recycled plastic block outs that passed TL-3 and were approved by FHWA. The Department has decided to use only recycled plastic block outs with FHWA approval for R-B 350 and MD-B 350 guide rail.

The maximum dynamic deflection of R-B 350 guide rail is much less than that of three cable guide rail. The deceleration forces on vehicle occupants when impacting R-B 350 are significantly higher than impacts with three cable guide rail. Thus, three cable guide rail is the preferred system. However, R-B 350 guide rail has significant maintenance advantages over the flexible rail. It can often safely sustain a second impact even after a major first impact. For this reason, R-B 350 guide rail should be strongly considered where a site has a history of frequent run-off-the-road accidents or where the greater deflection distance required for three cable guide rail is not available or is only available intermittently.

13-4.01.05 Thrie Beam 350

The Thrie Beam 350 passed the TL-3 crash test criteria in NCHRP Report 350. It is a strong post semi-rigid guide rail with a 508-mm wide thrie-beam section, a W150 x 13.5 steel post, and a M369 x 26 steel block out with a notch cut out of the bottom of the web. This rail has a maximum dynamic deflection of 1.02 m at a 1905-mm post spacing. It may be used at selected sites on a case-by-case basis with approval of the Transportation Engineering Administrator.

13-4.01.06 Metal Beam Rail (Box Beam)

The box beam rail passed the TL-3 crash test criteria in NCHRP Report 350. It is a weak post semi-rigid guide rail with a S75 x 8 steel post and a TS152 x 152 x 4.8 steel box rail. This rail has a maximum dynamic deflection of 1.15 m at a 1830-mm post spacing. It may be used at selected sites on a case-by-case basis with approval of the Transportation Engineering Administrator.

13-4.01.07 Single-Faced Precast Concrete Barrier Curb (PCBC)

ConnDOT previously used the "Jersey Shape" PCBC. The Department's choice, when installing new permanent PCBC, is the 1145-mm "F-shape". The single faced F-shape PCBC may be used on the roadside in front of rigid objects where no deflection distance is available. If the rigid object is not continuous (e.g., bridge piers), the designer should backfill behind the PCBC.

Existing "Jersey Shape" PCBC may remain. However, designers should provide a proper transition where new construction meets existing. Refer to the *Connecticut Standard Sheets* for transition details.

13-4.01.08 Merritt Parkway Timber Rail

The Merritt Parkway steel-backed timber guide rail combines aesthetic appeal (i.e., the timber longitudinal member) with acceptable safety performance (i.e., it passed the TL-3 crash testing criteria in NCHRP Report 350). The Department has approved this rail for use solely on the Merritt Parkway. However aesthetically appealing, this rail has a high maintenance and installation cost which precludes its widespread application on other State-owned roadways.

13-4.02 Deflection Distance

The "deflection distance" is defined as the lateral distance that the outside (side away from traffic) face of a barrier will deflect when struck by an errant vehicle before that barrier system stops the movement away from the road. Deflection for heavy post systems is measured as the deflection from the outside face of the posts to the hazard. This distinction is made because weak post rail systems usually separate from the posts when struck, while heavy post systems will usually remain attached. The clear distance to an obstruction must therefore include an allowance for the width of the heavy post. This clear distance for deflection is determined by the vehicular weight, speed, angle of impact and strength or rigidity of the barrier system.

The deflection distance is an important parameter for two reasons. First, it determines the magnitude of the lateral deceleration. Rigid systems, such as concrete barriers, produce essentially instantaneous lateral decelerations which are more likely to result in injuries. This difference is the major safety factor favoring the selection of flexible systems. The second reason that deflection distance is important is that it determines the space that must be maintained between the hazard and the barrier. If a hazard is allowed to remain or grow within the deflection distance of a barrier, the longitudinal movement of an errant vehicle can still carry it into the obstacle, even if the lateral movement has been arrested. The results of crash tests have been analyzed to develop a method for estimating the deflections that may be expected when a standard 2000-kg vehicle strikes different types of barriers at different speeds and impact angles.

Figure 13-4D presents the deflection distances expected when various barrier systems are impacted at 100 km/h with a standard 2000-kg vehicle at 25 degrees. Vehicles traveling at lower speeds on narrow roadways with reduced lateral offsets tend to impact guide rail at smaller angles thereby creating a smaller deflection in the guide rail. For this reason, Figure 13-4B is used when needed to determine the maximum lateral offset for narrow roads. Figure 13-4C should be used to establish applicable reduction factors that may be used to decrease the normal dynamic deflection of guide rail when proposed for installation on lower speed, narrow roadways. Refer to the example problem in Figure 13-4C.

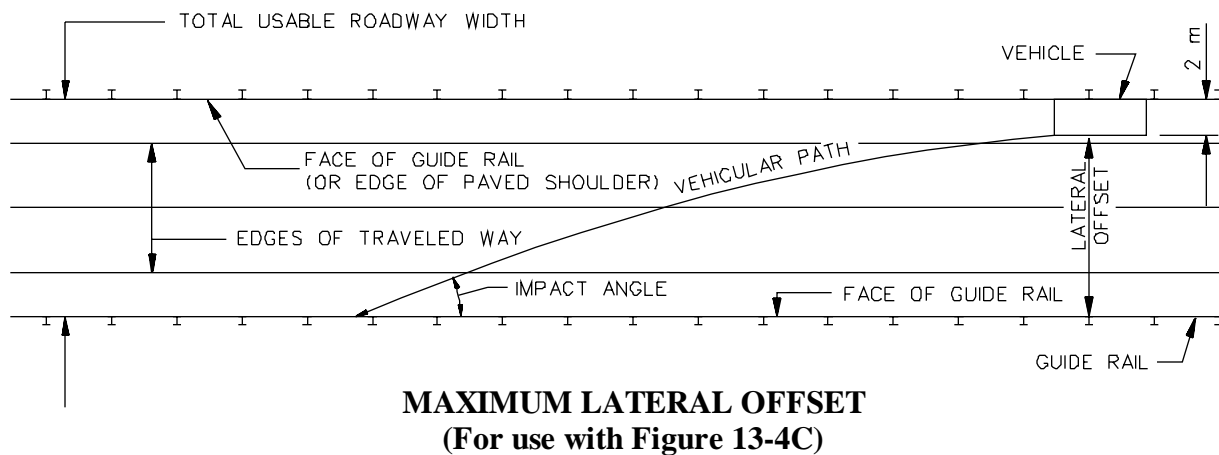
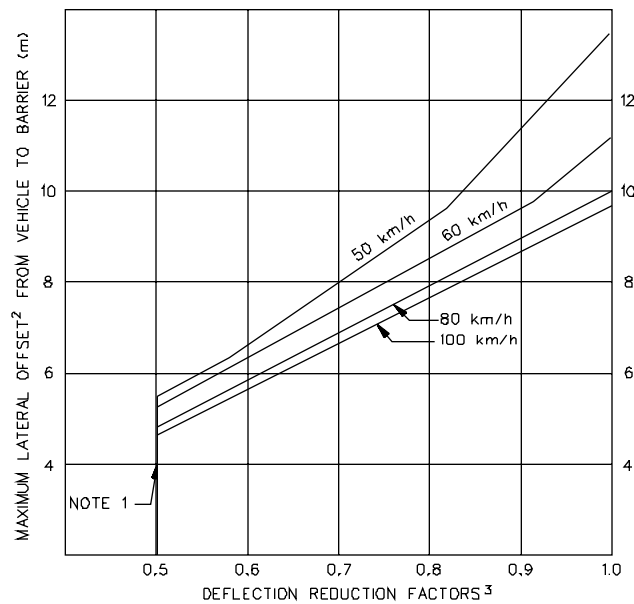


Figure 13-4B

Notes:

1. Factors will not be less than 0.5.
2. As illustrated in Figure 13-4B.
3. Reduction factors are used at specific locations when a smaller deflection is needed on a lower speed roadway to protect motorists from immovable objects.

Example:

1. Determine that the maximum lateral offset (as defined in Figure 13-4B) equals 8.0 m.
2. Determine that the guide rail's standard deflection (obtained from Figure 13-4D) is 2.4 m.
3. Determine the design speed to be 80 km/h.
4. From the graph in this figure, the reduction factor is 0.8.
5. Multiply 2.4 m by 0.8 = 1.92 m.
6. Use a reduced deflection, due to the narrow offset, of 1.9 m.

DEFLECTION REDUCTION FACTORS

Figure 13-4C

Barrier Type	Post Type (Deflection Category)	Post Spacing (meters)	Standard Deflection ⁷ (meters)
Three Cable Guide Railing ²	Weak Post (Flexible)	5.00	3.3 ⁵
		3.75	2.9 ⁵
		2.50 ⁸	2.4 ⁵
		1.25 ⁸	2.1
Corrugated W-Beam Guide Rail ³	(Type R-I) Weak Post (Flexible)	3.810	2.4 ⁵
		1.905 ⁹	1.8
		1.270 ⁹	1.5
	(Type R-B 350) Heavy Post (Semi-Rigid)	1.905	1.305 ⁶
		0.952 ⁹	0.800 ⁶
		0.476 ⁹	0.550 ⁶
Box Beam Guide Rail ⁴	Weak Post (Semi-Rigid)	1.830	1.5
		0.915 ⁹	1.2
Corrugated W-Beam Median ³	(Type MD-I) Weak Post (Flexible)	3.810	2.1
		1.905 ⁹	1.5
	(Type MD-B 350) Heavy Post (Semi-Rigid)	1.905	0.6 ⁶
Box Beam Median ⁴	Weak Post (Semi-Rigid)	1.83	0.9
Concrete Shapes	N/A	N/A	0

Notes:

1. Standard impact was produced with a 2000-kg test vehicle traveling at 100 km/h impacting the barrier at a 25° angle.
2. Must be properly tensioned and anchored to limit deflection to values shown.
3. Must be properly anchored to limit deflections to values shown.
4. To develop beam strength, must be a minimum length of 40 m.
5. To minimize rollover problems, barrier systems with deflections of 2.4 m or more should not be used adjacent to slopes steeper than 1:2.
6. Measured from outside face of post.
7. Where extra long weak posts are required, these deflections should be multiplied by 1.3.
8. Split spacing achieved by use of backup posts bolted to cable.
9. Split spacing achieved by use of backup posts driven behind the rail but not fastened to it.

BARRIER DEFLECTIONS FOR STANDARD¹ IMPACTS**Figure 13-4D**

Department policy for selecting guide rail with respect to deflection needs is summarized below:

1. The barrier system with the largest acceptable deflection should be selected when a barrier is required.
2. The deflection of the selected system must be less than the distance from the line of the barrier to the nearest hazard that cannot be removed or relocated.
3. All removable hazards must be removed from the area within the deflection distance of the selected guide rail. Maintenance work may be needed to prevent trees within the deflection distance from growing to more than 100 mm in diameter. Because the Department cannot control development beyond the right-of-way (ROW) line, the selection of a barrier system should ensure that its deflection will not extend beyond the ROW.

13-4.03 Disposition of Existing Guide Rail

13-4.03.01 NHS Facilities

Refer to the latest Guide Rail Procedure in Appendix A for disposition of existing guide rail systems on NHS facilities and the Merritt Parkway.

13-4.03.02 All Other Facilities

It is Department policy that all future and existing roadside safety hardware meet the crash testing requirements presented in NCHRP Report 350. Therefore, when any of the longitudinal barriers listed in the Guide Rail Procedure mentioned in Appendix A are encountered within the limits of a project, designers should upgrade the guide rail to the new standards.

13-5.0 MEDIAN BARRIERS

13-5.01 Warrants

The following summarizes the Department's criteria:

1. Freeways. Median barrier is warranted on all medians of 20.1 m or less. A median barrier may also be warranted on wider medians if a significant number of accidents have occurred.

Medians may vary in width. If a section warrants a median barrier but a wider section does not, the barrier should be extended into the wider median by approximately 30 m.

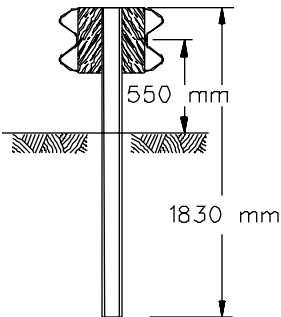
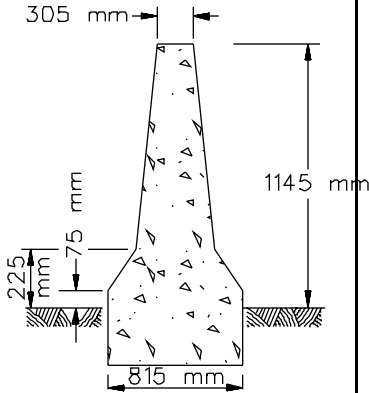
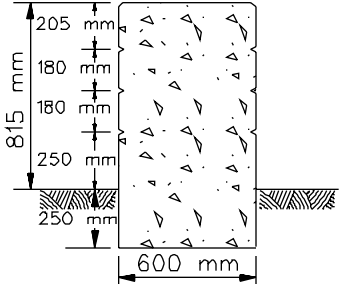
2. Non-Freeways. On lower-speed, lower-class highways, some judgment must be used. On highways without access control, the median barrier must terminate at each at-grade intersection, which is undesirable. In addition, lower speeds will reduce the likelihood of a crossover accident. On non-freeways, the designer should evaluate the accident history, traffic volumes, travel speeds, median width, alignment, sight distance and construction costs to determine an appropriate median barrier.

13-5.02 Median Barrier Types

All new installations of median barrier on NHS roadways must meet the TL-3 crash testing criteria in NCHRP Report 350. Figure 13-5A presents the types of median barriers which are typically used by the Department. The figure summarizes the hardware requirements for each system. Unless indicated otherwise, all types have met TL-3 criteria in NCHRP Report 350. Section 13-5.03 provides additional guidance on the selection of median barriers.

13-5.02.01 Metal Beam Rail (Type MD-I)

Metal beam rail (Type MD-I) is a weak-post flexible median barrier. Its performance is similar to metal beam rail (Type R-I). FHWA has tested Type R-I guide rail at TL-3 and it failed. As a result, corresponding median Type MD-I has also been deemed a failure. Therefore, Department policy is that no new installations of this system will be allowed on any State-owned roadway.

			
System	Metal Beam Rail (Type MD-B 350)	Double Faced PCBC F-Shape	Merritt Parkway Median Barrier
AASHTO Designation	SGM06a (Modified)	SGM10b (Modified)	N/A
General Type	Strong-post Semi-rigid	Rigid	Rigid
Standard Post Spacing	1905 mm	N/A	N/A
Deflection Distance	1.2 m	0	0
Post Type	W150 x 13.5 Steel	N/A	N/A
Beam Type	Two Steel W Sections	N/A	N/A
Offset Brackets	Two 150 mm x 200 mm x 330 mm Recycled Plastic Block outs	N/A	N/A

Note: The Merritt Parkway Barrier has been designed for use solely on the Merritt Parkway where only passenger cars are present. It is not suitable for use where there are trucks allowed in the traffic mix. See the Connecticut Standard Sheets.

13-5.02.02 Metal Beam Rail (Type MD-B)

Metal beam rail (Type MD-B) is a strong-post semi-rigid system with steel posts and steel block outs. Its performance is similar to metal beam rail (Type R-B). FHWA has tested Type R-B guide rail at TL-3 and it failed. As a result, corresponding median Type MD-B has also been deemed a failure. Therefore, Department policy is that no new installations of this guide rail will be allowed on any State-owned roadway.

13-5.02.03 Metal Beam Rail (Type MD-B 350)

Metal beam rail (Type MD-B 350) is a strong-post semi-rigid median barrier with steel posts and recycled plastic block outs. Its performance is similar to metal beam rail Type R-B 350. MD-B 350 median guide rail is most applicable in medians with narrow or intermediate widths on non-freeways. One special application for MD-B 350 is to separate adjacent on/off ramps at interchanges.

13-5.02.04 Double-Faced F-Shape PCBC

As discussed in Section 13-4.01.07, the Department's choice for new permanent median PCBC is the 1145-mm F-shape. See the latest Guide Rail Policy and Procedure in Appendix A.

When installing median PCBC, the distance between the edge of traveled way and the concrete median barrier should not exceed 3.6 m as illustrated in Figures 4I and 5K.

13-5.02.05 Merritt Parkway Median Barrier

Two individual roadside sections of the standard steel-backed timber guide rail discussed in Section 13-4.01.08 may be used in the median on the Merritt Parkway when the median is greater than or equal to 4 m wide. Two individual roadside sections of System 2 or System 3 shown in the *Connecticut Standard Sheets* may be used when the median is between 2 m and 4 m wide. Ideally, designers should install the appropriate steel-backed timber guide rail system with the proper deflection needed for the site.

Where the median width is too narrow to accommodate the deflection of the steel-backed timber guide rail, the Merritt Parkway median barrier will be used. See the *Connecticut Standard Sheets* for more details on its use and placement.

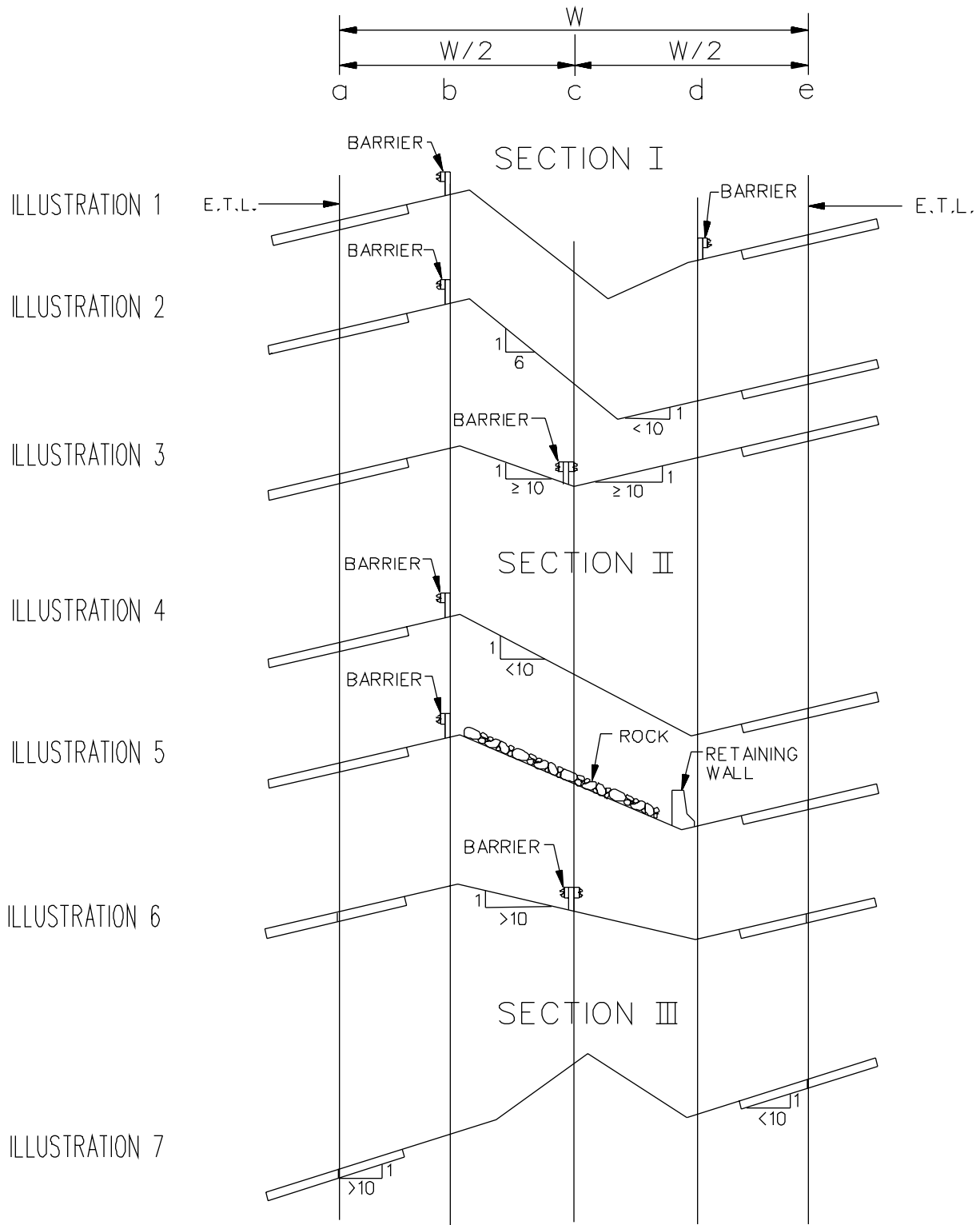
13-5.03 Median Barrier Placement

The ideal location for the median barrier is in the center of the median which will provide a maximum clear recovery area for each direction of travel. The presence of excessive slopes or existing drainage in the center may make it impossible to locate a barrier there. Therefore, the following criteria will apply:

1. Slopes. A median barrier should not be placed where the roadside slope up to the barrier exceeds 1:10. For a PCBC, the slope leading up to the barrier will be the shoulder slope. Existing median slopes greater than 1:10 should be flattened to a desirable 1:12 rate or maximum 1:10 rate.

Figure 13-5B illustrates three basic types of sloped medians. The following discusses each type; it assumes a median barrier is warranted:

- a. For Cross Section I, the designer should determine if the individual slopes warrant protection based on the criteria in Section 13-3.0. If both slopes warrant protection (Illustration 1), guide rail should be placed at “b” and “d”. If one slope warrants protection, a median barrier should be placed to shield that slope. If neither slope warrants protection and both slopes are steeper than 1:10 (Illustration 2), a median barrier should be placed at “b” or “d”, whichever is shielding the steeper slope. If the slopes are 1:10 or flatter (Illustration 3), the median barrier should be placed slightly to one side of the center of the median so that it does not interfere with highway drainage.
- b. For Cross Section II, the slope in the median will determine the proper treatment. If the slope is between 1:10 and 1:4 (Illustration 4), the median barrier should be placed at “b.” If the median slope is 1:4 or steeper, guide rail at “b” is the only necessary treatment. If the median slope is a roadside hazard (e.g., rough rock cut) (Illustration 5), guide rail should be placed at both “b” and “d.” If the median slope is 1:10 or flatter (Illustration 6), the median barrier should be placed in the center of the median.
- c. For Cross Section III (Illustration 7), the redirective capacity of the median slope will determine the proper treatment. If the median slope is 1:4 or steeper and ≥ 1 m in vertical height, no roadside nor median barrier is necessary. If the median slopes are flatter than 1:4 and/or < 1 m in vertical height, the median barrier should be placed at the apex of the cross section.



SLOPED MEDIANS

Figure 13-5B

13-5.03.01 Divided Median Barriers

It may be necessary to intermittently divide a median barrier. The slope criteria in Section 13-5.03 or a fixed object in the median may require this. The median barrier may be divided by one of these methods:

1. A fixed object may be encased by an F-shaped PCBC.
2. A single-faced F-shaped PCBC may be used on both sides to shield a fixed object. Backfilling may be necessary.
3. Metal beam rail MD-B 350 may be split into two separate runs of guide rail passing on either side of the median hazard (fixed object or slope).

If a median barrier is split, the design should adhere to the acceptable flare rates (Figure 13-6A). Where practical, the flare rate should be 50:1.

The designer should note that, when a vehicle impacts a PCBC, the vehicle may lean over the top of the barrier and strike bridge piers, sign supports, light poles, etc., that have been placed on the top of the barrier. If practical, fixed objects should be placed on the outside of the highway beyond the clear zone, instead of on top of the PCBC. Designers should refer to the *Connecticut Standard Sheets* for placement of PCBC's adjacent to bridge piers.

13-5.04 Glare Screens

Headlight glare from opposing traffic can be bothersome and distracting. Glare screens can be used in combination with median barriers to eliminate this problem. The Department has not adopted specific warrants for the use of glare screens.

The typical application, however, is on urban freeways with narrow medians and high traffic volumes or between on/off ramps at interchanges where the two ramps adjoin each other. Here, the sharp radii of curvature and the narrow separation may make headlight glare especially bothersome. Designers should consider the use of glare screens at these sites especially if the Department has received a significant number of public complaints.

Blocking headlight glare can be achieved in several ways:

1. Vegetation can be used; however, the designer should not introduce hazardous fixed objects in a narrow median.

2. Several commercial glare screens are available. Considering both effectiveness and ease of maintenance, the paddle glare barrier may be the best choice. These are a series of plastic paddles which are usually mounted to a PCBC.

Glare screens should be designed for a cutoff angle of 20°. This is the angle between the median centerline and the line of sight between two vehicles traveling in opposite directions. The glare screen should be designed to block the headlights of oncoming vehicles up to the 20° cutoff angle. On horizontal curves, the design cutoff angle should be increased to allow for the effect of the curvature on headlight direction. See Figure 13-5C. The criteria is:

$$\text{Cutoff Angle} = 20 + 1746.8/R$$

where R = Curve radius, m

The designer should also evaluate the impact of a glare screen on horizontal sight distance on curves to the left. The screen could significantly reduce the available middle ordinate for stopping sight distance. See Section 8-2.0 for a discussion of sight distance at horizontal curves.

13-5.05 Disposition of Existing Median Barriers

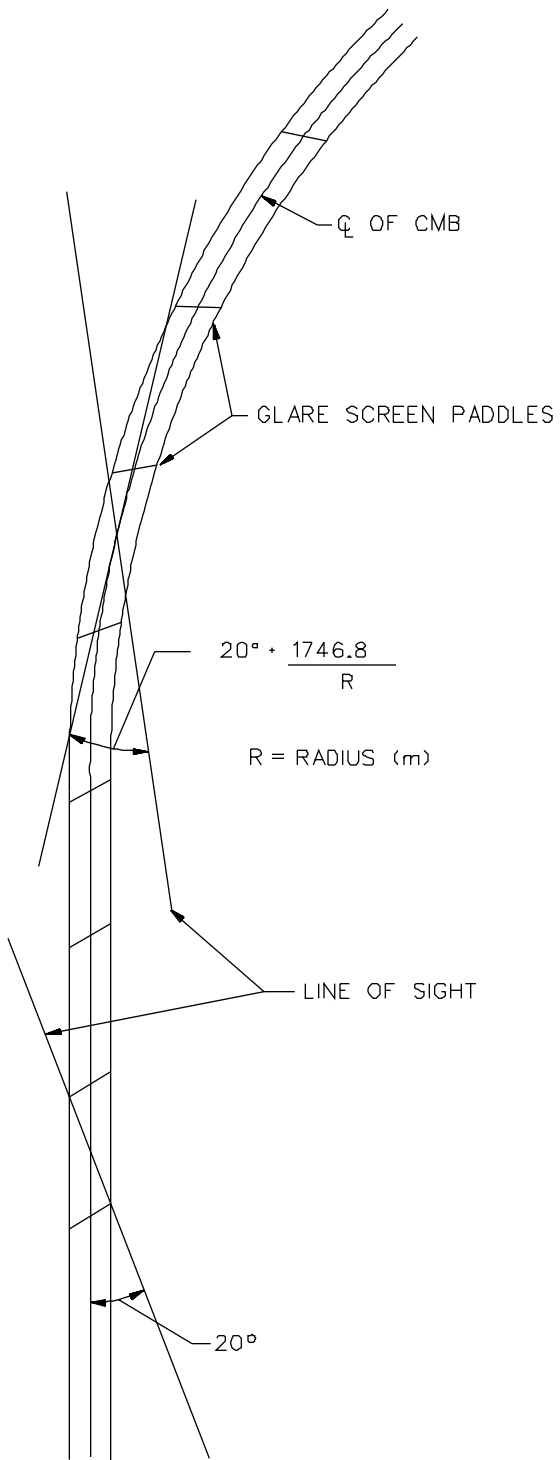
13-5.05.01 NHS Facilities

Refer to the latest Guide Rail Procedure in Appendix A for disposition of existing median barriers on the NHS facilities and the Merritt parkway.

13-5.05.02 All Other Facilities

It is Department Policy that all future and existing roadside safety hardware meet the crash testing requirements presented in NCHRP Report 350. Therefore, when any of the longitudinal barriers listed in the Guide Rail Procedure are encountered within the limits of a project, designers should upgrade the guide rail to the new standards.

Temporary median Jersey-shaped PCBC may continue to be used for maintenance and protection of traffic during construction, provided that positive moment connection between barriers, as shown in the Miscellaneous Connecticut Details, is incorporated.



CUTOFF ANGLE FOR GLARE SCREENS

Figure 13-5C

13-6.0 GUIDE RAIL LAYOUT

13-6.01 Length of Need

The Department's criteria for determining the length of need is as follows:

1. Terminal Outside The Clear Zone. The *Connecticut Standard Sheets* illustrate the typical treatment for leading end anchors of R-B 350 or MD-B 350 guide rail placed outside the clear zone as determined from Section 13-2.0. Where this layout cannot be achieved, see Comment #2.
2. Terminal Within The Clear Zone. Designers should use Section 5.6.4 in the *RDG* to determine the length of need for all leading ends of guide rail located within the clear zone.

13-6.02 Flare Rate

It may be necessary to laterally relocate a run of guide rail to terminate the end anchorage outside the clear zone or to meet a bridge parapet. This lateral relocation may increase the angle of impact on the guide rail. Therefore, guide rail flare rates should be based on Figure 13-6A.

13-6.03 Lateral Placement

Guide rail should be placed as far as practical from the edge of the traveled way. This will minimize the chance that it will be struck. The following factors should be considered when determining guide rail lateral placement:

1. The dynamic deflection distance of the guide rail, as shown in Figure 13-4D, should be met.
2. At a minimum, 0.6 m should be provided between the back of the guide rail post and the break in the fill slope. This will provide the necessary soil resistance for the post. In addition, on fill slopes steeper than 1:2, three cable guide railing should not be installed unless the distance between the back of the post and the break in the fill slope is at least 2.4 m.
3. Drivers tend to "shy" away from continuous longitudinal obstacles along the roadside, such as guide rail. Therefore, the minimum lateral guide rail offset without curbing should be based on Figure 13-6B.

Design Speed (km/h)	Flare Rate for Barrier Inside Shy Line	Flare Rate for Barrier Beyond Shy Line	
		Rigid	Flexible/Semi-Rigid
50	13:1	8:1	7:1
60	16:1	10:1	8:1
70	18:1	12:1	10:1
80	21:1	14:1	11:1
90	24:1	16:1	12:1
100	26:1	18:1	14:1
110	30:1	20:1	15:1

GUIDE RAIL FLARE RATES

Figure 13-6A

Design Speed (km/h)	Shy Line Offset (m)
50	1.1
60	1.4
70	1.7
80	2.0
90	2.2
100	2.4
110	2.8
120	3.2

MINIMUM LATERAL OFFSET FOR GUIDE RAIL WITHOUT CURBING (from Edge of Traveled Way)

Figure 13-6B

13-6.04 Curbs and Curb/Barrier Combinations

When the tires of an errant vehicle strike a curb, the impact tends to bounce the vehicle upwards which may contribute to vaulting or penetration of the rail. This problem is increased when curbs are located between 0.3 m and 3.0 m in front of guide rail. When the destabilizing or vertical bounce of the vehicle acts in combination with the longitudinal barrier, undesirable results may occur. The placement of curbing in conjunction with guide rail must be considered carefully.

The following criteria will apply for curb and curb/barrier combinations on high-speed ($V > 80$ km/h) roadways:

1. Curbing of any height is not permitted for use in conjunction with either concrete barriers or attenuating devices. Refer to Bridge Design for exceptions at abutments.
2. Curbing should not be used in gore areas or wide medians. Existing curbing should be removed wherever practical.
3. When curbing is necessary for drainage control on high-speed roadways, a maximum height of 100 mm may be used. W-beam guide rail will be installed with the face of the rail flush with the face of the curbing and the height of the rail measured from the gutter line. However, where railing is behind a sidewalk, measure it from the top of the sidewalk. See the *Connecticut Standard Sheets* for 100-mm park curbing.
4. Curbing must not be placed along high-speed highways to shield pedestrians. Curbing is ineffective as a barrier and, at high speeds, vehicles that contact curbing are at an increased risk of departing the traveled way and encroaching into areas frequented by pedestrians.
5. Due to the propensity for vehicles to vault or roll over W-beam guide rail when used with curbing, the allowable guide rail deflection should not exceed 1.2 m.
6. Three cable guide rail when used with curbing shall be placed a maximum of 0.3 m from the face of curbing. The installation height will be measured from the top of pavement.
7. Refer to the Guide Rail Procedure and *Connecticut Standard Sheets* for transition curbing at bridge parapets.

The following criteria will apply to curb and curb/barrier combinations on low-speed ($V \leq 80$ km/h) roadways:

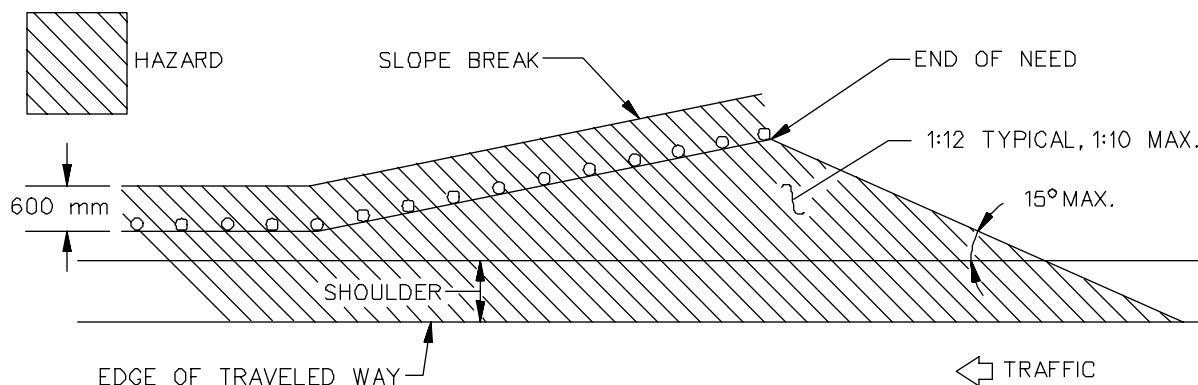
1. Curbing of any height is not permitted for use in conjunction with either concrete barriers or attenuating devices. Refer to Bridge Design for exceptions at abutments.

2. For general guidance, curbs may be used in low-speed situations where justified by present or anticipated pedestrian traffic. Use of vertical faced curbing should be avoided. The preferred curb choice is the park curb.
3. When curbing is used in conjunction with any guide rail type, the face of rail should be placed no more than 0.3 m from the face of curbing.
4. When a sidewalk is present, the guide rail should typically be placed with the rail element flush with the back of the sidewalk.

13-6.05 Placement on Slopes

If guide rail is improperly located on slopes, an errant vehicle could impact the rail too high or too low, causing destabilization of the vehicle. Therefore, the following criteria will apply:

1. W-beam guide rail should not be placed on a cut or fill slope steeper than 1:10. This also applies to the areas in front of the flared section of guide rail, if used. See Figure 13-6C.
2. Three cable guide rail may be placed on slopes between 1:10 and 1:6 when needed (i.e., barn-roof sections). It has been demonstrated through crash test evaluation that the cable engages vehicles better than other rail systems for this range of slopes.



Note: When the hazard being shielded is ≥ 4.5 m from the edge of traveled way.

SLOPES IN FRONT OF GUIDE RAIL

Figure 13-6C

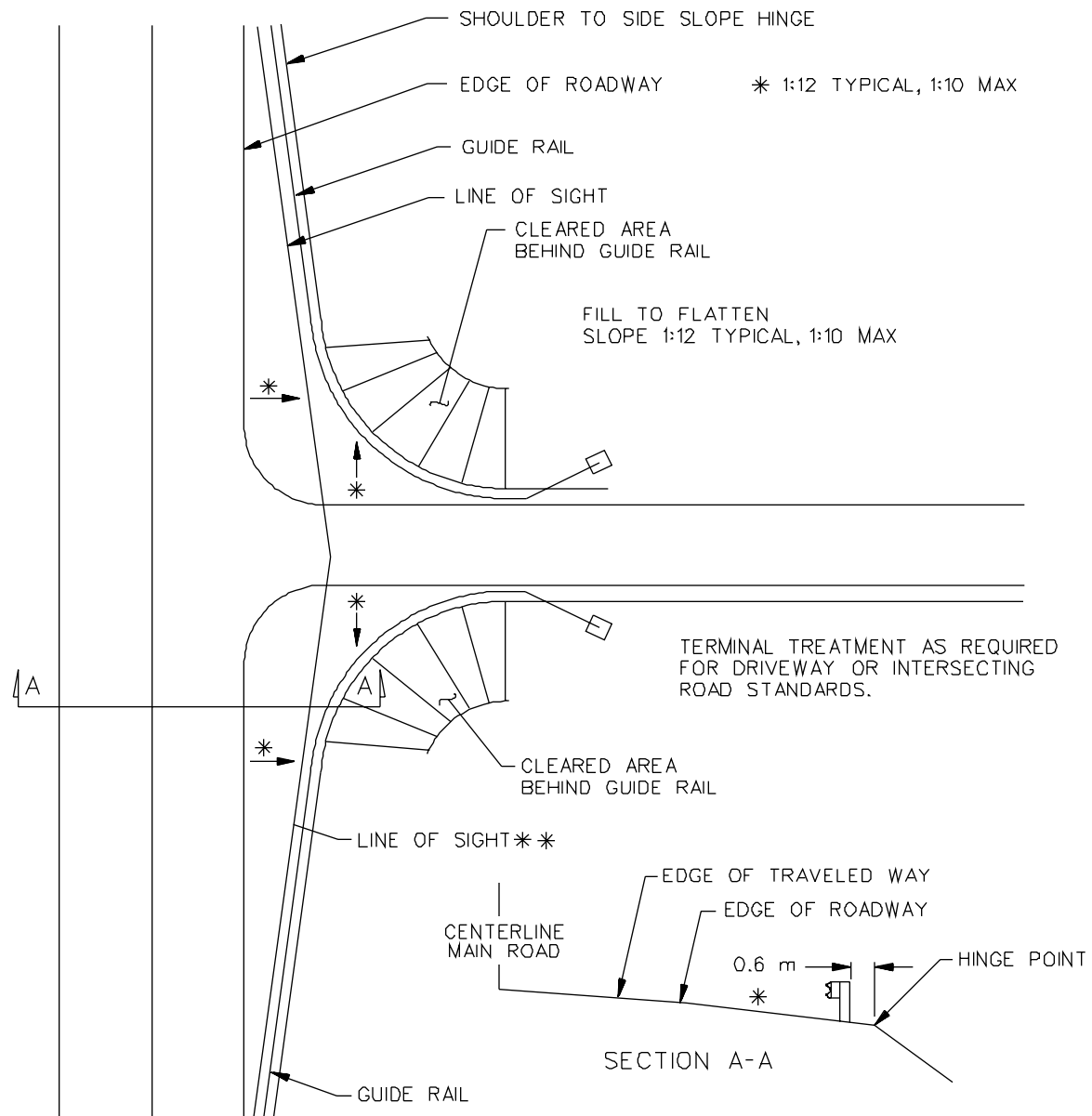
13-6.06 Minimum Length and Guide Rail Gaps

Short runs of guide rail have limited value and should be avoided. As a general rule, the three cable guide railing should have at least 60 m of length at full height. Type R-B 350 guide rail should have at least 26 m of length at full height. Likewise, short gaps between runs of guide rail are undesirable. In general, gaps less than 60 m between guide rail termini should be connected into a single run. However, this may not be possible on roadways with numerous driveway openings. Whenever possible, removal of the need for guide rail should be investigated to prevent short runs of guide rail or multiple short gaps of guide rail.

13-6.07 Treatment at Intersecting Roads and Driveways

Guide rail runs on non-freeway facilities must often be interrupted by intersecting roads and driveways. Figure 13-6D presents the typical treatment that should be used for terminating guide rail at intersecting roads and driveways. When using this figure, the designer should consider the following:

1. Studies have shown that there is an increased chance for vehicles to impact this type of guide rail installation at 90°. Because of the potential for high-angle impact, three cable guide railing should not be used.
2. The guide rail should be flared away from the main road to allow sufficient sight distance for vehicles on the intersecting road or driveway.
3. The slope between the main line and the guide rail should not exceed 1:10.
4. The end treatments should meet the criteria in Section 13-7.0.
5. The designer should ensure that the treatment reflects the applicable safety considerations for the intersecting road or driveway.
6. On intersecting roads and driveways with design speeds of $V \leq 80$ km/h, designers should investigate the possibility of using the "Washington Curved Guide Rail Treatment." Refer to Appendix A for design criteria and the Connecticut Standard details.
7. Curbing should not be used in the area where guide rail is flared for the sight line.



** WHERE NECESSARY, GUIDE RAIL MAY BE WITHIN SIGHT TRIANGLE IF THE DRIVER (1070-mm HEIGHT OF EYE) CAN SEE OVER THE GUIDE RAIL TO THE OBJECT (1070-mm HEIGHT)

Note: Refer to Appendix A for the Washington Curved Guide Rail Treatment for application at sharp radii where $V \leq 80$ km/h.

GUIDE RAIL TREATMENT AT INTERSECTING ROADS AND DRIVEWAYS

Figure 13-6D

13-6.08 Guide Rail Curvature Criteria

Guide rail must sometimes be placed on the inside of radii at, for example, interchange ramps. This condition presents a problem when standard post spacings are used because a vehicle may impact the guide rail at close to 90°. Therefore, the post spacing on radii must be decreased. The criteria for guide rail post spacing on radii is presented in Figure 13-6E.

Radius of Curve	Acceptable Guide Rail Type
$R \geq 220 \text{ m}$	3 cable @ 4900-mm post spacing Type R-B 350
$220 \text{ m} > R \geq 135 \text{ m}$	3 cable @ 3660-mm post spacing Type R-B 350
$135 \text{ m} > R \geq 11 \text{ m}$	Type R-B 350
$R < 11 \text{ m}$	Refer to Washington Treatment Details

Note: R-B 350 guide rail must be shop fabricated for radii $\leq 45 \text{ m}$. Three cable guide rail should not be used for radii $< 135 \text{ m}$.

CRITERIA FOR GUIDE RAIL CURVATURE

Figure 13-6E

13-6.09 Transitions

13-6.09.01 Transitions Within Same Type System

Where conditions allow, designers should always choose the guide rail with the largest dynamic deflection possible. This selection will be governed by the available distance between the guide rail and the hazard. However, there may be sites where this distance is interrupted by short sections where the available deflection distance is less. The desirable treatment, if practical, is to stiffen the existing guide rail by tightening up the post spacing through the section of reduced deflection distance. Transitions for metal beam rail are illustrated in the *Connecticut Standard Sheets*, and reduced post spacing for different rail types are listed in Figure 13-4D.

13-6.09.02 Transitions Between Systems

Figures 13-6F and 13-6G illustrate the various transition treatments between two different systems. Normally, overlap transitions between two different guide rail types are undesirable. However, they may be necessary, for example, when a new guide rail meets a different type of existing guide rail of considerable length. See the *Connecticut Standard Sheets* for illustrations of R-B 350 guide rail transitions to bridge parapets.

From	To	Transition By	Reference
R-B 350 R-B 350 R-B 350	Parapet/Barrier 3-cable R-I	Leading End Rail Overlap Rail system	Standard Sheets Figure 13-6G Standard Sheets
Parapet/Barrier	R-B 350	Trailing End Rail	Standard Sheets

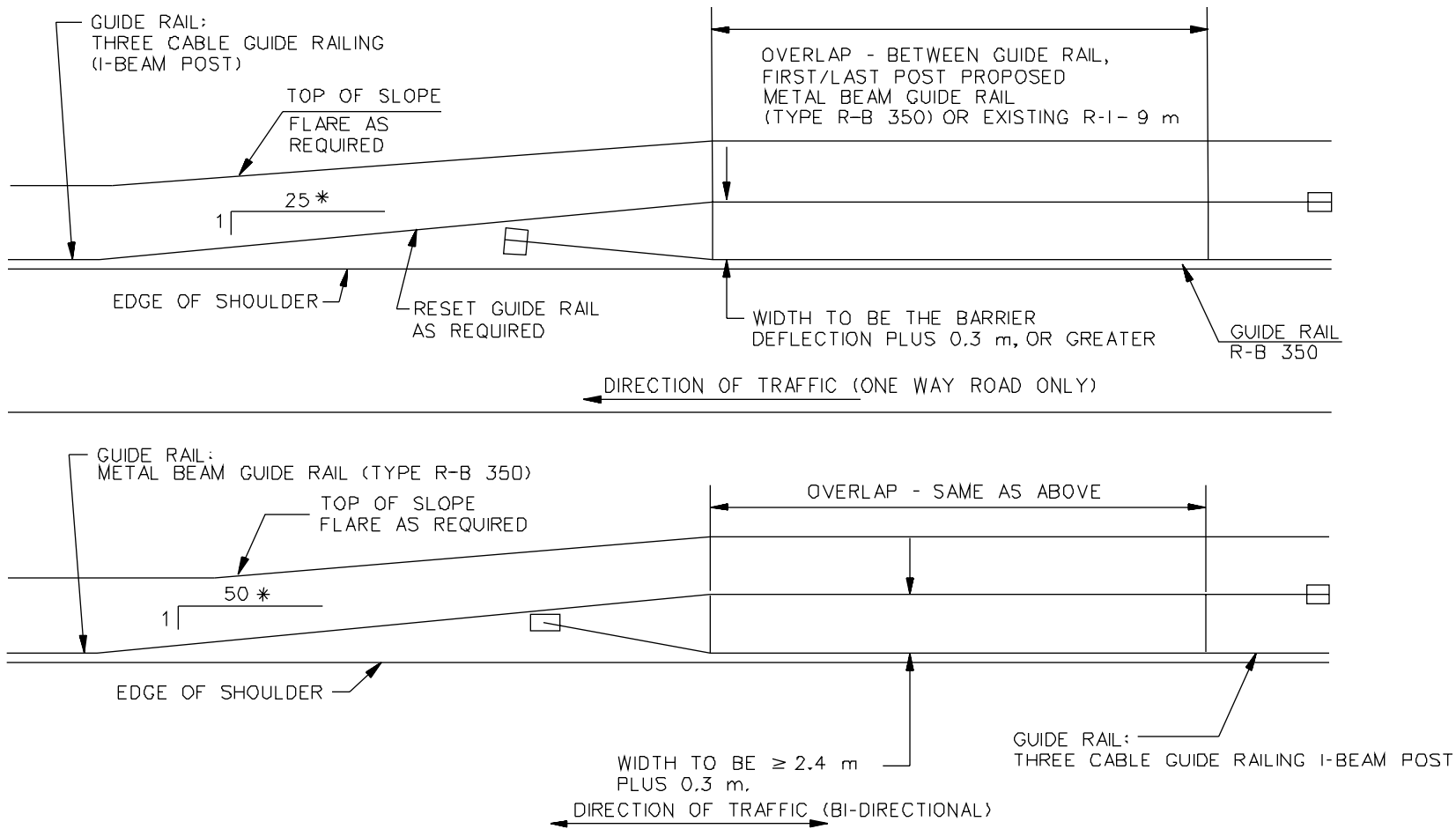
GUIDE RAIL TRANSITIONS

Figure 13-6F

13-6.10 Pavement for Railing

In general, herbicides will be used to control growth under the railing. However, bituminous concrete will be used 1) under the railing when the railing is within a public water supply watershed area, and 2) at the approaches to bridges over streams and rivers. The application of herbicide is the responsibility of the Office of Maintenance and will not be included in construction contracts. Public water supply watershed areas can be located in the "Atlas of the Public Water Supply Sources and Drainage Basins of Connecticut," D.E.P. Bulletin No. 4. In all other areas and when the water-course is less than 15.24m from the road and paralleling it, use processed aggregate under the rail.

Pavement for railing may be used under the W-beam End Terminals, as specified in the Guide Rail Procedure. See Department Standard grading details for impact attenuators.



* Use 1:8 maximum for $V \leq 80$ km/hr and 1:15 maximum for $V > 80$ km/hr

Note: Transitions are overlapped to prevent the errant vehicle from overrunning the lapped rail and being released into the area of concern. Grading in the transition area should be 1:12 typical, 1:10 maximum.

TRANSITIONS BETWEEN DIFFERENT RAIL TYPES

Figure 13-6G

13-6.11 Placement on High Fills with Sidewalk and Utility Pole Lines.

Theoretically, the preferred location for guide rail is behind the sidewalk with the utility pole line located at the guide rail deflection distance plus 0.3 m. In most locations, the pole would then be placed at least five meters from the edge of the roadway. This is beyond the practical distance for which utility lines can be easily maintained and would increase the likelihood of the lines being too close to buildings. In practice, the utility poles will usually be placed within a utility strip/snow shelf between the street and the sidewalk. In high-speed areas where there are few driveway breaks requiring guide rail between the street and the walk, consideration should be given to placing the rail adjacent to the curb and the utility poles immediately behind the walk. See Utility Pole Placement Policy in Section 13-2.04.

13-7.0 IMPACT ATTENUATORS

13-7.01 General

Impact attenuators may be categorized as either inertial or compression systems. Inertial systems are designed to transfer the kinetic energy of a vehicle to a series of yielding masses. Sand barrel arrays are a typical example. Compression systems are designed to absorb the energy of the vehicle by the progressive deformation or crushing of the elements of the system. W-beam end terminals are a typical example.

13-7.01.01 Definitions

Designers are encouraged to fully understand the following definitions before specifying impact attenuators:

1. Critical Impact Point (CIP). For a given test, the CIP is the initial point of vehicular contact along the longitudinal dimension of a feature judged to have the greatest potential for causing a failure.
2. Length of Need (LON). That part of a longitudinal barrier or terminal designed to contain and redirect an errant vehicle.
3. Crash Cushion (Impact Attenuators). A device designed primarily to safely stop a vehicle within a relatively short distance.
4. Redirective Crash Cushion. A device designed to contain and redirect a vehicle impacting downstream from the nose of the cushion.
5. Non-Redirective Crash Cushion. A device designed to contain and capture a vehicle impacting downstream from the nose of the cushion.
6. Gating Device. A device designed to allow controlled penetration of the vehicle when impacted between the nose and the beginning of the LON of the device.
7. Non-Gating Device. A device designed to contain and redirect a vehicle when impacted downstream from the nose of the device. An end terminal or a crash cushion with redirection capabilities along its entire length is a non-gating device.

13-7.01.02 Crash Cushion and End Terminal Types.

As with all roadside safety appurtenances, impact attenuators used on the State-owned highway system must satisfy NCHRP Report 350 criteria (TL-3 minimum). When determining the appropriate type of impact attenuator, the designer should refer to the latest Guide Rail Procedure for Department approved systems.

13-7.01.03 Crash Cushion Selection

Crash cushions are most often installed to shield fixed-point hazards which are close to the traveled way. Examples include exit gore areas, bridge piers and non-breakaway sign supports. Crash cushions are often preferable to guide rail to shield these hazards. They offer a smaller target area and often cost less than a guide rail installation. However, when these hazards are a considerable distance from the traveled way, guide rail is usually preferred.

The selected crash cushion must be compatible with the specific site characteristics. This includes a consideration of:

1. the width of the hazard to be shielded,
2. the need for redirective capability,
3. the anticipated frequency of impact,
4. any attenuation capacity after impact,
5. the initial cost of the system, and
6. maintenance of the crash cushion.

13-7.01.04 Crash Cushion Design

Once a crash cushion system has been selected, the designer must ensure that its design is compatible with the traffic and physical conditions at the site. All of the Department approved crash cushions are patented; therefore, the designer should contact the manufacturer of the system for assistance. The following presents additional information on the design of crash cushions:

1. Deceleration. For all safety appurtenances, acceptable vehicular deceleration is determined by the occupant impact velocity measured during full-scale crash tests. These are discussed in detail in NCHRP Report 350 *Recommended Procedures for the Safety Performance of Highway Features*. The crash cushion should be designed to meet the recommended acceptance limits for deceleration.

2. **Impact Speed.** To determine the length and/or layout of a crash cushion, the appropriate design speed must be selected. Figure 13-7B presents the criteria for selecting the initial impact speed for designing the crash cushion.
3. **Placement.** Several factors should be considered in the placement of a crash cushion:
 - a. **Level terrain.** All crash cushions have been designed and tested for level conditions. Vehicular impacts on devices placed on a non-level site could result in an impact at the improper height which could produce undesirable vehicular behavior. Therefore, the crash cushion should be placed on a level surface or on a cross slope not to exceed 5 percent.

Highway Design Speed (V) (km/h)	Crash Cushion Impact Speed (km/h)	
	Freeways	Non-Freeways
$V \geq 100$	100	100
$80 < V < 100$	100	Design Speed
$V \leq 80$	--	70

IMPACT SPEED FOR CRASH CUSHIONS

Figure 13-7B

- b. **Curbs.** Curbs in front of or along the side of a crash cushion can induce vehicular vaulting. This may result in impacts at an improper height or in other undesirable vehicular behavior. Therefore, no curbs shall be designed for new projects at proposed crash cushion locations. On projects where existing crash cushions are present with curbing, the curbing shall be removed and drainage redesigned where necessary.
- c. **Surface.** A paved, bituminous or concrete pad may be needed under some of the crash cushions. The manufacturer's recommendations will prevail.
- d. **Elevated Structures.** There is some concern that the unanchored inertial systems may walk or crack due to the vibration of an elevated structure. This could adversely affect its performance. Therefore, designers should locate gore areas, etc., to avoid the use of crash cushions on a structure.

- e. Reserve Area. The designer should, as early as practical in the project design process, determine the need for and approximate dimensions of a crash cushion. This will avoid late changes which could significantly affect the project design. Figure 13-7C provides recommended criteria for the crash cushion reserve area.

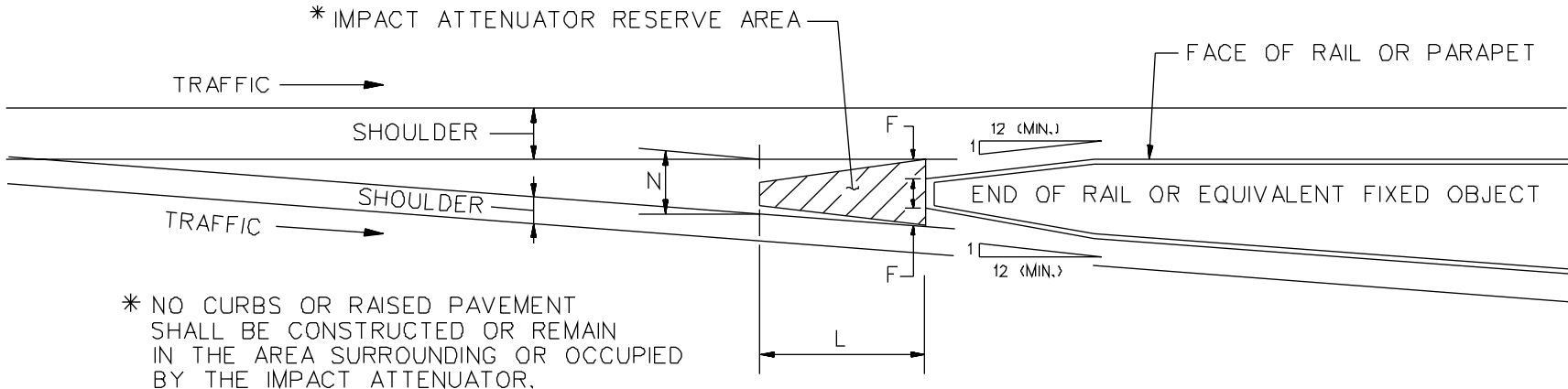
13-7.02 End Treatment Selection

Guide rail end treatments present a potential roadside hazard if not properly selected, designed, and installed. Department policy is that all new end treatments installed on the State-owned highway system must meet the NCHRP Report 350 criteria (TL-3 minimum). This Section discusses those treatments which are acceptable for use.

13-7.02.01 End Treatment Design

For the leading ends of metal beam rail Type R-B 350 guide rail, the following will apply:

1. End Anchorage Outside Clear Zone. The preferred end treatment is to flare the guide rail to outside the clear zone and use the End Anchorage Type I. See the *Connecticut Standard Sheets* for details of the Type I end anchorage.
2. Earth Cut Slope and Rock Cut Anchorages. Wherever practical, use these anchorages for the R-B 350. They eliminate the possibility of an errant vehicle striking the terminal end or running behind the terminal. The *Connecticut Standard Sheets* illustrate the details for these anchorages with the R-B 350.
3. Terminal Within Clear Zone (NHS). If a crash worthy end terminal is needed to anchor W-beam guide rail within the clear zone, designers should choose an impact attenuator from the approved list in the latest Guide Rail Procedure in Appendix A. When the recommended length of need is not attainable due to intersecting roads or driveways and when the use of an impact attenuator or 3-cable guide rail is inappropriate, a radius rail with a Type II end anchor may be placed down the driveway. In some cases, an easement for placement of the anchor may be required. Refer to Section 13-6.07 for details and sight line requirements.
4. Terminal Within Clear Zone (Non-NHS). As with NHS roadways, designers should strive to anchor w-beam guide rail by extending the anchor outside the clear zone and/or anchoring the end in an earth cut slope or rock outcrop. An impact attenuator may be used as a last option only if all grading requirements and design features can be obtained. Refer to Department grading plans for impact attenuators. If the above options are not appropriate, designers may consider regrading the roadside so that a proper anchor can be installed. Refer to Figure 13-6D for guide rail treatment at intersecting roads and driveways.



Design Speed on Mainline (km/h)	Dimensions for Crash Cushion Reserve Area (meters)								
	Minimum						Preferred		
	Restricted Conditions			Unrestricted Conditions					
	N	L	F	N	L	F	N	L	F
80	2	2.5	0.5	2.5	3.5	1	3.5	5	1.5
90	2	5	0.5	2.5	7.5	1	3.5	10	1.5
100	2	8.5	0.5	2.5	13.5	1	3.5	17	1.5
110	2	11	0.5	2.5	17	1	3.5	21	1.5

RESERVE AREA FOR CRASH CUSHION IN GORES
Figure 13-7C

For the trailing ends of metal beam rail Type R-B 350 guide rail, the following will apply:

1. Undivided Facilities (NHS). The above criteria for the approach ends of Type R-B 350 also applies to its trailing end on a two-way facility and on an undivided multi-lane facility.
2. One-Way Roadways (NHS and Non-NHS). These include interchange ramps and one roadway of a divided facility. In these cases, the trailing end of Type R-B 350 may be the End Anchorage Type I placed within the clear zone. The rationale is that the end anchorage cannot be impacted head on.

13-7.02.02 Three Cable Guide Rail

It is not necessary to place the end anchorage outside of the clear zone. The following applies to its end treatments:

1. End Anchorage Type I. This is the preferred end treatment.
2. End Anchorage Type II. This terminal is used where narrow openings must remain for driveways, crossing roads, etc., and the use of the End Anchorage Type I is impractical.

See the *Connecticut Standard Sheets* for the use of each end treatment with three cable guide rail.

13-7.02.03 Merritt Parkway

See the *Connecticut Standard Sheets* and the latest Guide Rail Procedure in Appendix A for acceptable end treatments.

13-7.02.04 Metal Beam Rail Median Barrier (Type MD-B 350)

The Department uses these types of terminal treatments for the Type MD-B 350:

1. End Anchorage Type I. This treatment is used when the median metal beam rail can be flared to a point outside the clear zone or to another safe location. The details for this terminal type are illustrated in the *Connecticut Standard Sheets*.
2. Terminal End Treatments. There are several types of special end treatments available for median metal beam rail. These end treatments are used where the terminal end for the median rail cannot be flared to a point outside of the clear zone (e.g., in narrow medians).

The selection of the appropriate end treatment will be based on a case-by-case assessment considering initial cost, maintenance, grading requirements, etc. Refer to the Guide Rail Procedure in Appendix A for the Department approved list.

When the medial rail extends down an on/off ramp to a T intersection, an MD-B End Anchorage Type I may be used. The anchor shall be placed so that sight line is not compromised and that clear zone requirements for the intersecting road is met.

13-7.02.05 Concrete Median Barrier

A variety of situations exist on Connecticut roadways where the leading ends of concrete barriers require shielding. Refer to the Guide Rail Procedure in Appendix A for the Department approved list.

13-8.0 REFERENCES

1. *Roadside Design Guide*, AASHTO.
2. *Guide for Selecting, Locating, and Designing Traffic Barriers*, AASHTO, 1977.
3. *A Supplement to A Guide for Selecting, Locating, and Designing Traffic Barriers*, Texas Transportation Institute, March, 1980.
4. *Safety Design and Operational Practices for Streets and Highways*, FHWA, March, 1980.
5. FHWA-IP-83-4 *A Procedure for Determining Frequencies to Inspect and Repair Highway Safety Hardware*, December, 1983.
6. Research Report 67-1 *New Highway Barriers, The Practical Application of Theoretical Design*, New York Department of Public Works, May, 1967.
7. NYSDOT-ERD-76-RR38 *Testing of Highway Barriers and Other Safety Appurtenances*, New York State Department of Transportation, December, 1976.
8. Transportation Research Record 970, "Development of Proposed Height Standards and Tolerances for Light-Post Traffic Barriers," James E. Bryden, 1984.
9. "A Roadside Design Procedure," James Hatton, Federal Highway Administration, January, 1974.
10. FHWA/NY/RR-80/83 *Crash Tests of Sharply Curved Light-Post Guide rail*, New York State Department of Transportation, July, 1980.
11. NCHRP Report 150 *Effect of Curb Geometry and Location on Vehicle Behavior*, Transportation Research Board, 1974.
12. NCHRP Report 158 *Selection of Safe Roadside Cross Sections*, Transportation Research Board, 1975.
13. NCHRP Synthesis 66 *Glare Screen Guidelines*, Transportation Research Board, December 1979.
14. NCHRP Report 350 *Recommended Procedures for the Safety Performance of Highway Features*, Transportation Research Board, 1993.
15. *Crash Cushions -- Selection and Design Criteria*, FHWA, 1975.
16. "Crash Cushions, Safety Systems," Technical Notebook, Energy Absorption Systems, Inc.

Appendix

This Appendix to Chapter Thirteen presents the following:

1. Guide Rail Procedure
2. FHWA Technical Advisory T5040.32 “Curved W-Beam Guardrail Installations at Minor Roadway Intersections.”

Guide Rail Procedure

When the American Association of State Highway and Transportation Officials and Federal Highway Administration's (AASHTO-FHWA) agreement regarding the National Cooperative Highway Research Program (NCHRP) Report 350 was published in 1997, the Department developed a procedure for its implementation dated, December 1, 1997. The following procedure will supersede that guide rail procedure.

It has always been Department practice to attempt to provide the traveling public with a forgiving roadside. Although a forgiving roadside is not always possible, every effort should be made to eliminate the need for railing. When all means to remove the need for railing have been exhausted, designers should refer to the following procedure and Chapter 13 of the Department's Highway Design Manual (HDM). When special instances arise, that are not addressed in this procedure, the appropriate Division Manager must approve alternate designs.

Section 13-A.01: National Highway System (NHS) and State Roadways with Design Speeds > 80kph and/or Traffic Volumes > 6000 vpd and all Freeway Ramps

13-A.01.a Railing: All new roadside safety appurtenances installed on NHS and State roads, as noted above must meet the testing criteria found in NCHRP Report 350 Test Level 3 (TL-3) or better.

1. When any of the longitudinal barriers requiring removal, as listed below, are within the limits of a project, and their need cannot be eliminated, the railing shall be replaced with a barrier chosen from the approved longitudinal barrier list.

Longitudinal Barriers Requiring Removal:

- a) Two-cable on wood posts.
- b) Three cable with steel bracket on steel or wood posts.
- c) R-I and MD-I w-beam guide rails on weak steel posts.
- d) R-B and MD-B w-beam guide rails with the steel blockouts.

Approved Longitudinal Barriers:

- a) Three Cable Guide Railing (I-Beam Posts), TL-3.
- b) R-B 350 and MD-B 350 w-beam guide rail with polyethylene blockout, TL-3.
- c) 1145 mm F-shaped Precast Concrete Barrier Curb (PCBC), TL-5.
- d) 152 mm x 152 mm roadside box beam, TL-3 *
- e) 152 mm x 200 mm median box beam, TL-3. *
- f) Thrie-beam 350 guide rail with modified steel blockout, TL-4+. *
- g) Innovative Barriers. See Section 13-A.01.e.

* Note: These barriers may only be used with the written permission of the Transportation Engineering Administrator.

Guide Rail Procedure

2. New installations of R-I, MD-I, R-B, and MD-B guide rail are prohibited.
3. New R-B 350 guide rail including systems, anchors, and transitions installed on limited access highways and ramps shall use 10 gauge w-beam rail elements. Standard sheets have been revised to include this change.
4. Existing guide rail types R-I, MD-I, R-B, and MD-B shall be either eliminated, replaced, or converted to R-B 350 or MD-B 350. See Department Specifications.
5. Avoid gaps less than 60 m between guide rail end anchors.

13-A.01.b Anchors:

1. Leading-end, turned-down end anchors, except three cable guide railing (I-Beam Posts), are no longer allowed within the clear zone. Refer to HDM Section 13-2 for clear zone applications. Existing leading end anchors within the limits of a project in the clear-zone shall be either flared away from the roadway to meet clear-zone requirements, anchored into an earth-cut slope, attached to a rock face or, as a last option, installed with an impact attenuator. When proposing an impact attenuator, refer to the attached chart for design parameters and the Department's standard sheets for grading requirements. There shall be no curbing in front of, or fixed objects in the vicinity of, any impact attenuator.
2. Remove all existing leading-end blunt ends and terminate the rail using an appropriate end treatment chosen from Section 13-A.01.b1 above.
3. Pavement for railing shall be used only within public water supply watershed areas and at the approaches to bridges over waterways. In all other areas and when the water course is greater than 15.24 m from the road and paralleling it, use processed aggregate under railing. Some impact attenuators require a deck structure and others may be installed with processed aggregate or pavement for railing.
4. Trailing-end, turned-down end anchors for w-beam guide rail may continue to be placed within the clear-zone on divided or one-way roadways. On bi-directional roadways, the trailing-end, turned-down end anchor shall be placed outside the clear-zone. The clear-zone, in this case, is measured from the centerline of the road to the last post before the turndown. The concrete anchor for the turndown shall then be measured and placed as shown on the Department's standard sheets.
5. When the recommended length of need is not attainable due to intersecting roads or driveways and when the use of an impact attenuator or three cable guide rail is inappropriate, a radius rail with a Type II end anchor may be placed down the driveway. In some cases, an easement for placement of the anchor may be required. Refer to the HDM Section 13-6.07 for details and sight line requirements.

Guide Rail Procedure

13-A.01.c Guide Rail to Bridge Rail Transitions:

1. At this time, the R-B 350 transition to a vertical-shaped bridge parapet has successfully met NCHRP Report 350 guidelines. FHWA has scheduled testing for the R-B 350 transition to a safety-shaped parapet and expects results by September of 2000. (Both of these transitions were originally approved by FHWA per NCHRP Report 230 guidelines.)
2. All existing bridge rail transitions not meeting NCHRP Report 230 requirements within the limits of a project shall be converted to one of the R-B 350 guide rail transitions. A deficient-approach guide rail is one where the rubrail is not attached to the parapet, where the system improperly transitions strength, or where the system is completely unattached.
3. The R-B 350 trailing-end bridge attachment shall only be designed for single-direction roadways. All four corners of a bridge on a bi-directional roadway shall be treated as an approach end regardless of clear-zone requirements.

13-A.01.d Curbs and Curb/Barrier Combinations :

1. The standard curb used on high-speed, high-volume NHS or State roadways shall be the 100 mm bituminous concrete park curbing shown in the Department standard sheets.
2. When w-beam guide rail is installed without curb, it may be placed 305 mm or more from the edge of pavement only on slopes 1:10 or flatter. If the rail is installed within 600 mm of the edge of shoulder, the rail height is measured from the shoulder slope extended to the rail. If the rail is installed beyond 600 mm from the edge of shoulder, the rail height is measured from the ground directly below the rail. Deflection requirements must be adhered to at all times.
3. When w-beam guide rail is installed with curb, install it flush with the face of curb and measure the rail height from the top of pavement. If curb and sidewalk are present and the rail is placed behind the sidewalk, measure the rail height from the top of sidewalk. Deflection requirements must be adhered to at all times.
4. The use of granite stone transition curbing (gstr) has been discontinued. Existing gstr may remain in place if a 100 mm reveal at the parapet can be obtained to accommodate the R-B 350 Safety Shape Attachment. If the existing curb does not have a 100 mm reveal, replace it with the Department standard curb. When installing the R-B 350 Vertical Shape Attachment, measure the rail height from the top of curb.

Guide Rail Procedure

13-A.01.e Innovative Barriers:

1. Section 328 of the NHS Act entitled Roadside Barrier Technology requires 2.5% of all barrier installed on the NHS beginning with calendar year 1996 to be innovative. The term barrier, as used in Section 328, includes both temporary and permanent median and roadside barrier, but excludes guide rail. The following is a list of NCHRP Report 350 approved innovative barriers. Designers should review and investigate the possibility of using them in their projects.

Permanent:

1070 mm high (or higher) Jersey-Shaped PCBC.

1070 mm high (or higher) F-Shaped PCBC. (Dept. standard is 1145mm)

1070 mm high (or higher) Vertical-Shaped PCBC.

1070 mm high (or higher) Single-Sloped PCBC.

13-A.01.f Concrete Barriers:

1. Due to the superior performance during crash tests, FHWA has deemed the F-Shape PCBC as the preferred barrier shape. Therefore, 1145 mm F-Shape PCBC shall be used for new construction to provide positive median separation on limited access highways or when needed on the roadside. Replacement of existing Jersey Shape PCBC within the limits of a project is not required.
2. Temporary median Jersey-shaped PCBC may continue to be used for maintenance and protection of traffic during construction provided that positive moment connection between the barriers as shown in the Department Special Provision 822 or Miscellaneous Connecticut Detail is incorporated.

13-A.02 Merritt Parkway

13-A.02.a Railing:

1. The Merritt Parkway Guide rail (MPGR) has successfully met NCHRP Report 350 TL-3 guidelines and is approved exclusively for use on the Merritt Parkway. Any existing longitudinal barrier requiring replacement within the limits of a project shall be replaced with the MPGR. Refer to Section 13-A.01.a for the list of longitudinal barrier requiring replacement.

13-A.02.b Anchors:

1. A crash-worthy end treatment is not available for MPGR. Use one of the following applications to anchor the leading-end.
 - a) Anchor the rail to a rock face.

Guide Rail Procedure

- b) Bury the anchor in an earth cut slope.
- c) Place the anchor outside the clear zone and bury the end.
- d) Bury the anchor in a built-up berm.(Use only as a last option.)

13-A.02.c Guide rail to Bridge Rail Transitions:

1. The MPGR transition to a bridge rail has been successfully crash tested to meet NCHRP Report 350 TL-3 guidelines. It was tested with gsc and is currently the only place where new gsc can be installed. Refer to Department standard sheets and the HDM Sections 13-4 and 13-5 for more information.

13-A.03 State Roadways with Design Speeds < 80kph and Traffic Volumes < 6000 vpd

13-A.03.a Railing:

1. Existing metal beam rail (type R-I and R-B) does not need to be replaced provided it meets length of need and deflection requirements. The rail shall be extended if the length of need is inadequate. All other new installations of guide rail should meet the testing criteria in NCHRP Report 350.
2. Replace rail such as two-cable on wood posts and three cable with steel brackets on wood or steel posts according to Department standards, even if the run of rail extends beyond the project limits.

13-A.03.b Anchors:

1. Review existing anchors for location and type. Extend the anchor to meet clear-zone requirements or anchor it into an earth cut slope or rock face. Use an impact attenuator only if all grading requirements and design features can be obtained. Refer to standard grading plans for proper installation. If the railing can be extended up to an additional 60 m to provide proper anchorage, this should be done instead of installing an impact attenuator. Types R-I and MD-I guide rail needing an impact attenuator will require 7.62 m of strong post transition before installing the impact attenuator.
2. Do not terminate guide rail at a second rail type unless a transition meeting Department standards can be applied. Refer to HDM Section 13-6.09.02 and Figure 13-6G. Never transition or terminate guide rail at a critical juncture such as at the radii of intersections.
3. If the above options are not appropriate, designers may consider re-grading the roadside so that a proper anchor can be installed. Refer to figure 13-6D in the HDM for guide rail treatment at intersecting roads and driveways.

Guide Rail Procedure

13-A.03.c Guide Rail to Bridge Rail Transition:

1. Unconnected top rail and/or rubrail for bridge-approach guide rail transitions shall be connected with an approved transition design meeting the requirements of NCHRP Report 350. See Department standard sheets. Existing bridge-approach guide rail transitions for types R-I or R-B are acceptable provided any rubrail is also attached.

13-A.04 Scenic Roadways

1. For installations on scenic roads, the designer will have the option of using ASTM A-588 steel, “weathering steel” rail elements and posts for metal beam rail, and weathering steel posts for three cable guide rail (I-beam posts). Where there is a large body of water, such as major rivers and lakes adjacent to a scenic roadway or within the roadway fill slope, the designer has the option of using galvanized or weathering steel box beam rail elements and posts. If the body of water is a potable reservoir, Section 13-3.08 of the HDM governs.

13-A.05 Local Roadways

1. Municipalities are encouraged to use current Department guide rail standards, and procedures for their roadside safety appurtenances. Refer to Chapters Two, Four, Five and Thirteen of the HDM.

13-A.06 General

1. When a designer considers using three cable guide rail (I-beam posts), accident history should be investigated. If the accident history shows a significant number of accidents have occurred; designers should consider using R-B 350 guide rail instead. In this case, R-B 350 guide rail may be more appropriate because it may remain in services after a hit where as the three cable may not.

Guide Rail Procedure

CHARACTERISTICS OF IMPACT ATTENUATORS

April 1, 2000

ALL THE SYSTEMS HAVE FHWA APPROVAL PER NCHRP-350 TEST LEVEL II

System	Manufacturer or Distributor	FHWA Approval Date	W-beam End Terminal	Crash Cushion	Hazard Location	Trans. to Rigid System Required	Std. Width (mm)	Std. Length (mm)	Deck Structure Required	Bi-direct Capable	Redirect Capable	Comments	Estimated Cost Mat. & Labor
Gating Tangential Systems													
SKT-350	Distributed by Road Systems Inc. 1-915-263-2435	4/2/97	yes	no	Roadside and *Median	yes	610+H15	15,240	no	yes only if head of system is placed outside clear zone for opposing direction of traffic	yes	*Use in a median where the opposing travelway is > 9.1m away. Site grading req'd.	\$3,200 to \$3,500
ET-2000	Manufactured by Syro/Trinity 1-800-321-2755	12/20/96	yes	no	Roadside and *Median	yes	610	15,240	no	yes only if head of system is placed outside clear zone for opposing direction of traffic	yes	*Use in a median where the opposing travelway is > 9.1m away. Site grading req'd.	\$3,200 to \$3,500
Gating Flared Systems													
SRT - 350 (Ross-350)	Manufactured by Syro/Trinity 1-800-321-2755	1/27/98	yes	no	Roadside and *Median	yes	910	11,430	no	no	yes	*1.2m flare. Use in a median where opposing travelway is >9.1m away. Site grading req'd.	\$2,100 to \$2,500
FLEAT 350	Distributed by Road Systems Inc. 1-915-263-2435	4/2/98	yes	no	Roadside and *Median	yes	610	11,430	no	yes only if head of system is placed outside clear zone for opposing direction of traffic	yes	*Use in a median where the opposing travelway is > 9.1m away. Site grading req'd.	\$2,100 to \$2,500

Guide Rail Procedure

CHARACTERISTICS OF IMPACT ATTENUATORS

April 1, 2000

ALL THE SYSTEMS HAVE FHWA APPROVAL PER NCHRP-350 TEST LEVEL II

System	Manufacturer or Distributor	FHWA Approval Date	Wbeam End Terminal	Crash Cushion	Hazard Location	Trans. to Rigid System Required	Std. Width (mm)	Std. Length (mm)	Deck Structure Required	Bidirect Capable	Redirect Capable	Comments	Estimated Cost Mat. & Labor
Gating Bi-directional Systems													
BRAKEMASTER	Distributed by TRANSPO 1-800-321-7870	6/19/97	yes	yes	Roadside *Median and Gore	yes	610	9125	yes	yes	yes	*Median width 6.1m or more. Site grading req'd.	\$5,000
C-A-T	Manufactured by Syro/Trinity 1-800-321-2755	5/1/96	yes	yes	Roadside, Median and Gore	yes	705	9125	no	yes	yes	Site grading req'd.	\$5,000
ADIEM 350	Manufactured by Syro/Trinity 1-800-321-2755	3/3/97	yes	yes	Roadside and Median	no	711	9144	yes	yes	yes	Use to shield fixed objects 610 mm wide.	\$13,500
Gating Sand Barrel Systems													
FTCH UNIVERSAL MODULE BARRELS	Distributed by TRANSPO 1-800-321-7870	6/28/95	no	yes	Roadside, Median & Gore	no	1980 to unlimited	5496 to 11887	no	yes	no	Primarily used as a temporary barrier	\$375 per barrel
ENERGTE III (BARRELS)	Distributed by TRANSPO 1-800-321-7870	6/28/95	no	yes	Roadside, Median & Gore	no	1980 to unlimited	5496 to 11887	no	yes	no	Primarily used as a temporary barrier	\$375 per barrel
Non-Gating Systems													
REACT 350 Family	Distributed by TRANSPO 1-800-321-7870	Various Dates	yes	yes	Roadside, Median & Gore	no (Transition to Wbeam Available)	914 to 3048	4704 to 9296	yes	yes	yes	Primarily used in locations where a high # of accidents have occurred on high speed high volume roadways	\$15,000 to \$28,000
QUADGUARD Family	Distributed by TRANSPO 1-800-321-7870	Various Dates	no	yes	Roadside, Median & Gore	no	610 to 2286	1740 to 11,810	yes	yes	yes	Primarily used to shield fixed objects	\$7500 to \$30,000
NCIAS	CTDOT	3/26/99	no	yes	Roadside, Median & Gore	Backup Support Required	914	9144	no	yes	yes	Non-Proprietary	\$12,000
TRACC	Manufactured by Syro/Trinity 1-800-321-2755	11/13/98	yes	yes	Roadside, Median & Gore	no	800	6040	yes	yes	yes	Unit is shipped completely assembled	\$10,500

CURVED W-BEAM GUARDRAIL

INSTALLATIONS AT MINOR ROADWAY
INTERSECTIONS

T 5040.32

April 13, 1992

- Par. 1. Purpose
2. Background
3. Summary
4. Recommendations
5. Related Technical Information

1. PURPOSE. To transmit information on two different operational designs of curved guardrail for radii between 8½ and 35 feet, as well as a specialized application of an 8½ foot radius curved guardrail. These new designs have been successfully crash tested and are acceptable for new construction, as well as for improving safety at existing sites. These designs are most appropriate for use on low volume highways.

2. BACKGROUND

- a. Often roads or driveways intersect a highway close to the end of a bridge or other immovable, restrictive features of the highway. To shield both the end of the bridge and the steep embankment, a strong post W-beam guardrail curved around the radius is typically used. Often, these installations have not been effective when the curved section of the barrier has been hit at higher speeds. A vehicle which impacts the barrier under such conditions will generally vault over or penetrate the guardrail; or, in the event that the vehicle is contained by the guardrail, the resulting decelerating forces often exceed the recommended limits for occupant safety. In many of these situations, it is not practical to change the site conditions by relocating the intersecting roadway further away from the bridge end in order to allow room for a standard approach guardrail. It was, therefore, necessary to develop a curved guardrail installation which would substantially improve the safety at these sites.

- b. A cooperative research program between the Washington State Department of Transportation and the Federal Highway Administration was undertaken to design improved curved guardrail approaches and transitions. Subsequently, Yuma County in Arizona tested and developed a stiffer 8½-foot radius curved guardrail for sites where canals or other features such as drainage are close to the guardrail. Both systems are intended primarily for use on lower-speed through roadways intersected by low-speed, low-volume roads, driveways, or maintenance rights-of-way.

3. SUMMARY

- a. This information can be used to enhance highway safety in certain locations where it is desirable to use curved strong post guardrail sections. This information is appropriate for use in new construction and for improving or upgrading existing curved guardrail installations.
- b. The curved sections have been successfully crash tested within the performance limits detailed in this Technical Advisory. Crash tests also indicated that these sections have limitations and should not be used in situations which vary excessively from the conditions (such as grading, layout, or vehicle speed) under which these successful crash test results were obtained.
- c. Adherence to detail is important. Guardrail section layout and construction details such as rates of curvature, use of breakaway Controlled Releasing Terminal (CRT) posts, adequate deflection zone behind curved guardrail and appropriate end anchorages are elements which can critically affect performance.
- d. The recommended designs and details listed below are shown in the attached drawings:
 - (1) Figure 1: Curved W-Beam Guardrail Installation for an 8½-foot radius.
 - (2) Figure 2: Curved W-Beam Guardrail Installation for a 35-foot radius.
 - (3) Figure 3a: Special Anchor Details.

(4) Figure 3b: Special Anchor Details.

(5) Figure 4: Yuma County, AZ, Curved W-Beam Guardrail Installation for an 8½-foot radius.

4. RECOMMENDATIONS

- a. The curved guardrail designs detailed in this Technical Advisory should be considered for use in new construction projects as appropriate. Existing curved guardrail installations may also be replaced or upgraded as the opportunity becomes available.
- b. These curved guardrail designs are for radii of 8½ feet and 35 feet. Crash test results and technical experience indicate that this system will also perform satisfactorily with other intermediate radii as noted in the table on Figure 1. Situations which require a curved guardrail installation which falls beyond this range of radii should be designed individually and not subjected to a "make it fit" misapplication of these details.

5. RELATED TECHNICAL INFORMATION

- a. The following details are essential to proper system performance in the field:
 - (1) Breakaway CRT posts are used within the curved "nose" of the guardrail installation. Wood blockouts are not used on the CRT posts. The W-beam rail in the curved area is attached directly to the CRT post with a button-head bolt which has no washer. This is done to have the posts break away in the curved nose area and thus separate from the rail. This minimizes rotation of the rail during impact and minimizes the likelihood that a vehicle will vault over the guardrail upon impact.
 - (2) For the 8½-foot radius layout (Figure 1), the guardrail is not bolted to the one CRT post at the center of the curved nose area. This allows the center post to easily separate from the guardrail upon impact, and facilitates guardrail deflection without having this bolt ripping or snagging the W-beam rail section.

- (3) A flat approach to the curved guardrail installation is necessary in order to ensure proper performance of the system. The slope in front of the installation should not exceed 15:1. If the installation is on a superelevated section, analysis should be performed in order to evaluate the potential for vaulting of an errant vehicle.
 - (4) The embankment slope should break at least 2 feet behind the post (so that the post will have adequate bearing strength when hit). It is desirable that the embankment slopes behind the guardrail not be steeper than 2:1. Successful crash tests were done on installations with 2:1 slopes behind the guardrail.
 - (5) Considerable deflection of the W-beam guardrail can be expected with higher speed impacts on the curved guardrail portion of the installation. Therefore, the area behind the curved portion of the guardrail, shown as the cross-hatched areas on Figures 1, 2 and 4, must be kept free of fixed objects.
- b. These curved guardrail installations are not appropriate for use in all situations. To avoid misapplication, the designer should be aware of the following limitations:
- (1) When used in close proximity to a bridge with a rigid bridge rail, these design layouts require an adequate space between the curved guardrail installation and the bridge end (approximately 25 feet) to place a crashworthy W-beam transition from the W-beam guardrail to a rigid bridge rail.
 - (2) Since the special end anchor shown in Figures 3A and 3B has not been crash tested as a guardrail terminal, its use should be limited to low-speed, low-volume facilities with a stop condition such as intersecting driveways or service-type roadways. For most intersecting public highways, the curved guardrail installation should be either terminated along the intersecting roadway with an acceptable terminal system, or connected to an existing guardrail system.
 - (3) The special end anchor system was developed for use when it is necessary to end the guardrail system immediately after the curved section. This end anchor uses many components

from the breakaway cable terminal design. It also includes another cable to connect the steel foundation of the next-to-last post to the end post anchoring cable system. One novel feature incorporated is a pivoting pipe section which is placed over the end post and improves rail performance by allowing it to swivel as it is deflected by a car. This special end anchor is not a crashworthy terminal for high speed highways. Therefore, as stated previously, its use should be limited to driveways or service roadways.

- (4) In the high speed crash tests, some heavy debris was observed flying about in the area behind the impact. Judgment must be used when installing these sections where people are likely to be present in the area behind the curved section.

c. Curved guardrail installations of the Washington State design having radii of $8\frac{1}{2}$ feet and 35 feet were successfully crash tested, but it should be noted that the 35-foot radius installation did not perform adequately when impacted at 60 MPH by a large vehicle (4740 lbs.). Satisfactory results were obtained for the 35-foot radius installation when a test was performed at a reduced speed of 50 MPH with the large vehicle. Two intermediate radii (17 feet and $25\frac{1}{2}$ feet) are provided in Figure 1. Installations having a different radius between $8\frac{1}{2}$ feet and 35 feet must be specially detailed so as to use only full lengths of W-beam rail, and to shop bend only full sections of rail. Any such intermediate radius designs must incorporate all other critical details and post types and locations as shown on the attached Figures 1 and 2 in order to be considered acceptable.

- (1) It is important to note that the Yuma County design shown in Figure 4 was successfully crash tested at 50 mph. Radii larger than $8\frac{1}{2}$ feet should not be used without further testing.
- (2) All of the attached designs are based on an intersection angle of 90 degrees. If field conditions vary excessively from 90 degrees, it will be necessary to specially detail a curved guardrail section so that the curved rails will fit the intersection geometry, and that only full sections of W-beam rail will be shop bent for installation.

d. The attached drawings, in a format suitable for use on the

FHWA TECHNICAL ADVISORY T 5040.32
April 13, 1992

Intergraph CAD system, are available from the Federal Highway Administration, Office of Engineering, Geometric and Roadside Design Branch, HNG-14, 400 Seventh Street, S.W., Washington, D.C. 20590.

/s/ Thomas O. Willett

Thomas O. Willett
Director, Office of Engineering

/s/ R. Clarke Bennett

R. Clarke Bennett
Director, Office of
Highway Safety

Attachments (Not on disk-see printed copy of Technical Advisory)

Chapter Fourteen

MAINTENANCE AND PROTECTION OF TRAFFIC THROUGH CONSTRUCTION ZONES

Table of Contents

		<u>Page</u>
14-1.0	GENERAL	14-1(1)
	14-1.01 <u>Responsibilities</u>	14-1(1)
	14-1.02 <u>Maintenance and Protection of Traffic Plans (MPT)</u>	14-1(2)
14-2.0	TRAFFIC CONTROL MANAGEMENT	14-2(1)
	14-2.01 <u>Work Zone Type</u>	14-2(1)
	14-2.02 <u>Work Zone Traffic Control Strategy</u>	14-2(2)
14-3.0	GEOMETRIC DESIGN	14-3(1)
	14-3.01 <u>Design Speed</u>	14-3(1)
	14-3.02 <u>Sight Distance</u>	14-3(1)
	14-3.03 <u>Lane/Shoulders Widths</u>	14-3(1)
	14-3.04 <u>Transition Taper Rates</u>	14-3(2)
	14-3.05 <u>Alignment</u>	14-3(4)
	14-3.06 <u>Exceptions</u>	14-3(4)
14-4.0	ROADSIDE SAFETY	14-4(1)
	14-4.01 <u>Warrants for Positive Protection</u>	14-4(1)
	14-4.02 <u>Clear Zones</u>	14-4(2)
	14-4.03 <u>Roadside Barriers</u>	14-4(2)
	14-4.04 <u>End Treatments</u>	14-4(3)
	14-4.05 <u>Design/Layout</u>	14-4(3)
14-5.0	REFERENCES	14-5(1)

Chapter Fourteen

MAINTENANCE AND PROTECTION OF TRAFFIC THROUGH CONSTRUCTION ZONES

14-1.0 GENERAL

Because much of the Department's highway program will include work on existing highways, highway construction will often disrupt existing traffic operations. Therefore, the designer must devote special attention to traffic control in construction zones to minimize possible operational and safety problems through the work zone.

14-1.01 Responsibilities

The following summarizes the division of responsibilities for the Maintenance and Protection of Traffic (MPT):

1. Designer. The prime designer is responsible for initiating action on the MPT, and he/she will request input from the Division of Traffic Engineering. If a temporary road will be constructed for traffic during construction (i.e., a detour), the designer is responsible for its geometric and roadside safety design. The designer will work with Traffic to determine the traffic control strategy for the MPT on existing roads; see Section 14-2.0. Also, the designer is responsible for ensuring that the highway can be constructed using the developed MPT plans.
2. Division of Traffic Engineering. Traffic will prepare or review the traffic control plans, including all traffic control devices, on all projects on all temporary, proposed and existing roads. Traffic also maintains special standard sheets for traffic control devices, which are included with all projects. For a temporary road which will be used by traffic during construction, Traffic will provide the layout or review the layout of all traffic control devices on that road. Traffic and the designer will work together to determine the traffic control strategy for the MPT.

14-1.02 Maintenance and Protection of Traffic (MPT) Plans

The purpose of the MPT plans is to develop a concept for the safe and efficient movement of traffic through a highway or street construction zone. They may range in scope from a set of plans which describes every detail of traffic accommodation to the standard traffic control plansheets provided by the Division of Traffic Engineering. The scope of the MPT plans will depend on the complexity and duration of the construction project.

The MPT plans are included in the plans, specifications and estimates (PS&E) submission for every project. These plans should address the following, as applicable:

1. signing;
2. application and removal of pavement markings;
3. temporary signalization;
4. delineation and channelization;
5. lane closures;
6. detours and crossovers;
7. selection and placement of all traffic control devices;
8. locations and types of safety appurtenances;
9. means of maintaining access to and from existing interchange ramps and/or roadside properties;
10. flagging;
11. work scheduling restrictions, if applicable;
12. storage of equipment and materials;
13. traffic regulations, if applicable;

14. duration of use of any traffic control feature (throughout construction period, only during closure of left lane, etc.);
15. surveillance and inspection requirements;
16. contractor access to the work site;
17. coordination with any other construction projects;
18. truck-mounted attenuators;
19. capacity analyses;
20. liquidated damages; and/or
21. use of special materials.

For construction work which may involve a significant disruption to existing traffic operations, the designer should consider during the MPT plan development the likely impact on all affected local interests. These include, where applicable, the operations of the local:

1. public works or highway/street department,
2. police,
3. fire department,
4. ambulance services,
5. public transportation services,
6. school boards,
7. pedestrians and bicyclists, and
8. businesses.

14-2.0 TRAFFIC CONTROL MANAGEMENT

14-2.01 Work Zone Type

There are several basic work zone types that may be considered in a maintenance and protection of traffic plan. Note that work sites which are completely off the roadway and do not disrupt traffic are not addressed because they will generally not have a major effect on traffic. The following presents a description for each of the work zone applications:

1. Lane Constriction. This work zone type is configured by reducing the width of one or more lanes to retain the number of lanes normally available to traffic. This application is the least disruptive of all work zone types, but it is generally appropriate only if the work area is mostly outside the normal traffic lanes. It should be noted that narrow lane widths may reduce the facility's capacity, especially where there is significant truck traffic. The use of shoulders as part of the lane width will help reduce the amount of lane width reduction that may be required. Where this application is applied for long-term work zones, the current lane markings must be obliterated to avoid motorist confusion. Section 14-3.0 discusses the minimum lane widths that must be provided.
2. Lane Closure. This work zone type closes off one or more normal traffic lanes. Capacity and delay analyses may be required to determine whether serious congestion will result from lane closures. In some cases, use of the shoulder or median area as a temporary lane will mitigate the problems arising from the loss in capacity. Upgrading or replacement of existing pavement may be necessary.
3. Alternating One-Way Traffic Operation. This work zone type involves utilizing one lane for both directions of traffic. Flaggers or signals are normally used to coordinate the alternating directions of traffic. Signing alone may be sufficient for short-term work zones on very low-volume, 2-lane roads. This work zone type is generally only applicable for low- and intermediate-volume roads or short-term work zones.
4. Temporary Roadway. This work zone involves the total closure of the roadway (one or both directions) where work is being performed and the traffic is rerouted to a temporary roadway. This application may require the purchase of temporary right-of-way and usually requires extensive preparation of the temporary roadway.
5. Intermittent Closure. This work zone type involves stopping all traffic in one or both directions for a relatively short period of time to allow the work to proceed. After a specific time, depending on traffic volumes, the roadway is re-opened and all vehicles can travel through the area. This

application is normally only appropriate on low-volume roadways or during time periods where there are very low volumes (e.g., Sunday mornings).

6. Use of Shoulder or Median. This work zone type involves using the shoulder or the median as a temporary traffic lane. To use this technique, it may be necessary to upgrade the shoulder to adequately support the anticipated traffic loads. This technique may be used in combination with other work zone types or as a separate technique.
7. Crossover. This work zone type involves routing a portion or all of one direction of the traffic stream across the median to the opposite traffic lanes. This application might also incorporate the use of shoulders and/or lane constrictions to maintain the same number of lanes. Section 14-3.0 discusses the geometric design criteria that should be used to develop crossovers.
8. Detour. This work zone type involves total closure of the roadway (one or both directions) where work is being performed and rerouting the traffic to existing alternate facilities. This application may be used where there is unused capacity on roads running parallel to the closed roadway.

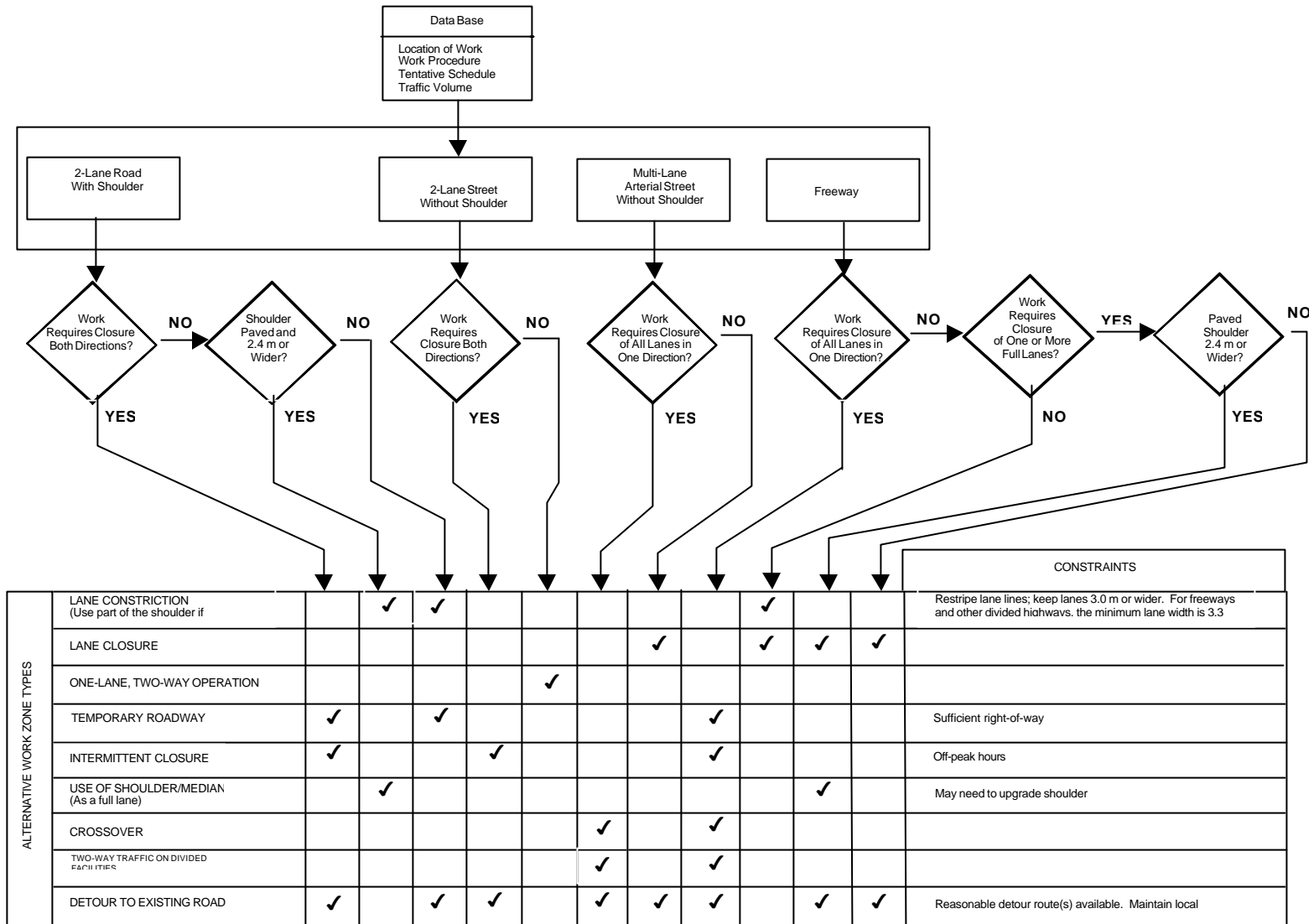
The designer must also carefully consider the impact that the detoured traffic will have on other State or local roads. A detour agreement with the Town is required when the State highway traffic is detoured onto a local road. The Division of Traffic Engineering is responsible for coordinating between the State and Town(s).

14-2.02 Work Zone Traffic Control Strategy

Selection of the appropriate work zone type represents one of the most significant elements of a control strategy. Other elements of a control strategy that should be considered include length of the work zone, time of work, number of lanes, width of lanes, traffic speeds and right-of-way. Considering these and other factors, reasonable alternates can be narrowed to a selected few for further review. Typically, only a small number of feasible work zone alternates will emerge for a particular project and, in many cases, only one may be practical. Identification of these alternates at an early stage in the planning process can reduce significantly the analysis effort necessary.

Figure 14-2A provides guidelines for identifying feasible work zone alternates based on roadway type, lane closure requirements, shoulder width, traffic volume, and the availability of right-of-way and detour routes. However, it should be recognized that every work zone location will have a wide variation of conditions and that an all-inclusive selection matrix is not practical.

In using Figure 14-2A, local policy and regulations should be recognized. Many jurisdictions have adopted safety regulations and public convenience policies as safeguards against the unacceptable impacts of work zones. These regulations and policies may impose additional constraints regarding the types of control strategies that can be implemented. Knowing these constraints can help eliminate infeasible alternates from consideration. The public convenience policies or local regulations may specify peak hour restrictions, access requirements, noise level limitations, material storage and handling, excavation procedures, work zone lengths and number of traffic lanes that must remain open.



✓ Feasible

CHART FOR IDENTIFICATION OF FEASIBLE WORK ZONE TYPES
Figure 14-2A

14-3.0 GEOMETRIC DESIGN

The following sections present design criteria which apply to temporary crossovers on divided highways, existing roadways through construction zones, and detours specifically designed for construction projects (e.g., crossovers, temporary roadways). These criteria do not apply to detours over existing routes.

14-3.01 Design Speed

Do not select a construction-zone design speed which is significantly lower than a facility's existing design speed and then attempt to mitigate the driver's speed by regulatory or advanced warning means. This may lead to poor operating conditions. With the exception of, perhaps, warning signs at horizontal curves, regulatory and warning speed signs are generally ineffective for controlling excessive vehicular speeds through construction zones. Consider providing a construction-zone design speed that will be the same as that for the existing facility.

14-3.02 Sight Distance

For the approach to the first physical indication of the construction zone, where practical, the sight distance available to the motorist should be based on the decision sight distance criteria provided in Section 7-2.0 and, at a minimum, based on the stopping sight distance criteria provided in Section 7-1.0. Through the construction zone itself, the designer should ensure that at least the minimum stopping sight distance is available to the driver. Unfortunately, the location of many design features is often dictated by construction operations. However, some elements may have an optional location. For example, lane closures and transitions should be located where the approaching driver has decision sight distance available to the lane closure or transition. Through horizontal curves in the construction area, the designer should check the horizontal clearance (i.e., the middle ordinate) of the horizontal curve using its radius and the minimum stopping sight distance for the construction-zone design speed (see Chapter Eight).

14-3.03 Lane/Shoulder Widths

In general, there should not be a reduction in the roadway cross section width through the construction zone. However, this is often not practical. Section 14-3.04 presents the minimum taper rates that should be used on approaches to lane width reductions. The following minimum lane and shoulder widths should be used in construction zones:

1. Divided Highways. For freeways and other divided highways, at a minimum, a 3.3-m lane width should be maintained with, preferably, 0.6-m or wider right and left shoulders.
2. Undivided Highways. For other highway facilities, the designer should maintain a minimum 3.3-m lane width and 0.3-m wide shoulder. Under restricted conditions, the shoulder width may be 0.0 m.

14-3.04 Transition Taper Rates

Lane closures, lane width reductions and lane shifts require the use of transition tapers to safely maneuver traffic around the encroaching restriction. Figures 14-3A and 14-3B present the minimum taper lengths for various taper applications in construction zones (e.g., lane closures, lane shifts).

Type of Taper	Taper Length
<u>Upstream Tapers</u>	
Merging Taper	L Minimum
Shifting Taper	½ L Minimum
Shoulder Taper	a L Minimum
Alternating One-Way Traffic Taper	30 m Maximum 15 m Minimum
<u>Downstream Tapers (Optional)</u>	
	30 m per lane

Length "L" is determined using the following:

$$L = 0.6 SW \quad (S \geq 70 \text{ km/h})$$

$$L = \frac{WS^2}{155} \quad (S \leq 60 \text{ km/h})$$

Where:

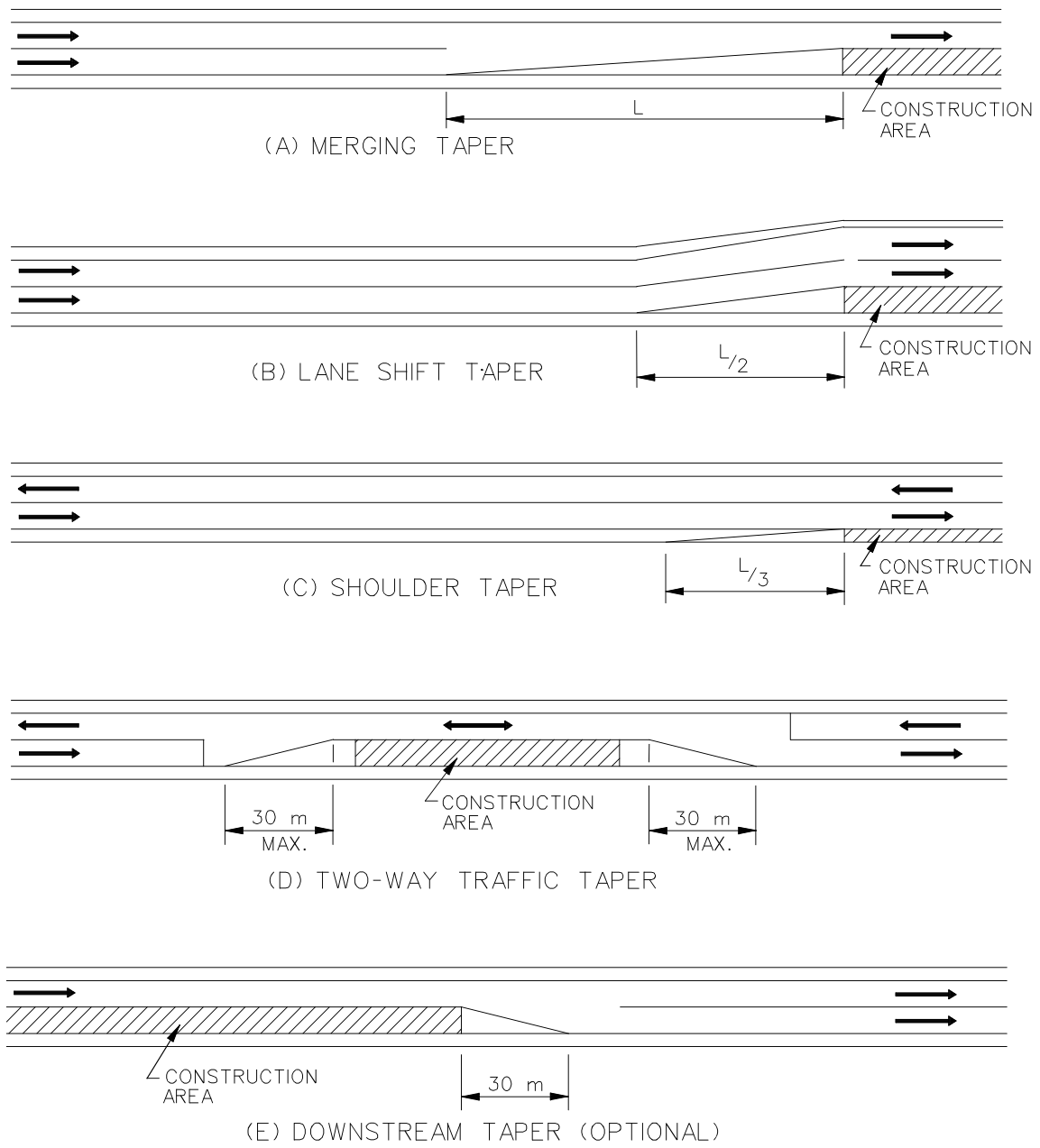
L = minimum length of transition (m)

S = 85th percentile speed (km/h), or, at a minimum, posted speed limit before construction (km/h)

W = width of offset (m)

TAPER LENGTH CRITERIA FOR CONSTRUCTION ZONES

Figure 14-3A



Note: Length "L" is determined from Figure 14-3A.

**TAPER LENGTH CRITERIA FOR CONSTRUCTION ZONES
(Application)**

Figure 14-3B

14-3.05 Alignment

Once the design speed is selected for the construction zone, the designer will use the criteria in Chapter Two (geometric design of 3R projects) for alignment considerations. Note that, although Chapter Two applies to the permanent design of non-freeways, the 3R criteria in Chapter Two is applicable to the design of the construction zones for all facilities. One application of the 3R criteria, for example, will be the minimum radius for maintaining the normal crown section through a horizontal curve for a given design speed and given (negative) superelevation (see Figure 2-5A). This will then be the minimum radius for a horizontal curve which transitions traffic from the mainline to a temporary roadway without superelevation. For low-speed urban streets, the designer will use Figure 8-3B for the minimum radius for a normal crown section.

14-3.06 Exceptions

It is not Department policy to obtain formal design exceptions for temporary conditions in construction zones.

14-4.0 ROADSIDE SAFETY

Through a construction zone, drivers are often exposed to numerous hazards (e.g., restrictive geometrics, construction equipment, opposing traffic). The designer must devote special attention to reducing a motorist's exposure to these hazards. The following sections offer roadside safety criteria which apply only to the roadside elements within the construction zone. These criteria do not apply to detours over existing routes.

14-4.01 Warrants for Positive Protection

Positive protection for run-off-the-road vehicles may be warranted in construction zones. This decision will be made on a project-by-project and site-by-site basis. The following factors should be considered:

1. duration of construction activity;
2. traffic volumes (including seasonal fluctuations);
3. nature of hazard (e.g., edge of travel lane drop-offs);
4. design speed;
5. highway functional class;
6. proximity between traffic and construction workers and construction equipment;
7. adverse geometrics which may increase the likelihood of run-off-the-road vehicles;
8. length and depth of dropoffs;
9. length of hazard; and/or
10. lane closures or lane transitions.

During the planning and design of a project, careful consideration should be given to traffic control plan alternatives which do not require the use of temporary barriers. The alternatives include construction of detour roadways, minimizing the exposure time and depth of drop-offs, and providing maximum separation between traffic and workers.

However, even with proper project planning and design, there will be many instances where barriers are clearly needed. In a barrier system, the greatest hazard occurs at the approach end. To achieve the safest condition, three goals are important:

1. flare the approach end to a location outside the clear zone or as far away from the through traffic lanes as practical; and
2. if the approach end cannot be placed outside the clear zone, provide the most crashworthy end treatment as technically and economically feasible; and

3. provide adequate delineation in advance of and along the temporary barrier.

Where traffic is directed onto the opposing roadway, the designer should consider the effect this will have on the operational characteristics of roadside appurtenances. For example, existing trailing ends of unprotected bridge rails may require approach guardrail transitions or impact attenuators, or blunt guardrail terminals may need to be protected with an acceptable end treatment.

14-4.02 Clear Zones

Section 13-2.0 provides the appropriate clear zone values for new construction/reconstruction projects. For construction zones, the clear zone should be the distances in Section 13-2.0. It is important to select the appropriate clear zone based on the construction zone design speed and not the posted speed. If the recommended clear zone cannot be achieved, the safest end treatment should be provided consistent with cost-effectiveness and geometric considerations.

14-4.03 Roadside Barriers

In general, there are two types of roadside barriers — guide railing and temporary precast concrete barrier curb (TPCBC). Design and installation details for temporary guide railing should be the same for permanent installations; see Chapter Thirteen for additional information. Metal beam rail must first be stiffened before it is attached to TPCBC.

When it has been determined that TPCBC should be used in a work zone, special care must be given to its layout. Although it provides the greatest protection to the work zone, it is also the least forgiving to the driver. Impact with the blunt end of concrete barrier (including contractor's access openings) will result in an intolerable impact, even at low speeds. All barriers will require an appropriate end treatment; see Section 14-4.04.

TPCBC should be extended at an appropriate flare rate to a point beyond the clear zone. The flare rate for TPCBC on freeways is 1:10, and for non-freeways the flare rates should be based on the design speed through the work zone. The TPCBC flare rates for non-freeways are shown in Figure 14-4A. The designer should meet these flare rates unless extenuating circumstances render these rates impractical (e.g., stop conditions, driveways, intersections).

Design Speed	Flare Rates
50 km/h or less	1 to 4
50-70 km/h	1 to 6
80 km/h or greater	1 to 8

TPCBC FLARE RATES FOR NON-FREEWAYS

Figure 14-4A

14-4.04 End Treatments

The end treatments for guide railing should be designed the same as for permanent installations. See Chapter Thirteen. Figure 14-4B lists acceptable crashworthy end treatments for TPCBC, in descending order of preference, together with recommended specific limitations and/or criteria. Figures 14-4C and 14-4D illustrate typical end treatments for TPCBC.

14-4.05 Design/Layout

Where practical, temporary roadside safety appurtenances should be designed and located as determined in Chapter Thirteen. However, it is usually not cost effective to meet the permanent installation criteria due to the limited time a motorist is exposed to construction hazards. The following offers several alternatives the designer may use in designing and locating temporary roadside safety appurtenances within construction zones:

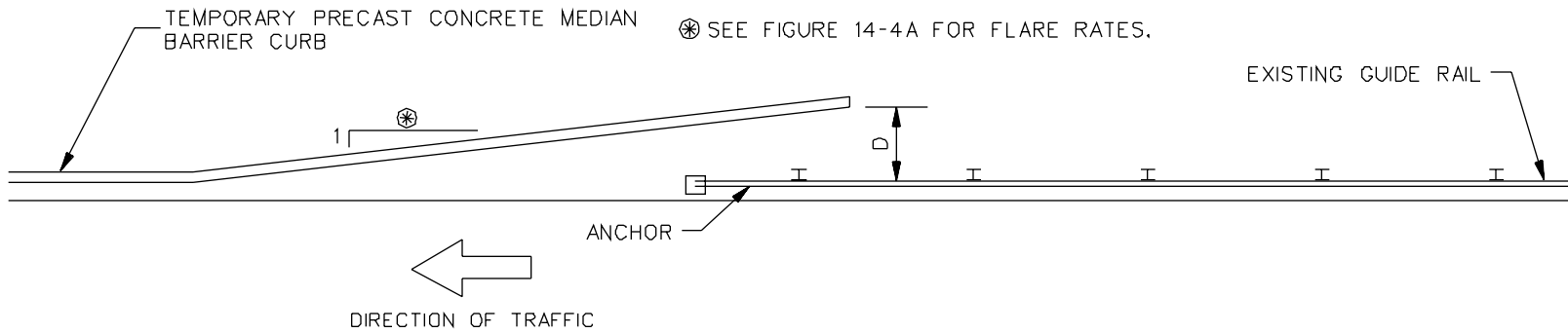
1. Length of Need. For temporary locations in construction areas, the length of barrier needed can be determined by the intersection of a line along the barrier with a line at an angle of 10° to 15° from the back of the hazard or from the clear zone distance off the travelway, whichever is less. The approach end of the barrier may be flared to a point outside of clear zone or shielded with a crashworthy end terminal or impact attenuator. For barrier lengths less than 30 m, the designer should consider removing the barrier because the barrier may be more of a hazard than the obstacle itself.
2. Restricted Widths. Where barriers are located near the traveled way on both sides of the roadway, the beginning of the barriers should be staggered to minimize the tendency drivers have to shy away from the barrier ends.

Type of End Treatment	Maximum Design Speed	Remarks
Physically connected to existing barrier.	N/A	Ensure connections provide adequate strength and potential for snag is minimized.
Buried in Backslope	N/A	Ditches may pose difficulty.
Terminate end behind existing guide railing	N/A	Ensure proper deflection of guide railing is available. See Figure 14-4C.
Protected by a crash cushion (e.g., sand-filled plastic barrels).	Limited by crash cushion design and available space.	See Figure 14-4D.

END TREATMENTS FOR TEMPORARY CONCRETE MEDIAN BARRIERS

Figure 14-4B

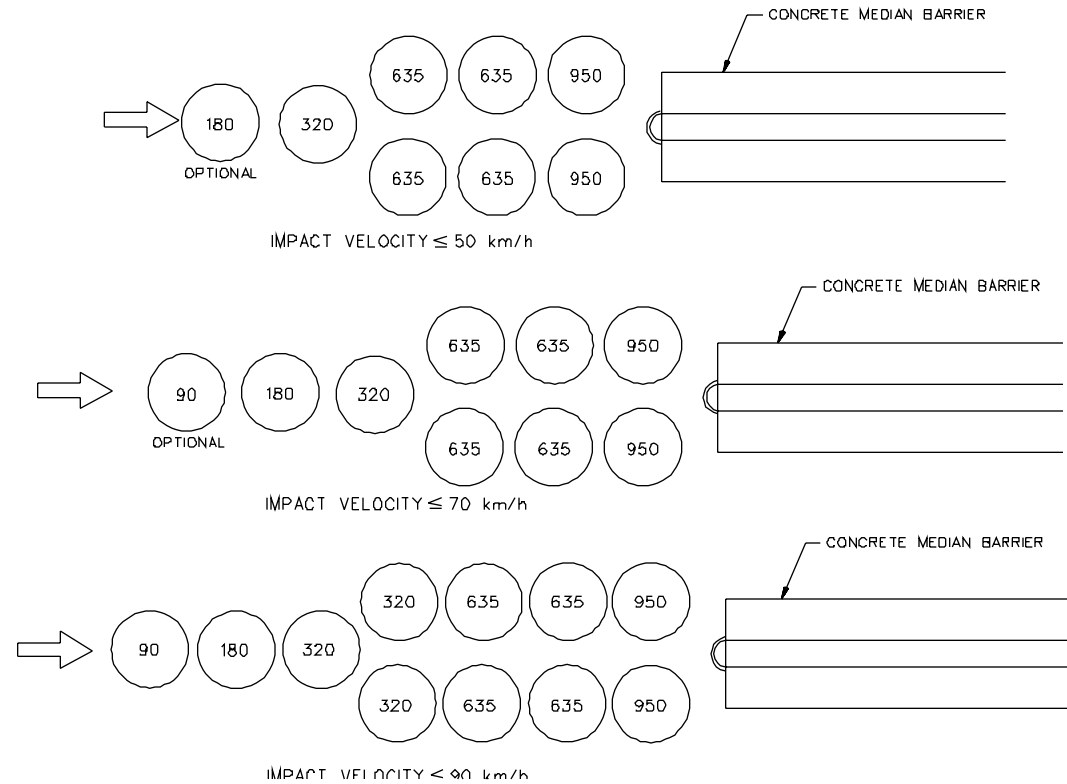
3. Flare Rates. Where practical, the TPCBC terminal should be flared beyond the travelway to a point outside of the construction clear zone. Figure 14-4A presents the flare rates that should be used for the TPCBC based on the selected construction-zone design speed. The designer should provide these flare rates unless extenuating circumstances render this impractical (e.g., stop conditions, driveways, intersections).
4. Openings. Openings in the barriers should be avoided, if practical. Where necessary, barrier ends should have an acceptable end treatment as discussed in Section 14-4.04. This also applies to breaks in the barrier for the contractor's access to the work site.
5. Delineation. Appropriate delineation should be provided in advance of and along the temporary concrete barrier installation. Reflectorized drums or barricades placed according to the MUTCD in advance of the concrete barrier should help to reduce the probability of vehicular encroachment and impact. Reflective devices, as shown on the details of the barrier, should be installed to provide the recommended delineation along the barrier. These should supplement but not replace the need for reflectorized edge line markings.



Existing Guide Rail Type	Overlap Offset D (m)
3 Cable Rail I-Beam Posts	3.9
Cable Rail Wood or Steel Posts	3.9
Metal Beam Rail Type R-I	2.7
Metal Beam Rail Type R-B	1.5
R-I System 2	2.1
R-I System 3	1.5
R-I System 4	1.2
R-I System 6	0.9

TRANSITION OF EXISTING GUIDE RAIL TO TEMPORARY PRECAST CONCRETE MEDIAN BARRIER CURB FOR TEMPORARY TRAFFIC CONTROL (One-Way Traffic)

Figure 14-4C



Note: Numbers indicates mass of sand in kilograms in each barrel. These array designs should only be used for temporary installations.

INERTIAL SYSTEM (SAND BARRELS)

Figure 14-4D

14-5.0 REFERENCES

1. *Manual on Uniform Traffic Control Devices, Part VI*, FHWA, 1993.
2. *Planning and Scheduling Work Zone Traffic Control*, FHWA-IP-81-6, FHWA, 1981.
3. *A Policy on Geometric Design of Highways and Streets*, AASHTO 1994.
4. *Roadside Design Guide*, AASHTO 1996.

Chapter Fifteen

SPECIAL DESIGN ELEMENTS

Table of Contents

		<u>Page</u>
15-1.0	ACCESSIBILITY FOR HANDICAPPED INDIVIDUALS	15-1(1)
15-1.01	<u>Buildings</u>	15-1(1)
15-1.02	<u>Bus Stops</u>	15-1(1)
15-1.03	<u>Parking</u>	15-1(2)
	15-1.03.01 Off-Street Parking	15-1(2)
	15-1.03.02 On-Street Parking	15-1(5)
15-1.04	<u>Accessible Route</u>	15-1(6)
15-1.05	<u>Sidewalks</u>	15-1(8)
	15-1.05.01 Criteria for Accessible Routes	15-1(8)
	15-1.05.02 Criteria for Non-Accessible Routes	15-1(9)
15-1.06	<u>Stairs</u>	15-1(10)
15-1.07	<u>Ramps</u>	15-1(10)
15-1.08	<u>Curb Ramps</u>	15-1(13)
	15-1.08.01 General	15-1(13)
	15-1.08.02 Location	15-1(13)
	15-1.08.03 Crossing Controls	15-1(14)
	15-1.08.04 Types	15-1(16)
15-1.09	<u>Pedestrian Overpasses and Underpasses</u>	15-1(19)
15-2.0	COMMUTER LOTS	15-2(1)
15-2.01	<u>General</u>	15-2(1)
15-2.02	<u>Layout</u>	15-2(1)
	15-2.02.01 Entrances and Exits	15-2(1)
	15-2.02.02 Traffic Circulation	15-2(2)
	15-2.02.03 Pedestrian and Bicyclist Considerations	15-2(2)
	15-2.02.04 Accessibility for Handicapped Individuals	15-2(2)
15-2.03	<u>Design Elements</u>	15-2(2)

Table of Contents
(Continued)

		<u>Page</u>
15-3.0	BUS STOPS AND TURNOUTS	15-3(1)
15-3.01	<u>Location</u>	15-3(1)
	15-3.01.01 Bus Stops	15-3(1)
	15-3.01.02 Bus Turnouts	15-3(1)
15-3.02	<u>Design</u>	15-3(2)
	15-3.02.01 Bus Stops	15-3(2)
	15-3.02.02 Bus Turnouts	15-3(2)
	15-3.02.03 Bus Stop Pads	15-3(5)
	15-3.02.04 Bus Shelters	15-3(5)
15-4.0	BIKEWAYS	15-4(1)
15-4.01	<u>Bikeway Classifications</u>	15-4(1)
15-4.02	<u>Warrants</u>	15-4(1)
15-4.03	<u>Bikeway Design Elements</u>	15-4(2)
15-5.0	LANDSCAPING	15-5(1)
15-5.01	<u>General Benefits</u>	15-5(1)
15-5.02	<u>Landscaping Policies</u>	15-5(2)
	15-5.02.01 Planting Policy	15-5(2)
	15-5.02.02 Protection of Existing Vegetation	15-5(2)
	15-5.02.03 Turf Establishment, Topsoil and Sodding	15-5(2)
15-6.0	FENCING	15-6(1)
15-6.01	<u>General Warrants and Location</u>	15-6(1)
15-6.02	<u>Freeways</u>	15-6(2)
15-6.03	<u>Unlimited Access Highways</u>	15-6(3)
15-6.04	<u>Fencing and Railings on Highway Structures</u>	15-6(3)
	15-6.04.01 General	15-6(3)
	15-6.04.02 Highway Overpasses with Sidewalks	15-6(4)
	15-6.04.03 Highway Overpasses without Sidewalks	15-6(4)
	15-6.04.04 Stream and Wetland Overpasses	15-6(4)
	15-6.04.05 Railroad Overpasses	15-6(5)
	15-6.04.06 Pedestrian Overpasses	15-6(5)

Table of Contents
(Continued)

	<u>Page</u>
15-6.04.07 Walls	15-6(5)
15-6.04.08 Railing and Fencing at Lighting and Signing Standards	15-6(6)
15-6.05 <u>Fencing Delineation on Contract Plans</u>	15-6(6)
15-7.0 NOISE BARRIER IMPACTS	15-7(1)
15-7.01 <u>Roadside Safety</u>	15-7(1)
15-7.02 <u>Sight Distance</u>	15-7(1)
15-7.03 <u>Right-of-Way</u>	15-7(1)
15-7.04 <u>Interference with Roadside Appurtenances</u>	15-7(1)
15-7.05 <u>Additional Design Criteria</u>	15-7(2)
15-8.0 REFERENCES	15-8(1)

Chapter Fifteen

SPECIAL DESIGN ELEMENTS

15-1.0 ACCESSIBILITY FOR HANDICAPPED INDIVIDUALS

Many highway elements can affect the accessibility and mobility of handicapped individuals. These include sidewalks, parking lots, buildings at transportation facilities, overpasses and underpasses. The Department's accessibility criteria complies with the 1990 *Americans with Disabilities Act* (ADA) and the *General Statutes of Connecticut* (CGS). The following sections present accessibility criteria which are based on information presented in the *ADA Accessibility Guidelines for Buildings and Facilities* (ADA Guidelines). Designers are required to meet the criteria presented in the following sections. Where other agencies or local codes require standards which exceed the *ADA Guidelines*, then the stricter criteria may be required. This will be determined on a case-by-case basis.

15-1.01 Buildings

ADA Reference: Section 4.1

For interior accessibility criteria in all buildings, airport terminals, rest areas, weigh stations and transit stations (e.g., stations for intercity bus, intercity rail, high-speed rail and other fixed guideway systems), the accessibility criteria set forth in the *ADA Guidelines* shall apply. The designer should review the *ADA Guidelines* to determine the appropriate accessibility requirements for building interiors, including rest rooms, drinking fountains, elevators, telephones, etc.

15-1.02 Bus Stops

ADA Reference: Section 10.2

The following accessibility criteria apply to the construction of bus stops:

1. Bus Stop Pads. New bus stop pads constructed to be used in conjunction with a lift or ramp shall meet the following criteria:
 - a. A firm stable surface must be provided.

- b. It must have a minimum clear length of 2440 mm (measured from the curb or roadway edge) and minimum clear width of 1525 mm (measured parallel to the roadway) depending on the legal or site constraints.
 - c. It must be connected to streets, sidewalks or pedestrian paths by at least one accessible route.
 - d. The slope of pad parallel to the roadway must be the same as the roadway to the maximum extent practical.
 - e. For drainage purposes, a maximum cross slope of 2% perpendicular to the roadway is allowable.
2. **Bus Shelters.** Where new or replaced bus shelters are provided, they must be installed or positioned to permit a wheelchair user to enter from the public way and reach a location within the shelter having a minimum clear floor area of 760 mm by 1220 mm. An accessible route shall be provided from the shelter to the boarding area.
3. **Signing.** All new bus route identification signs should be sized based on the maximum dimensions permitted by local, state or federal regulations or ordinances. The signs shall have an eggshell, matte or other non-glare finish. The characters or symbols shall contrast with their background (i.e., light characters on a dark background or dark characters on a light background).

15-1.03 Parking

ADA Reference: Section 4.1.2

Connecticut General Statutes: CGS 14-253a “Parking privileges for blind or handicapped persons. Identification card. License plates. Parking spaces. Penalty.”

15-1.03.01 Off-Street Parking

ADA Reference: Section 4.1.2 and 4.6

The following criteria apply to off-street handicapped parking spaces:

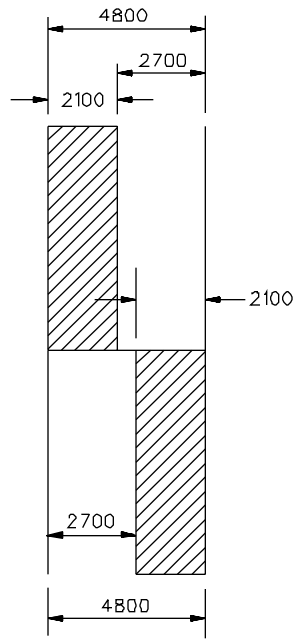
1. **Minimum Number.** Figure 15-1A provides the criteria for the minimum number of accessible spaces. A typical handicapped stall layout is shown in Figure 15-1B.

Total No. of Parking Spaces	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
201 to 300	7
301 to 400	8
401 to 500	9
501 to 1000	2% of total
1001 and over	20 plus 1 for each 100 over 1000

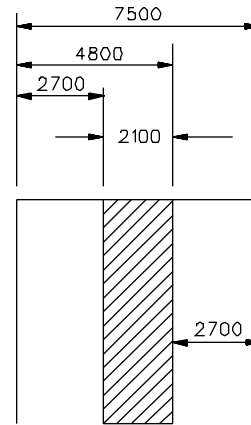
- Notes:
- a. *If one or more passenger loading zones are provided, then at least one passenger loading zone shall comply with Item # 5 in this Section.*
 - b. *Parking spaces for side-lift vans are accessible parking spaces and may be used to meet the requirements of this Section.*
 - c. *The total number of accessible parking spaces may be distributed among closely spaced parking lots, if greater accessibility is achieved.*

**MINIMUM NUMBER OF ACCESSIBLE SPACES
FOR HANDICAPPED USERS**

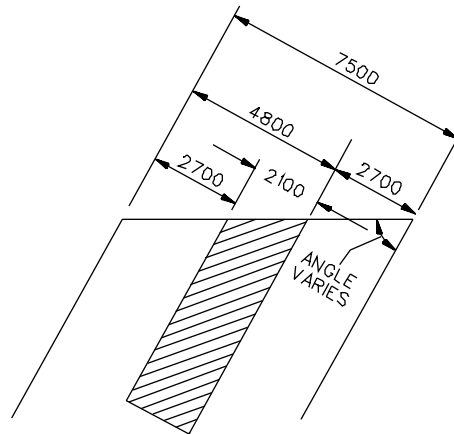
Figure 15-1A



PIGGY BACK STYLE



SIDE BY SIDE STYLE



ANGLED SIDE BY SIDE STYLE

- Notes:
1. All dimensions are in mm.
 2. Two accessible parking spaces may share a common access aisle.

**HANDICAPPED PARKING STALL DIMENSIONS
(Off-Street Parking)**

2. Location. Parking spaces for disabled individuals and accessible passenger loading zones that serve a particular building shall be the spaces or zones closest to the nearest accessible entrance on an accessible route. In separate parking structures or lots that do not serve a particular building, parking spaces for disabled individuals shall be located on the shortest possible circulation route to an accessible pedestrian entrance of the parking facility. In buildings with multiple access entrances with adjacent parking, accessible parking spaces shall be dispersed and located closest to the accessible entrances.
3. Signing. Parking spaces for the handicapped shall be designated by above-grade signs with white lettering against a blue background and shall bear the international symbol of access (see MUTCD), and the words “Handicapped Parking State Permit Required” and “Violators Will Be Fined.”. The sign shall not be obscured by a vehicle parked in the space.
4. Dimensions. The parking spaces designated for the handicapped shall be at a minimum 4800-mm wide which includes a 2100-mm minimum access aisle, or the space should be parallel to a sidewalk on a public highway. Parking access aisles shall be part of an accessible route to the building or facility entrance. Parked vehicular overhangs shall not reduce the clear width of an accessible circulation route. Parking spaces and access aisles shall be level with surface slopes not exceeding 2% in all directions. The Division of Traffic Engineering will determine the striping plan for the handicapped parking spaces.
5. Passenger Loading Zones. Passenger loading zones shall provide an access aisle at least 1525-mm wide and 6100-mm long adjacent and parallel to the vehicular pull-up space. If there are curbs between the access aisle and the vehicular pull-up space, then a curb ramp complying with Section 15-1.08 shall be provided. Vehicular standing spaces and access aisles shall be essentially level. Surface slopes shall not exceed 2% in all directions.
6. Parking Garages (Vertical Clearances). The designer must meet the requirements of the *Connecticut General Statutes*, CGS 14-253a for any parking garages: “Any parking garage or terminal constructed on and after October 1, 1985, shall have nine feet six inches vertical clearance (2895 mm) at its entrance and along the route to at least two parking spaces which conform with the requirements of subsection (f) of this statute and which have nine feet six (2895 mm) inches vertical clearance.” The criteria in Item #2 “Location,” #3 “Signing,” and #4 “Dimensions” meet the requirements of subsection (f) of CGS 14-253a.

15-1.03.02 On-Street Parking

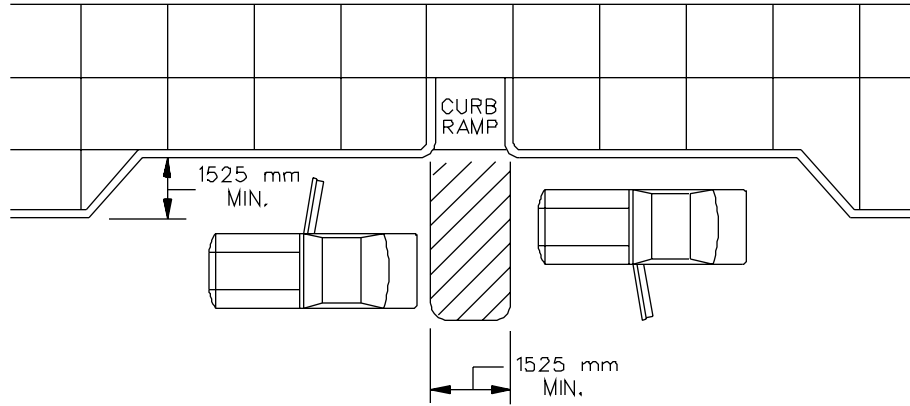
Where new on-street paid or time-limited parking is provided and designated in districts zoned for business uses, the designer should consider the following accessibility criteria for the on-street parking:

1. Minimum Number. Figure 15-1A provides the criteria for the minimum number of on-street accessibility spaces.
2. Location. On-street accessibility parking spaces will be dispersed throughout the project area. To the maximum extent feasible, accessible on-street parking should be located in level areas.
3. Dimensions. At a minimum, a 1525-mm wide perpendicular access aisle must be provided at the head or foot of the parking space. This is illustrated in Figure 15-1C. The travel lane shall not encroach into the access aisle.
4. Signing. Parking spaces for the handicapped shall be designated by above-ground signs with white lettering against a blue background, and the signs shall bear the international symbol of access (see MUTCD) and the words "Handicapped Parking State Permit Required" and "Violators Will Be Fined." These signs will be located to be visible from a driver's seat.
5. Curb Ramps. If there are curbs next to an on-street accessible parking space, then a curb ramp complying with Section 15-1.08 shall be provided. Access parking spaces adjacent to intersections may be served by the sidewalk curb ramp at the intersection, provided that the path of travel from the access aisle to the curb ramp is within the pedestrian crossing area.
6. Parking Meters. Where provided, parking meter controls shall be a maximum of 1220 mm above the sidewalk or pedestrian circulation path. Controls and operating mechanisms shall be operable with one hand and shall not require tight grasping, pinching or twisting of the wrist. The force required to activate controls shall be no greater than 22.2 N. A firm, stable and slip-resistant area (760 mm by 1220 mm), with the least possible slope, shall be provided at the controls and shall be connected to the sidewalk by a continuous passage that is a minimum of 915-mm wide.

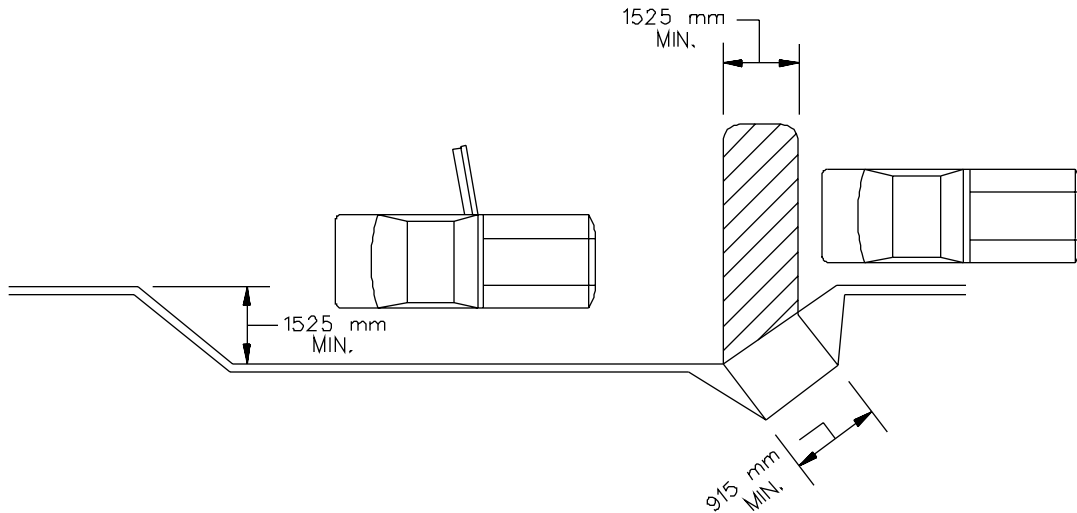
15-1.04 Accessible Route

ADA Reference: Section 4.3

An accessible route is a continuous, unobstructed path connecting all accessible elements and spaces in a building, facility or site. A "site" is defined as a parcel of land bounded by a property line or a designated portion of a public right-of-way. A "facility" is defined as all or any portion of buildings, structures, site improvements, complexes, equipment, roads, walks, passageways, parking lots, or other real or personal property on a site. Interior accessible routes may include corridors, floors, ramps, elevators, lifts and clear floor space at fixtures. Exterior accessible routes may include parking access aisles, curb ramps, crosswalks at vehicular ways, walks, ramps and lifts.



(a) TWO ACCESSIBLE PARALLEL PARKING SPACES IN SERIES, SEPARATED BY AN ACCESSIBLE AISLE, WITH BOTH DRIVER-SIDE AND PASSENGER-SIDE ACCESS DEMONSTRATED.



(b) SINGLE ACCESSIBLE PARALLEL PARKING SPACE WITH DRIVER-SIDE ACCESS DEMONSTRATED; PASSENGER SIDE ACCESS CAN BE PROVIDED BY PARKING IN LINE WITH STANDARD ON-STREET SPACES.

**HANDICAPPED PARKING
(On-Street Parking)**

Figure 15-1C

Accessible routes must be provided as follows:

1. At least one accessible route within the boundary of the site shall be provided from public transportation stops, accessible parking, accessible passenger loading zones, and public streets or sidewalks to the accessible building entrance they serve. The accessible route shall, to the maximum extent feasible, coincide with the route for the general public.
2. At least one accessible route shall connect accessible buildings, facilities, elements, and spaces that are on the same site.
3. At least one accessible route shall connect accessible buildings or facility entrances with all accessible spaces and elements and with all accessible dwelling units within the building or facility.

For highway projects, the application of the accessible route criteria applies to definitive sites which are related to highway purposes. These include rest areas, recreational areas, park-and-ride lots, etc. Section 15-1.05 provides the accessibility requirements for sidewalks. Most sidewalks along public right-of-way are considered non-accessible.

15-1.05 Sidewalks

Section 10-2.01 presents the Department's warrants and design criteria for sidewalks. In addition, all sidewalks must comply with the *ADA Guidelines* presented in the following sections.

15-1.05.01 Criteria for Accessible Routes

ADA Reference: Various.

For sidewalks on accessible routes, the following accessibility criteria shall be met:

1. Width. The minimum clear width shall be 915 mm, except at doors which may have a minimum width of 815 mm.
2. Passing Space. If the sidewalk has less than 1525-mm clear width, then passing spaces at least 1525 mm by 1525 mm shall be located at reasonable intervals not to exceed 61 m. A T-intersection between two walks is an acceptable passing space. Paved driveways also provide acceptable passing space in residential areas.

3. Surface. All sidewalk surfaces shall be stable, firm and slip resistant. The longitudinal gradient should be flush and free of abrupt changes. However, changes in level up to 6 mm may be vertical and without edge treatment. Changes in level between 6 mm and 13 mm shall be beveled with a slope no greater than 50%. Changes greater than 13 mm shall be accommodated with a ramp (see Section 15-1.07).

Gratings should not be placed within the walking surface. If, however, gratings are located in walking surfaces, then they shall have spaces no greater than 13-mm wide in one direction. If gratings have elongated openings, then they shall be placed so that the long dimension is perpendicular to the dominant direction of travel.

4. Slope. The sidewalk cross slope shall not exceed 2%. If the longitudinal gradient exceeds 5%, the sidewalk must meet the accessibility criteria for ramps (see Section 15-1.07).
5. Protruding Objects. Objects projecting from walls (e.g., signs, telephones, canopies) with their leading edges between 685 mm and 2030 mm above the finished sidewalk shall not protrude more than 100 mm into any portion of the sidewalk. Freestanding objects mounted on posts or pylons may overhang their mountings up to a maximum of 305 mm when located between 685 mm and 2030 mm above the sidewalk or ground surface. Protruding objects less than 685 mm or greater than 2030 mm may protrude any amount provided that the effective width of the sidewalk is maintained. Where the vertical clearance is less than 2030 mm, a barrier shall be provided to warn the blind or visually-impaired person.
6. Separation. Sidewalks will be separated from roadways by curbs, snow shelf or other barriers, which will be continuous except where interrupted by driveways, alleys or connections to accessible elements.
7. Bus Stops. Where bus passenger loading areas or bus shelters are provided on or adjacent to sidewalks, they must comply with the criteria in Section 15-1.02.
8. Curb Ramps. All curb ramps on an accessible route must comply with the criteria in Section 15-1.08.

15-1.05.02 Criteria for Non-Accessible Routes

In general, sidewalks on non-accessible routes should meet the criteria presented in Section 15-1.05.01. However, some flexibility is required to meet the adjacent roadway conditions and to provide practical designs. The criteria in Section 15-1.05.01 should be implemented, unless noted as follows:

1. Slopes. The flattest longitudinal slope practical should be provided. Preferably, the longitudinal slope should not exceed 8%. Sidewalk slopes 5% or greater do not require the use of handrails as defined in Section 15-1.07. Cross slopes greater than 2% may be used provided adjacent portions are smoothly blended.
2. Stairs. Sidewalks with stairs are allowed on non-accessible routes, provided an unobstructed route is available between accessible entrances. Section 15-1.06 presents criteria for stairs.
3. Separation. Sidewalks adjacent to the curb or roadway may be offset to avoid a non-conforming cross slope at driveway aprons by diverting the sidewalk around the apron.
4. Protruding Objects. Objects on or along a sidewalk which are not fixed, such as newspaper vending machines, trash receptacles, etc., are not subject to the *ADA Guidelines*.

15-1.06 Stairs

ADA Reference: Section 4.9

Stairs shall not be part of an exterior accessible route because they cannot be safely negotiated by individuals in wheelchairs. Where stairs are used, they should be designed to be accessible by other handicapped individuals. Therefore, the design of stairs must comply with Section 4.9 of the *ADA Guidelines* and the *Connecticut Standard Sheets*. This includes the provision of handrails.

15-1.07 Ramps

ADA Reference: Sections 4.1.6, 4.8 and 4.26

Any part of an accessible route with a slope greater than 5% shall be considered a ramp and shall conform to the *ADA Guidelines*. This includes the provision of handrails. The following criteria must be met for ramps on accessible routes:

1. Slope and Rise. The least possible slope should be used for any ramp. Figure 15-1D provides the maximum allowable ramp slopes for new construction. Curb ramps and ramps to be constructed on existing sites or in existing buildings or facilities may have slopes and rises as shown in Figure 15-1E, if space limitations prohibit the use of a 1:12 slope or less.
2. Width. The minimum clear width of a ramp shall be 915 mm.

Slope	Maximum Rise	Maximum Run
Steeper than 1:16 but no steeper than 1:12	760 mm	9000 mm
Steeper than 1:20 but no steeper than 1:16	760 mm	12 000 mm

Note: A slope steeper than 1:12 is not allowed.

**ALLOWABLE RAMP DIMENSIONS
(New Construction)**

Figure 15-1D

Slope	Maximum Rise	Maximum Run
Steeper than 1:10 but no steeper than 1:8	75 mm	600 mm
Steeper than 1:12 but no steeper than 1:10	150 mm	1500 mm

Note: A slope steeper than 1:8 is not allowed.

**ALLOWABLE RAMP DIMENSIONS
(Existing Sites, Buildings and Facilities)**

Figure 15-1E

3. Landings. Ramps shall have level landings at the bottom and top of each run. Landings shall have the following features:
 - a. The landing shall be at least as wide as the ramp run leading to it.
 - b. The landing length shall be a minimum of 1525 mm clear.
 - c. If ramps change direction at landings, the minimum landing size shall be 1525 mm by 1525 mm.
4. Handrails. If a ramp run has a rise greater than 150 mm or a horizontal projection greater than 1830 mm, then it shall have handrails on both sides. Handrails are not required on curb ramps. Handrails shall have the following features:
 - a. Handrails shall be provided along both sides of ramp segments. The inside handrail on switchback or dogleg ramps shall be continuous.
 - b. If handrails are not continuous, they shall extend at least 305 mm beyond the top and bottom of the ramp segment and shall be parallel with the floor or ground surface.
 - c. The clear space between the handrail and the wall shall be 40 mm.
 - d. Gripping surfaces shall be continuous.
 - e. Top of handrail gripping surfaces shall be mounted between 865 mm and 965 mm above ramp surfaces.
 - f. Ends of handrails shall be either rounded or returned smoothly to floor, wall or post.
 - g. Handrails shall not rotate within their fittings.
5. Cross Slope and Surfaces. The cross slope of ramp surfaces shall be no greater than 2%. Ramp surfaces shall comply with the criteria for "Surface" for sidewalks (Section 15-1.05).
6. Edge Protection. Ramps and landings with dropoffs shall have curbs, walls, railings or projecting surfaces that prevent people from slipping off the ramp. Curbs shall be a minimum of 50 mm high.
7. Outdoor Conditions. Outdoor ramps and their approaches shall be designed so that water will not accumulate on walking surfaces.

15-1.08 Curb Ramps

ADA Reference: Section 4.7

Connecticut General Statutes: CGS 7-118a

15-1.08.01 General

“Curb cuts” and “curb ramps” are terms which each describe the treatment at intersections for gradually lowering the elevation of sidewalks with curbs to the elevation of the street surface. The term “curb ramps” will be used in this *Manual*.

All curbs and sidewalks shall be designed with curb ramps at all pedestrian crosswalks to provide adequate and reasonable access for the safe and convenient movement of physically handicapped persons. This applies to new construction, reconstruction, 3R and spot improvement projects. For the purpose of this section, a pedestrian crosswalk is defined as that portion of a highway or street ordinarily included within the prolongation or connections of lateral lines of sidewalks at intersections. It also includes any portion of a highway or street distinctly indicated as a crossing for pedestrians by lines or other markings on the surface, except such prolonged or connecting lines from an alley across a street.

15-1.08.02 Location

When determining the need for a curb ramp, the designer should consider the following:

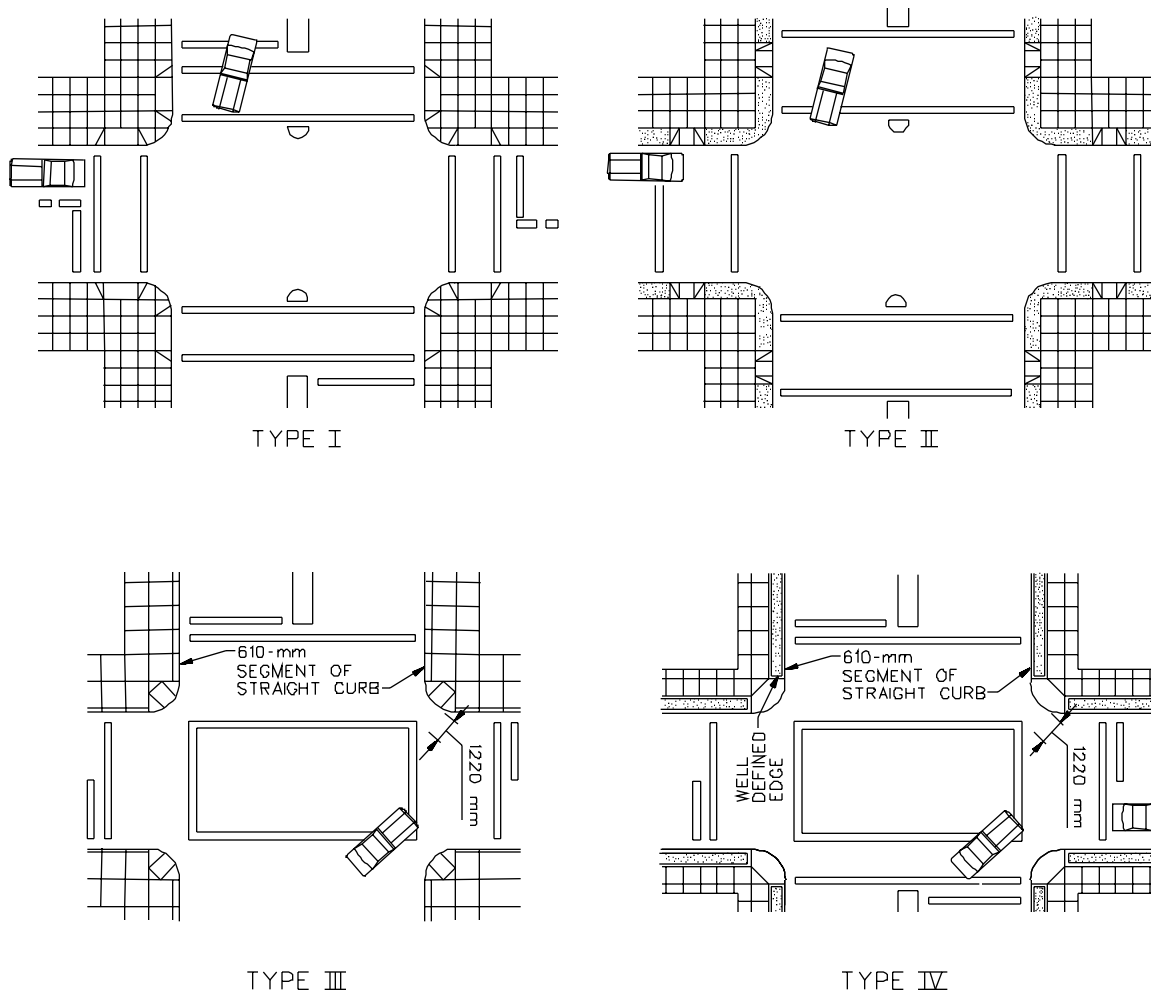
1. If at least one curb will be disturbed by construction at an existing intersection, then curb ramps shall be constructed at all crosswalks which extend from a paved sidewalk in that intersection.
2. For all projects, curb ramps will be constructed at all crosswalks which provide pedestrian access in that intersection and will be provided on all corners. At T-intersections, the designer must ensure that curb ramps are located on the side opposite the minor intersecting road.
3. Opposing ramps must always be provided on adjacent legs of an intersection even if outside project limits.
4. Curb ramps shall be positioned so as not to cause a safety hazard for blind pedestrians.
5. Curb ramps shall be located or protected to prevent their obstruction by parked vehicles.

6. Curb ramps at marked crossings shall be wholly contained within the markings, excluding any flared sides.
7. A diagonal curb ramp shall be wholly contained within the painted markings, including any flared sides. There shall be at least 610 mm of full-height curb within the crosswalk. In addition, there shall be at least 1220 mm between the gutter line and the corner of the two intersecting crosswalks. See Figure 15-1F for an illustration of these criteria.
8. The function of the curb ramp must not be compromised by other highway features (e.g., guide rail, catch basins, utility poles, signs).
9. Curb ramps are required at all curbed intersections with sidewalks or along all accessible routes.
10. The location of the curb ramp must be consistent with the operation of pedestrian-actuated traffic signals, if present. In addition, a pedestrian push-button must be located so it can be reached by wheelchair-bound individuals.
11. The designer will provide the Division of Traffic Engineering with a set of plans at the preliminary design stage and before the preliminary design review. The Division of Traffic Engineering, in its review, will determine the need and location of mid-block curb ramps. These recommendations will be incorporated into the design before the preliminary design review. In addition, the Division of Traffic Engineering will be notified of any geometric changes which will impact the location of any curb ramp included in the preliminary design review.

15-1.08.03 Crossing Controls

If a pedestrian crosswalk and curb ramp are present at an intersection with a traffic signal that has pedestrian detectors (push buttons), the following will apply:

1. Location. Controls shall be located as close as practical to the curb ramp and, to the maximum extent feasible, shall permit operation from a level area immediately adjacent to the controls.
2. Surface. A firm, stable and slip-resistant area, a minimum of 915 mm by 1220 mm, shall be provided to allow a forward or parallel approach to the controls.



Notes:

1. See Figure 15-1G for details of flared curb ramps (Types I and II).
2. See Figure 15-1H for details of diagonal curb ramps (Types III and IV).
3. As an alternative to the diagonal curb ramp, the designer can provide two Type I or two Type II flared curb ramps at each corner.

CURB RAMPS AT MARKED CROSSINGS

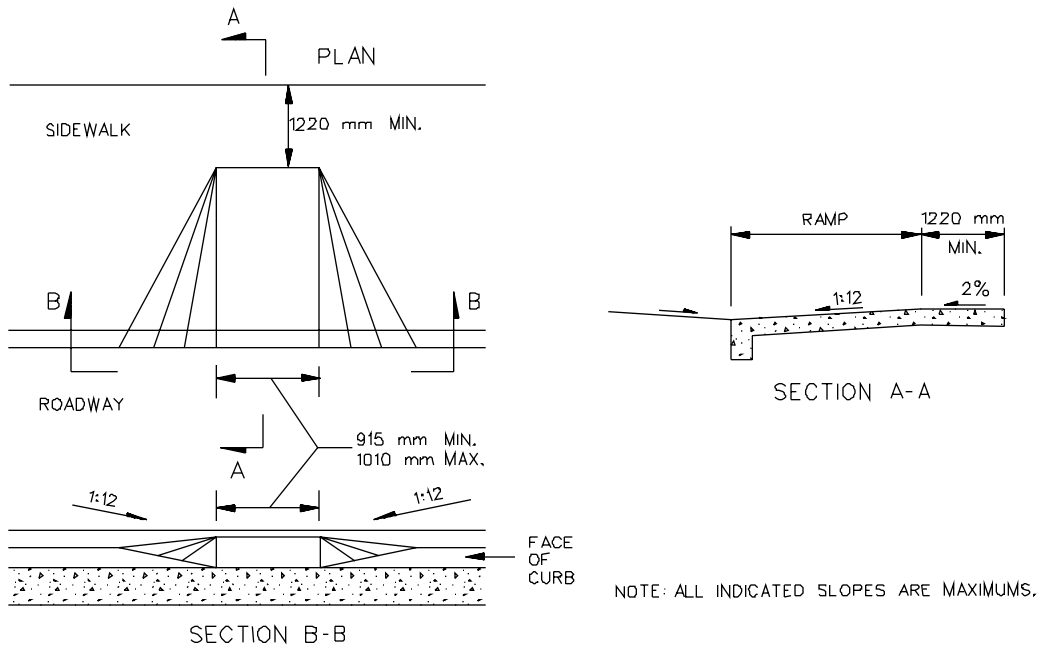
Figure 15-1F

15-1.08.04 Types

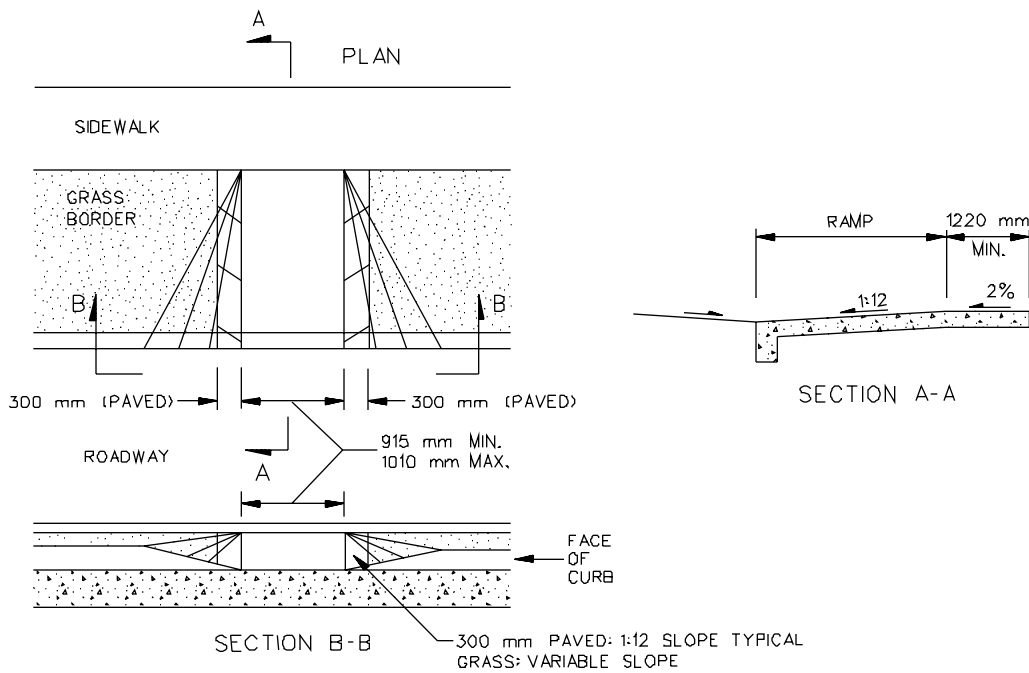
Figure 15-1F illustrates the two basic types of curb ramps — flared (Type I and II) and diagonal (Type III and IV). Details for the construction of flared curb ramps are provided in Figure 15-1G and for diagonal curb ramps in Figure 15-1H.

The following provides several suggestions for selecting the appropriate curb ramp:

1. Crosswalk Markings and Stop Bars. The placement of curb ramps affects the placement of crosswalk markings and stop bars. Conversely, the location of existing crosswalk markings and stop bars affect the placement of curb ramps. Some of the crosswalk marking constraints are shown in Figure 15-1F and in the *Connecticut Standard Sheets*. The *MUTCD* contains additional constraints on crosswalk markings and stop bar placement.
2. Obstructions. It is desirable to move any obstructions from curb ramps whenever practical. When this is not practical, the direction of traffic relative to the placement of the curb ramp must be considered. It is important that drivers can see the handicapped person using the curb ramp.
3. Diagonal Curb Ramps. The usage of a diagonal curb ramp should be avoided whenever practical due to its effect on the crosswalk width. It is preferable to use the straight curb ramp or several straight ramps rather than to use a diagonal curb ramp.
4. Islands. Any raised islands in a pedestrian crosswalk shall be cut through level with the street or have curb ramps at both sides and a level area at least 1220-mm long in the part of the island intersected by the crossing.
5. Material. Regardless of the type of pavement of the adjacent sidewalk, all curb ramps shall be constructed of portland cement concrete. Also, all curb ramps shall be constructed in accordance with the details of the *Connecticut Standard Sheets* for concrete sidewalk, except for the ramp which will have a textured and non-slip surface.
6. Specifications. Curb ramps shall be constructed, measured and paid for as concrete sidewalks, as referred to in the Department's *Standard Specifications for Roads, Bridges and Incidental Construction*, latest issue.



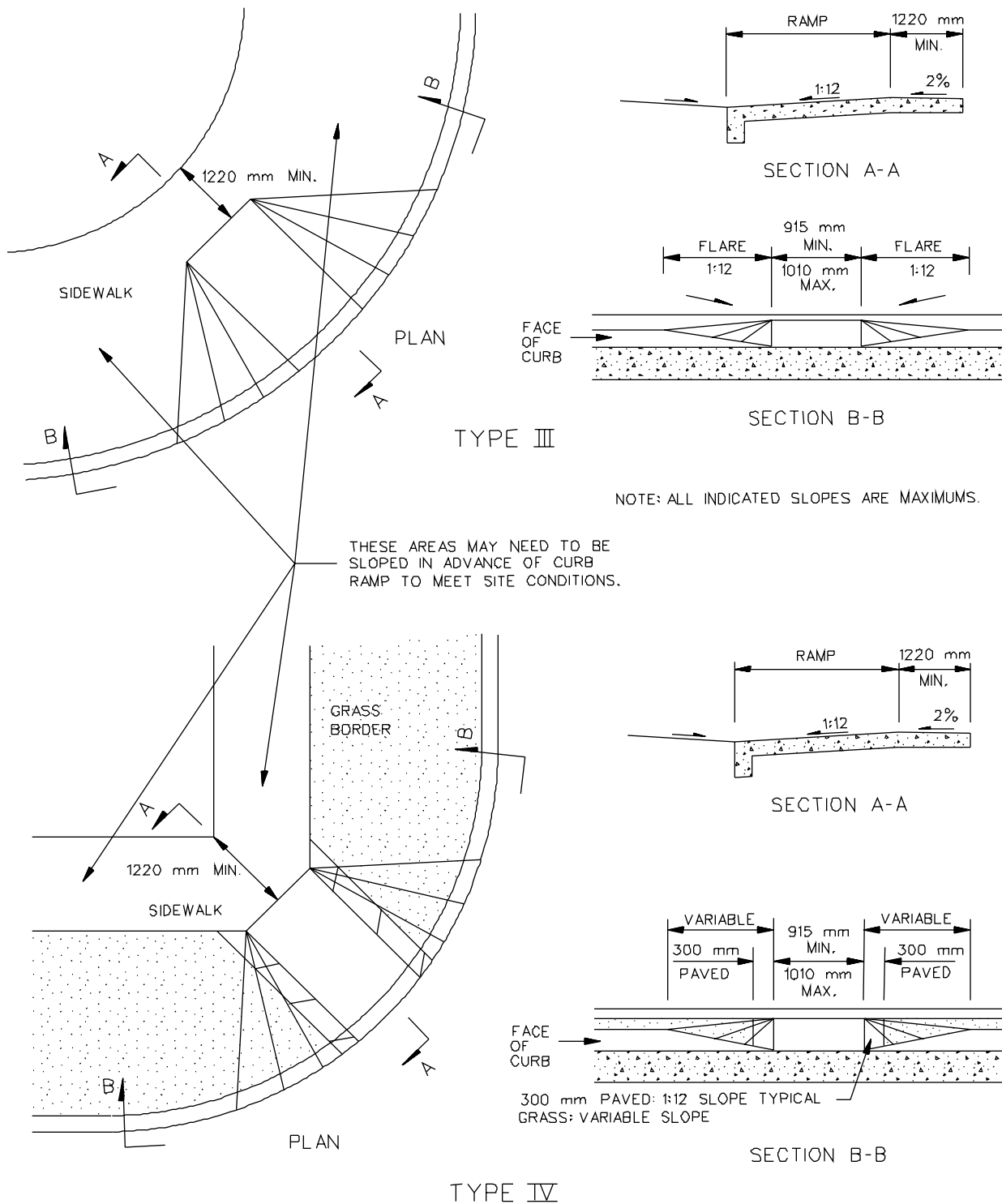
TYPE I



TYPE II

FLARED CURB RAMPS

Figure 15-1G



DIAGONAL CURB RAMPS

Figure 15-1H

15-1.09 Pedestrian Overpasses and Underpasses

ADA Reference: Various

When deciding where to locate a pedestrian crossing, the highway and structure designers must coordinate their efforts to properly address the accessibility considerations. The following are applicable:

1. All current and future accessible routes must be identified. If existing routes are inaccessible, the designer must evaluate the likelihood the routes will be made accessible in the future. This could be done as part of the project under design.
2. The evaluation in Item #1 may lead to the decision to relocate the pedestrian overpass or underpass to another site where accessibility can be more easily provided.
3. The proposed design must meet the *ADA Guidelines* criteria for stairs, ramps, curb ramps and accessible routes.
4. The designer should reference FHWA-IP-84-6 *Guidelines for Making Pedestrian Crossing Structures Accessible* for additional design information.

15-2.0 COMMUTER LOTS

15-2.01 General

Commuter lots may be located in both rural or urban areas to accommodate car-pooling or to provide access to transit terminals. By locating these lots outside of the downtown area, congestion is reduced, parking lot property costs are lowered, and accessibility is improved. The general location and size of commuter lots is normally determined during planning studies for transportation facilities by the Bureau of Planning. Guidance for site selections can be found in the *AASHTO Guide for the Design of Park-and-Ride Facilities*. The designer is responsible for the internal design and layout of the commuter lot

15-2.02 Layout

15-2.02.01 Entrances and Exits

The designer should locate entrances and exits so that they will have the least disruption to existing traffic on the street, allow easy access to and from the lot, and provide the maximum storage space within the lot. In addition, consider the following:

1. Location. Separate entrances and exits whenever practical, preferably on different streets. The entrance should be on the "upstream" side of the traffic flow nearest the lot and the exit on the "downstream" side. If separation is not possible, the combined entry-exit point should be as close to mid-block as practical.
2. Spacing. Entrances and exits should be at least 45 m apart and 45 m from a public intersection. Where practical, these distances should be 100 m. For lots with less than 150 spaces, these dimensions may be reduced to 30 m.
3. Storage. The designer needs to ensure that there is sufficient storage on the mainline for entering the lot. This may require providing a separate left-turn lane. Also, check the exiting traffic to ensure the exiting queue will not adversely affect the traffic circulation in the lot itself.
4. Design. Design all entrance and exits for capacity, sight distance, turning radii, acceleration and deceleration lanes, turn lanes, etc., according to the criteria in Chapter Eleven. The typical design vehicle will be a BUS.

15-2.02.02 Traffic Circulation

Arrange the traffic circulation to provide maximum visibility and minimum conflict between small vehicles (e.g., autos, taxis) and large vehicles (e.g., large vans, buses). Locate major circulation routes at the periphery of the lot to minimize vehicular-pedestrian conflicts. A counter-clockwise circulation of one-way traffic is preferred. This allows vehicles to unload from the right side.

15-2.02.03 Pedestrian and Bicyclist Considerations

The designer should consider pedestrian and bicycle routes when laying out the commuter lot. Avoid entrance and exit points in areas with high pedestrian volumes, if practical. Provide sidewalks between the parking areas and the modal transfer points. Locate passenger waiting areas in a central location or near the end of the facility. Maximum walking distances to loading area should not exceed 300 m. Longer walking distances may require more than one loading area.

Crosswalks should be provided where necessary and clearly marked and signed. Include signing and pavement markings for all pedestrian and bicycle paths to eliminate indiscriminate movements. In high-volume lots, fencing, barriers or landscaping may be warranted to channel pedestrians and bicyclists to appropriate crossing points. Crossings at major two-way traffic circulation lanes should have a refuge island separating the travel directions.

Include a bicycle parking area relatively close to the loading area. Provide bicycle stalls that allow the use of locking devices. If a large volume of bicycle traffic is expected, provide a designated bicycle lane to and from the bicycle parking area.

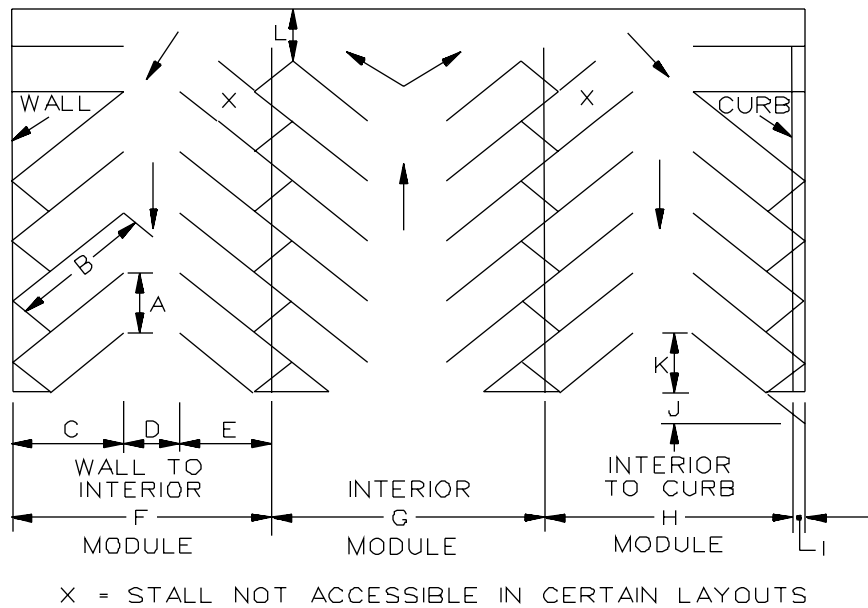
15-2.02.04 Accessibility for Handicapped Individuals

Section 15-1.0 discusses the accessibility criteria for handicapped individuals, which also apply to commuter lots.

15-2.03 Design Elements

Consider the following elements in the design of a commuter lot:

1. Parking Stall Dimensions. Figure 15-2A provides the design dimensions for 2.7-m x 5.6-m parking stalls based on one-way circulation and angle of parking. Where feasible, the lot should provide two-way flow with 90° parking spaces.



Parking Layout Dimension (in m) for 2.7 m x 5.6 m Stalls at Various Angles

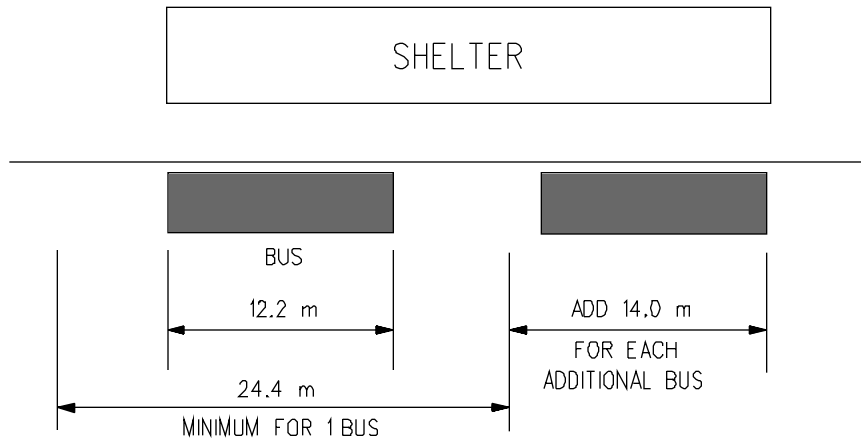
Dimension	On Diagram	Angle			
		45°	60°	75°	90°
Stall width, parallel to aisle	A	3.9	3.2	2.8	2.7
Stall length of line	B	8.4	7.2	6.4	5.6
Stall depth to wall	C	5.9	6.2	6.1	5.6
Aisle width between stall lines	D	3.7	4.9	7.0	7.9
Stall depth, interior	E	5.0	5.6	5.8	5.6
Module, wall to interior	F	14.6	16.8	18.9	19.2
Module, interior	G	13.7	16.2	18.6	19.2
Module, interior to curb face	H	14.0	16.0	18.1	18.4
Bumper overhang (typical)	I	0.6	0.7	0.8	0.8
Offset	J	2.0	0.8	0.2	0.0
Setback	K	4.0	2.8	1.5	0.0
Cross aisle, one-way	L	4.3	4.3	4.3	4.3
Cross aisle, two-way	—	7.3	7.3	7.3	7.3

- Notes:
1. See Section 15-1.0 for criteria on the number and dimensions of parking spaces for handicapped individuals.
 2. If a special section is designated for subcompact vehicles, these stalls can be 2.5 m x 4.6 m for a 90° angle.
 3. The designer should consider bumper overhang when placing lighting, railing, etc. Place these appurtenances beyond dimension "I" in the figure.
 4. Two-way traffic may only be used with a 90° parking angle.

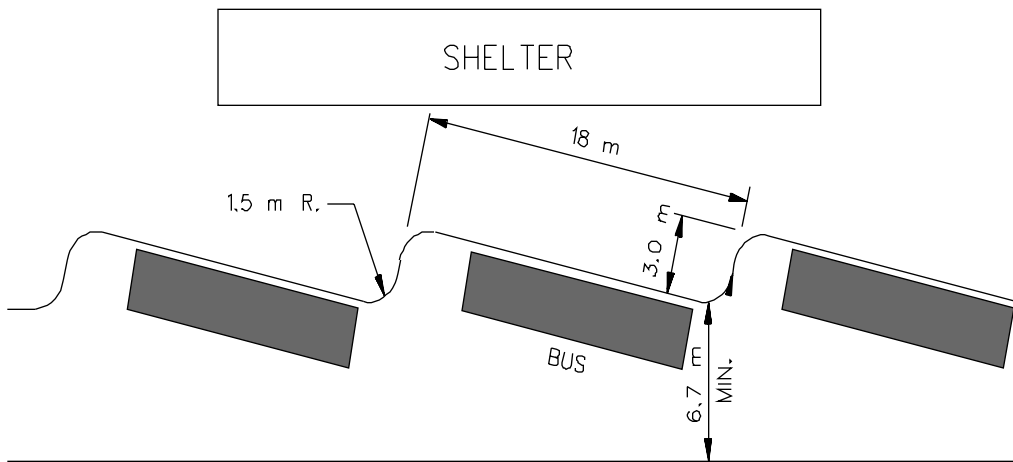
PARKING STALL DIMENSIONS

Figure 15-2A

2. Bus Loading Areas. Design the bus loading and unloading areas to provide for continuous counter-clockwise circulation and for curb parking without backing maneuvers. The traffic lanes and the curb loading area should each be 3.6-m wide. Figure 15-2B provides criteria for the recommended lengths of bus-loading areas. Section 15-3.0 discusses bus stops along streets and other access facilities.
3. Sidewalk Dimensions. All sidewalks should be paved and be at least 1.5-m wide. In loading areas, the width should be at least 3.6-m. Provide a 150-mm raised platform in the loading area to assist in the loading. Curb-cut ramps are required for access to sidewalks and loading areas, see Section 15-1.0.
4. Cross Slope. To provide proper drainage, the minimum gradient on the commuter lot should be 1%. As a maximum, the gradient should not exceed 5%. If available, design the lot to direct the drainage runoff into existing drainage systems. If water impoundment cannot be avoided along pedestrian routes, bicycle routes and standing areas, provide drop inlets and underground drainage. In parking areas, design the drainage to avoid standing water. The detailed drainage design for the lot should be prepared using the Department's *Drainage Manual* to determine design frequency, pavement discharge and capacity of drainage inlets.
5. Pavement Design. A typical pavement design for a commuter lot is 50 mm to 75 mm of bituminous concrete on 250 mm of subbase. Where curbs are used within the lot, they will normally be the bituminous concrete lip curbing (BCLC) type.
6. Shelters. Where a loading area for buses or trains will be provided, include a shelter in the design. The shelter should provide approximately 0.5 m² of covered area per person. At a minimum, the shelter should provide lighting, benches and trash receptacles. Other amenities may include routing information signs and a telephone. For handicapped accessibility requirements, see Section 15-1.0.
7. Lighting. Light the commuter lot for pedestrian safety and lot security. Ensure provisions are considered for location of lighting supports and power lines. Coordinate the lighting design with the Division of Traffic Engineering. All interior light standards should be protected from bumper damage.
8. Traffic Control Devices. Provide signs and pavement markings to direct drivers and pedestrians to appropriate loading zones, parking areas, bicycle facilities, handicapped parking and entrances and exits. Coordinate the use of traffic control devices with the Division of Traffic Engineering.
9. Fencing. Provide fencing around the entire lot according to field conditions.



PARALLEL PARKING



SHALLOW SAWTOOTH PARKING

RECOMMENDED LENGTHS FOR BUS-LOADING AREAS

Figure 15-2B

10. Landscaping. In some locations, consider landscaping to minimize the visual impact of the commuter lot. This may include providing a buffer zone around the perimeter of the lot or improving the aesthetics of the lot itself. Desirably, include a 3.0 m - 6.0 m buffer zone around the lot to accommodate vegetation screens. Also, traffic islands and parking lot separators provide suitable locations for shrubs and trees. Section 15-5.0 discusses Department policies on landscaping. Specifically for commuter lots, landscaping should include low maintenance vegetation and vegetation which does not cause visibility problems.

11. Maintenance Considerations. To minimize maintenance, the design should include a 3.0-m to 6.0-m snow shelf around the perimeter of the lot, at least on two sides, to provide storage space for snow removal. This area can coincide with the buffer zone around the lot, provided that the entire area is not filled with shrubs or trees. Place any fencing outside the snow shelf. Also, keep raised traffic islands to a minimum; painted islands are preferred.

15-3.0 BUS STOPS AND TURNOUTS

15-3.01 Location

15-3.01.01 Bus Stops

If local bus routes are located on an urban or suburban highway, the designer should consider their impact on normal traffic operations. The stop-and-go pattern of local buses will disrupt traffic flow, but certain measures can minimize the disruption. The location of bus stops is particularly important. These are determined not only by convenience to patrons, but also by the design and operational characteristics of the highway and the roadside environment. If the bus must make a left-turn, for example, do not locate a bus stop in the block preceding the left turn.

Some considerations in selecting an appropriate bus-stop location are listed below:

1. Far-Side Stops. The far side of at-grade intersections is generally superior to near-side or mid-block bus stops. Far-side stops produce less impediment to through traffic and right-turning traffic; they do not interfere as much with corner sight distance; and they lend themselves better to bus turnouts.
2. Near-Side Stops. Near-side stops allow easier vehicle re-entry into the traffic stream where curb parking is allowed, and they can increase street capacity. At intersections where there is a high volume of right-turning vehicles, near-side stops can result in traffic conflicts and should be avoided. However, near-side stops must be used where the bus will make a right turn at the intersection.
3. Mid-Block Stops. Mid-block bus stops may be advantageous where the distance between intersections is large or where there is a fairly heavy and continuous transit demand throughout the block. They may be appropriate if a large traffic generator is located in mid-block. Mid-block bus stops may also be considered where right turns at an intersection are high (250 in peak hour) and far-side stops are not practical.

15-3.01.02 Bus Turnouts

Interference between buses and other traffic can be reduced significantly by providing bus turnouts. Turnouts remove stopped buses from the through lanes and provide a well-defined user area for bus stops. Consider turnouts under the following conditions:

1. The street provides arterial service with high traffic speeds and volumes and high-volume bus patronage.

2. Right-of-way width is sufficient to prevent adverse impact on sidewalk pedestrian movements.
3. Curb parking is prohibited, at least during peak hours.
4. During peak-hour traffic, there are at least 500 vehicles per hour in the curb lane.
5. Bus volumes do not justify an exclusive bus lane, but there are at least 100 buses per day and at least 10 to 15 buses during the peak hour.
6. The average bus dwell time generally exceeds 10 seconds per stop.
7. At locations where specially equipped buses are used to load and unload handicapped individuals.

15-3.02 Design

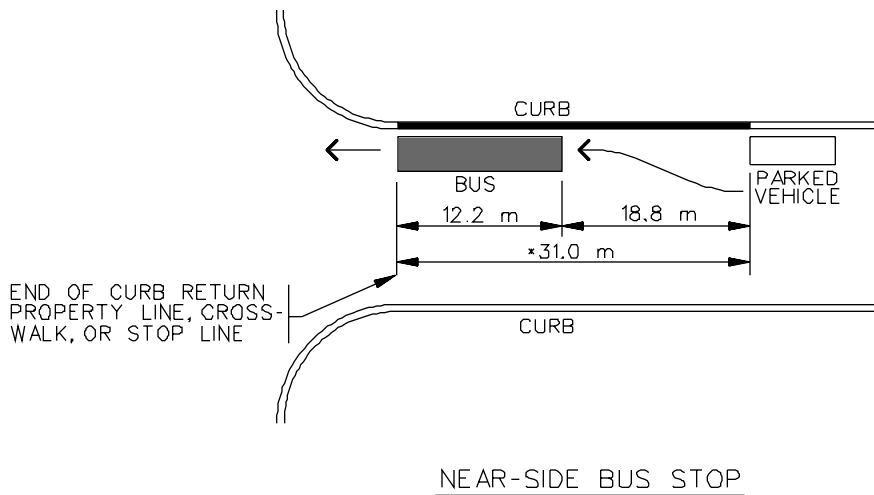
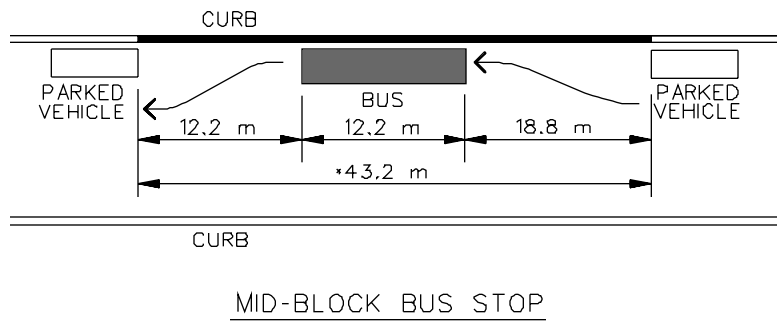
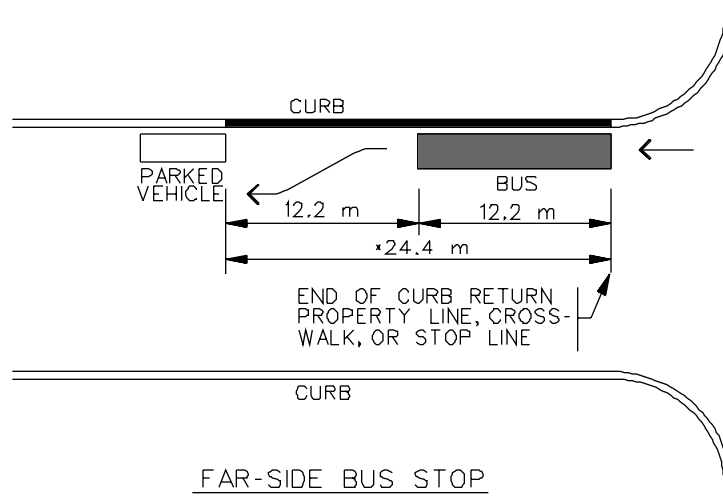
15-3.02.01 Bus Stops

Figure 15-3A provides the recommended distances for the prohibition of on-street parking near bus stops. Where articulated buses are expected to use these stops, add an additional 6 m to these distances. Provide an additional 14 m of length for each additional bus expected to stop simultaneously at any given bus stop area. This allows for the length of the extra bus (12.2 m) plus 1.8 m between buses.

15-3.02.02 Bus Turnouts

The following design criteria will apply:

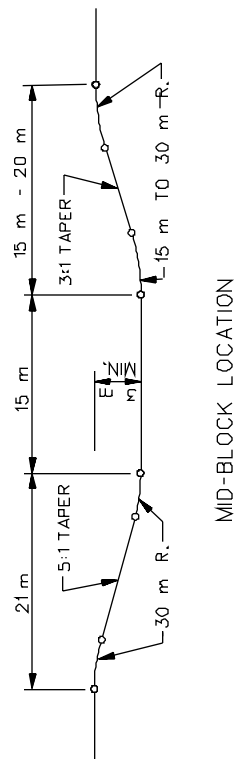
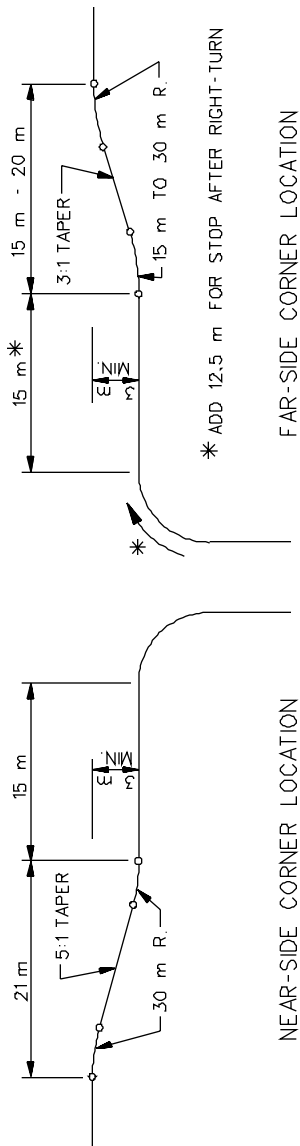
1. The bus turnout should be 3.0 m to 3.6 m wide.
2. The full-width area of the turnout should be at least 15 m long. Where articulated buses are expected, the turnout should be 21 m. For a two-bus turnout, add 14 m.
3. Figure 15-3B illustrates the design details for bus turnouts. In the transition areas, provide an entering taper no sharper than 5:1 and a re-entry taper no sharper than 3:1. As an alternative, short horizontal curves (30-m radius) may be used on the entry end and 15-m to



* Provide an additional 14 m of length for each additional bus.

ON-STREET BUS STOPS

Figure 15-3A



BUS TURNOUT DESIGN

Figure 15-3B

30-m curves on the re-entry end. Where a turnout is located at a far-side or near-side location, the cross street area can be assumed to fulfill the need for the exit or entry area, whichever applies.

15-3.02.03 Bus Stop Pads

All new bus stops which are constructed for use with lifts or ramps must meet the handicapped accessibility criteria set forth in Section 15-1.0.

15-3.02.04 Bus Shelters

Provide shelters at all major bus stops (more than 100 boarding or transferring passengers per day). Also, provide shelters at stops that primarily serve the elderly and handicapped individuals, such as retirement homes and hospitals. Benches are also desirable at these locations. The designer should consider the following in the design of bus shelters:

1. Visibility. To enhance passenger safety, the shelter sides should provide the maximum transparency as practical. In addition, do not place shelters such that it limits the general public's view of the shelter interior.
2. Selection. Contact the local transit agency to determine if they use a standardized shelter design.
3. Appearance. Shelters should be pleasing and blend with their surroundings. Shelters should also be clearly identified with "bus logo" symbols to discourage non-patron use.
4. Handicapped Accessibility. Design new bus shelters to meet the accessibility criteria presented in Section 15-1.0.
5. Placement. Do not place shelters where they will restrict vehicular sight distance, pedestrian flow or handicapped accessibility. It should also be placed so that waste and debris are not allowed to accumulate around the shelter.
6. Responsibility. The local transit agency is responsible for providing and maintaining the shelter.
7. Capacity. The maximum shelter size is based upon the maximum expected passenger accumulation at a bus stop between bus runs. This determination should be coordinated with the Bureau of Public Transportation. The designer can assume approximately 0.5 m² per

person to determine the appropriate shelter size. See Section 15-1.0 for minimum handicapped accessibility requirements.

15-4.0 BIKEWAYS

The majority of bicycling will take place on public roads with no dedicated space for bicyclists. Bicyclists can be expected to ride on almost all roadways. Sometimes they use sidewalks as joint bicycle and pedestrian facilities, unless such usage is prohibited by local ordinance. This section primarily provides information on the development of new facilities to enhance and encourage safe bicycle travel.

15-4.01 Bikeway Classifications

The Department has adopted the nomenclature used by AASHTO for bikeway classifications. The following definitions will apply:

1. **Bikeway**. Any road, path or way which in some manner is specifically designated as being open to bicycle travel, regardless of whether such facilities are designated for the exclusive use of bicycles or are to be shared with other transportation modes.
2. **Shared Roadway**. Any roadway upon which a bicycle lane is not designated and which may be legally used by bicycles regardless of whether such facility is specifically designated as a bikeway.
3. **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. Bicycle paths may assume different forms, as conditions warrant. They may be two-direction, multilane facilities or, where the path would parallel a roadway with limited right-of-way, a single lane on both sides of the road.
4. **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. It is distinguished from the traveled way portion of the roadway by a physical or symbolic barrier. Bicycle lanes may also assume varying forms but may generally be included in one of the following categories:
 - a. bicycle lane between parking lane and traveled way; or
 - b. bicycle lane between roadway edge and traveled way, where parking is prohibited.

15-4.02 Warrants

Each type of facility has its own merits and disadvantages. Care must be exercised in choosing the appropriate type of facility for a given situation. Each route is unique and must be judged on its

individual conditions. The *Connecticut Statewide Bicycle and Pedestrian Transportation Plan* and *AASHTO Guide for the Development of Bicycle Facilities* provides additional guidance on the selection of bikeways.

15-4.03 Bikeway Design Elements

For design details of bicycle facilities, the designer is referred to *the Connecticut Statewide Bicycle and Pedestrian Transportation Plan* and the *AASHTO Guide for the Development of Bicycle Facilities*.

15-5.0 LANDSCAPING

Roadside landscaping can greatly enhance the aesthetic value of a highway. Consider landscaping treatments early in the project development so that they can be easily and inexpensively incorporated into the project design. Landscaping will be considered on a project-by-project assessment. The designer should also reference the AASHTO *A Guide for Transportation Landscape and Environmental Design* for more information on landscaping. The Department's landscaping staff within the Office of Engineering will determine the proper landscaping treatment for each project.

15-5.01 General Benefits

Roadside landscaping can be designed advantageously to yield several benefits. The most important objective is to fit the highway naturally into the existing terrain. Retain the existing landscape to the maximum extent practical. Following is a brief discussion of the benefits of proper landscaping:

1. Aesthetics. Gentle slopes, mountains, parks, bodies of water, and vegetation have an obvious aesthetic appeal to the highway user. Landscaping techniques can be used effectively to enhance the view from the highway. The designer should reference the FHWA publication *Visual Impact Assessment for Highway Projects* for more information.

In rural areas, the landscaping should be natural and eliminate construction scars. The planting shape and spacing should be irregular to avoid a cosmetic appearance.

In urban areas, the smaller details of the landscape predominate and plantings become more formal. The interaction between the occupants of slow-moving vehicles and pedestrians with the landscape determines the scale of the aesthetic details. In some cases, the designer may be able to provide walking areas, small parks, etc. Landscaping should be pleasant, neat, sometimes ornamental, and require low maintenance.

2. Erosion. Landscaping and erosion control are interrelated. Flat and rounded slopes and vegetation serve to both prevent erosion and provide aesthetic value.
3. Screening. Landscaping can be used to effectively screen headlight glare and unsightly roadside views. It also can be used as a buffer for existing residences.
4. Maintenance. Landscaping decisions will greatly affect roadside maintenance. Maintenance activities for mowing, fertilizing, and using herbicides should be considered when designing the roadside landscape.
5. Safety. The effects on roadside safety should be reflected in the landscape treatment (see Chapter Thirteen). Flat, rounded slopes are both safer and more aesthetic. Unless protected

by guide rail, plant major trees outside of the clear zone, see Section 13-2.0. Shrubs and minor trees may be planted closer to the traveled way where traffic delineation will be required. Landscaping should not be placed in ramp gore areas, near intersections or turnouts that would restrict sight distances.

15-5.02 Landscaping Policies

15-5.02.01 Planting Policy

All projects which include planting must have a special provision which requires the contractor to be responsible for a plant establishment period of one growing season. The time begins after all plant materials in the contract have been planted.

15-5.02.02 Protection of Existing Vegetation

The Department's general policy is that, wherever practical, trees and other landscaping features will not be removed on highway projects. This objective, however, must be compatible with other considerations such as roadside safety, geometric design, utilities, terrain, public acceptance and economics. The Department has placed a special emphasis on saving valuable shade trees whenever practical. The plans should clearly designate all shade trees which will be saved.

15-5.02.03 Turf Establishment, Topsoil and Sodding

In areas disturbed by construction work, the designer must ensure that the turf is reestablished. Turf establishment refers to the reseeding of disturbed areas. The designer should use the guidance in the following comments to determine the appropriate turf establishment, depending upon individual site conditions. In addition, the turf placement must reflect the requirements of the Department's *Standard Specifications for Roads, Bridges and Incidental Construction*.

1. Topsoil. Place topsoil to a depth of 150 mm at all designated locations. The following topsoil requirements apply to the indicated location:
 - a. Freeways. Place topsoil on all fill slopes 1:5 and flatter to a width not to exceed 6.0 m from the edge of shoulder. Where abutting properties are subject to intensive

- mowing or in other special cases, include topsoil for all areas disturbed by construction.
- b. All other Highways. Topsoil should normally not be required at locations involving abutting undeveloped properties. In areas where sodding is required, include topsoil in accordance with the Department's specifications.
 - c. Medians. In general, median areas should be topsoiled to a width not to exceed 6.0 m from the edge of shoulders on both sides. Where the width remaining is 6.0 m or less, include topsoil for the entire median.
 - d. Gore Areas. Place topsoil from the end of the gore area pavement (3.0 m width) at the bifurcation for a distance not to exceed 22.5 m parallel to the highway for the full width between the roadways.
 - e. Bridge Abutments. For structures crossing roadways, place topsoil on the approach slopes for a distance not to exceed 15 m. This coverage is to extend from the top of slope to the toe of slope.
 - f. Other Locations. Place topsoil at any other special locations, especially in interchange areas as designated by qualified personnel.
2. Planting of Grass. Lime, seed, fertilize and mulch all areas disturbed by construction, except exposed rock surfaces and areas to be sodded, regardless of the presence or absence of topsoil. Estimate the amount of fertilizing, seeding, mulching, and liming for such areas. Estimate liming at the rate of 2200 kg per hectare.
 3. Sodding. Where developed properties and/or areas of intensive mowing abut the highway project (e.g., lawns of residences, hospitals, public parks), sod all adjacent areas disturbed by construction in accordance with the Department's specifications.

In addition to the above guidance for turf establishment, the designer must ensure that the project plans and quantity estimates adhere to certain criteria. The designer will determine the type of turf establishment and the areas within the construction limits which will be treated. These must be designated on the project plans. On this basis, the Office of Engineering, either by its own forces or with consulting engineers, will compute the quantities and prepare the necessary plans, special provisions and estimates for inclusion in the construction plans. In addition, the following will apply:

1. Project Plans. The requirements of turf establishment should be indicated on the plans according to the size of the project. On minor projects, these requirements generally should be reported on the detailed estimate sheet by stations. On larger projects which require Index

Plans, indicate the turf establishment on these sheets where such information will not seriously conflict with the data normally reported thereon. Otherwise, prepare supplemental Index Plan sheets showing turfing requirements and include them in the contract drawings.

2. Quantity Estimates. Before preparing quantity estimates, the designer should schedule a review of the proposed turf establishment requirements with the qualified personnel in the Office of Engineering. When estimating quantities of work for turf establishment, add 3.0 m to the measured length of slope to minimize the possibility of overruns. Do not indicate this additional slope length on the plans. When estimating topsoil and sodding quantities, use the measured length of the cross section and not the projected length from the plan sheets.

15-6.0 FENCING

Fencing should be provided along high-speed highways to protect the driver from unexpected intrusions from outside of the right-of-way line. Fencing prevents unauthorized and unsafe entry to the highway by vehicles, pedestrians or animals. It also prevents objects from being dropped or thrown from highway overpasses.

Except where warranted for highway reasons, fencing is normally the responsibility of the abutting property owner. They may be necessary for retaining livestock, discouraging trespassing, defining property boundaries, or otherwise to keep land use activities within bounds. If private fences are impacted by a highway project, their relocation or disposition is usually reconciled as part of the property agreement.

15-6.01 General Warrants and Location

In general, the following will apply:

1. Warrants. Fencing is warranted to:
 - a. keep animals off the highway;
 - b. keep children or pedestrians off the highway;
 - c. protect children and pedestrians from a precipitous slope or drop off;
 - d. prevent vehicles and people from entering or leaving the highway at unauthorized places;
and
 - e. prevent stones or other objects from being dropped or thrown from highway overpasses onto vehicles passing underneath.

2. Location. Fencing is typically provided along access-controlled facilities; near schools, playgrounds and parks; near livestock areas; on some bridges; and between frontage roads and the highway mainline. Fencing is usually erected parallel to the highway centerline. Where taking lines are irregular, the fencing should still be basically parallel to the highway, provided the fencing is within the highway right-of-way. The fence line should be reasonably close to the right-of-way line; however, deviations are acceptable where existing obstructions (e.g., hedges) would have to be destroyed.

Occasionally, the fence line will intersect a stream. The fencing may cross the stream without deviation, or it may be angled in and terminated at the bridge abutment or culvert wing wall. The treatment will vary according to the size of the stream.

15-6.02 Freeways

The following will apply to fencing along freeways:

1. Warrants. Provide continuous fencing on either the right-of-way or access-control line. However, engineering judgment should dictate exceptions. In addition, where a noise barrier exists, fencing may not be required to effectively preserve access control.
2. Location. Construct controlled-access fencing on State right-of-way with the face of the fencing toward the abutting property. It will be maintained by the State, delineated on contract plans and determined in the overall development of the design.
3. Type. The following will apply:
 - a. Chain link fence is generally used on freeways, see the *Connecticut Standard Sheets*. Use 1.8-m high chain link fence in areas having a high concentration of children such as schools, churches and playgrounds. Use 1.5-m high chain link fence in areas adjacent to housing developments, single-family homes, parks, reservoirs, commercial and industrial properties, etc. During design and construction, the designer must consider impending development of this type adjacent to the highway, and chain link fence of the appropriate height may be installed to preclude replacement a short time later. In rural areas where little development is planned, wire fencing on steel posts may be used.
 - b. Normally, a coil spring tension wire is used at the top of a chain link fence. However, in areas where the fence will be subject to abuse and where there is little likelihood that it will be struck by a vehicle, a top rail may be used to provide rigidity to the installation.
 - c. Provide gates with locks, where required, to allow access by maintenance forces.
4. Payments. Fencing payments (for fencing along the right-of-way boundary) will not be made in right-of-way settlements. The Office of Rights of Way will note on property agreements that fencing will be installed by the State wherever delineated on the plans.

15-6.03 Unlimited Access Highways

The following will apply to fencing along unlimited access highways:

1. Location. Posts will be on the land of the abutting owner, and the face of the fencing is usually on the highway line. If by agreement with the property owner, the face of the fence may be on the other side of post. For stone walls, the face will be on the highway line, and the wall on the land of the abutting owner. The abutting owner is responsible for maintenance of all fences on unlimited access highways. The designer will include an unassigned length in the contract estimate.
2. Type. Fencing may be:
 - a. wire fencing on wood posts (steel posts as required for ledge);
 - b. stone wall or farm wall fencing; or
 - c. chain link fence.

Fencing locations and types will be determined by agreement between the property owner and Department.

15-6.04 Fencing and Railings on Highway Structures

15-6.04.01 General

A railing is required on all parapets less than 1075 mm in height. The railing will be either a pedestrian railing, bicycle railing or protective fence. In addition to the following sections, Section 12 of the *Bridge Design Manual* contains additional information on railing and fencing of highway overpasses.

Protective fencing should satisfy the aesthetic consideration of the structure and should be designed in conformance with the latest Department criteria for fencing. From a maintenance perspective, vinyl-coated chain-link fabric should be used on most bridges. Anodized aluminum fences should only be used with written approval. If protective fencing is provided, pedestrian and bicycle railings do not need to be provided.

15-6.04.02 Highway Overpasses with Sidewalks

The following will apply for highway overpasses with one or more sidewalks:

1. Protective Fencing. Protective fencing is required on both parapets. The height of the fencing above the top of the parapet will be a minimum of 1525 mm. The maximum size opening in the fence will be determined by the designer and will be approved by the Department. Also, the designer should investigate the need for a curved top fence.
2. Pedestrian Railing. A pedestrian railing is not required.
3. Bicycle Railing. A bicycle railing is not required.

15-6.04.03 Highway Overpasses without Sidewalks

The following will apply for highway overpasses without sidewalks:

1. Protective Fencing. Protective fencing is required on highway overpasses without sidewalks, which carry local or secondary roads over a limited access highway.
2. Pedestrian Railing. A pedestrian railing is required on both parapets for parapets less than 1075 mm high, unless protective fencing is provided.
3. Bicycle Railing. A bicycle railing is required on designated bicycle routes, unless protective fencing is provided.

15-6.04.04 Stream and Wetland Overpasses

The following apply to stream and wetland overpasses with or without sidewalks:

1. Protective Fencing. In general, fencing is not required on highway overpasses without sidewalks, except where unusual conditions are present which affect public safety below.
2. Pedestrian Railing. A pedestrian railing is required on both parapets for parapets less than 1075 mm high.
3. Bicycle Railing. A bicycle railing is required on designated bicycle routes.

15-6.04.05 Railroad Overpasses

The following will apply to all railroad overpasses:

1. Protective Fencing. Protective fencing is generally required on both parapets on the span over the railroad tracks. On long structures, protective fencing is required over the tracks plus a minimum of 7600 mm beyond the outside of track, measured perpendicular to the track.

The following criteria pertain to the height of the protective fence above the top of the parapet and the maximum size of opening:

Location	Height (mm)	Maximum Size Opening
Non-Electrified Zone	1525 (min.)	13 mm or as approved by the Department
Electrified Zone	1525 (min.)*	Solid Barrier Required

* Use a 2135-mm high protective fence with a curved top at all sidewalks.

2. Pedestrian Railing. A pedestrian railing is not required where a protective fence is provided. However on long structures, provide pedestrian railing on both parapets outside the limits for protective fencing as defined in Comment #1.
3. Bicycle Railing. A bicycle railing is not required where a protective fence is provided. However on long structures, provide bicycle railing outside the limits for protective fencing as defined in Comment #1 on designated bicycle routes.

15-6.04.06 Pedestrian Overpasses

Provide complete enclosures for pedestrian structures crossing over highways and railroads. The need for protective fencing on pedestrian structures at streams or woodland crossings will be determined on a case-by-case basis.

15-6.04.07 Walls

The following will apply to fencing and railing on structures other than overpasses:

1. U-Type Wingwalls. The warrants for pedestrian railing, bicycle railing or protective fencing on U-type wingwalls are the same as for overpasses.

2. Retaining Walls Adjacent to Traffic. A pedestrian railing is generally required for retaining walls with parapets less than 1075 mm high and adjacent to traffic. Retaining walls along a sidewalk generally will follow the requirements of Section 15-6.04.02.
3. Retaining Walls not Adjacent to Traffic. A pedestrian railing or protective fencing is generally required for walls that are not adjacent to traffic or for a sidewalk where the vertical drop off is greater than 1500 mm.
4. Concrete Barrier Walls. Pedestrian railing, bicycle railing and protective fencing are generally not required on concrete barrier walls.

15-6.04.08 Railing and Fencing at Lighting and Signing Standards

Where lighting and signing standards are located on structures, the railing or fencing will be continuous at these locations. Locate the lighting and signing standards outside of the continuous railing or fence. Design the protective fencing with removable panels or other means to provide access to the handhole locations. Where practical, do not locate lighting and signing standards on a span over a railroad electrified zone.

15-6.05 Fencing Delineation on Contract Plans

Delineate all fencing requirements on contract plans. Show station references where needed for clarity. Where a fence is erected or replaced between a State highway and agricultural property, payment will be according to the provisions of the *Connecticut General Statutes*, Section 47-46 of Title 47, Chapter 823.

15-7.0 NOISE BARRIER IMPACTS

Noise barriers are erected to reduce the environmental impact on areas adjacent to a highway. They are designed to reduce the noise level of traffic adjacent to existing buildings to an acceptable level as determined by Federal guidelines. The Office of Planning is responsible for selection, location and design as related to the environment. However, the Office of Engineering must evaluate the impacts of the noise barrier on the highway design. This section discusses those impacts.

15-7.01 Roadside Safety

Section 13-2.0 provides the Department's design criteria for clear zones. If practical, noise barrier walls should be placed outside of the applicable clear zone value. Otherwise, guide rail should be considered to shield the wall from run-off-the-road vehicles. The designer must ensure that adequate deflection distance is available between the guide rail and noise barrier. Chapter Thirteen discusses the design of guide rail in detail.

If the noise barrier is a mound of dirt, the toe of the barrier should be traversable by a run-off-the-road vehicle.

15-7.02 Sight Distance

For at-grade intersections, noise barriers should not be located in the triangle required for corner sight distance. Section 11-2.0 provides the criteria to determine the required sight distance triangle.

Noise barriers can also impact sight distance along horizontal curves. Section 8-2.04 provides the detailed criteria to determine the middle ordinate value which will yield the necessary sight distance. The location of the noise barrier must be outside of this value.

15-7.03 Right-of-Way

The noise barrier must be located within the highway right-of-way.

15-7.04 Interference with Roadside Appurtenances

A noise barrier may be constructed on a new or on an existing highway. Its proposed location could interfere with proposed or existing roadside features, including signs, sign supports, utilities and

illumination facilities. The designer must determine if these features are impacted by the noise barrier and must coordinate with the applicable Department units to resolve any conflicts.

15-7.05 Additional Design Criteria

In addition to the criteria in the previous sections, the designer should also consider the following:

1. Standard Drawings. The *Connecticut Standard Drawings* provide additional details on noise walls used by the Department.
2. Plans. All approved noise wall options will be included in the plans, unless there is a specific noise design criteria which would suggest one design over another.
3. Bridges. Bridge designs will not include masonry walls, or other walls with similar weight or attachment problems, which would result in additional structural loading problems.
4. Transitions. The Contractor will be responsible for any transition details which are necessary to properly interface a structural noise wall with a ground mounted wall of a different type, subject to the approval of the Engineer.
5. Earth Berms. Where field conditions and right-of-way permit, earth berms will be the primary design for noise barriers.
6. Wood Walls. The designer will design the structure mounted noise barrier walls, which will include all of the wood noise barrier walls in the *Connecticut Standard Drawings*. For other than the wood noise barrier walls, the designer will invite the manufacturer to design the wall for each structure, unless the manufacturer has requested the Department not to have its wall included in structure designs.
7. Design Criteria. The designer will be responsible for obtaining the latest criteria for noise barrier walls immediately before submitting the project for processing. This will ensure that all of the latest criteria will be included. Where a structure is involved, the structural designer will obtain the latest criteria for noise barrier walls immediately before designing the structure to ensure that the structure is designed to accommodate all of the suitable types of walls. The structural designer is also responsible for all modifications to the design of the applicable standard walls which may be required to ensure their suitability for use as a structure mounted noise barrier wall and for the connection of the wall to the structure.

15-8.0 REFERENCES

1. *Accessibility Guidelines for Building and Facilities*, U.S. Architectural and Transportation Barriers Compliance Board, 1991, 1994.
2. FHWA-IP-84-6, *Guidelines for Making Pedestrian Crossing Structures Accessible*, August, 1984.
3. *A Policy on Geometric Design of Highways and Streets*, AASHTO, 1994.
4. *Guide for the Design of Park-and-Ride Facilities*, AASHTO, 1992.
5. *Traffic Engineering Handbook*, Institute of Transportation Engineers, 1992.
6. *The Location and Design of Bus Transfer Facilities*, Institute of Transportation Engineers, 1992.
7. *Proper Location of Bus Stops*, Institute of Transportation Engineers, 1986.
8. *Guide for the Development of Bicycle Facilities*, AASHTO, 1991.
9. *Visual Impact Assessment for Highway Projects*, FHWA, 1981.
10. *A Guide for Transportation Landscape and Environmental Design*, AASHTO, 1991.
11. *An Informational Guide on Fencing Controlled Access Highways*, AASHTO, 1967.

GLOSSARY

General

1. Access Control. The condition where the public authority fully or partially controls the right of abutting owners to have access to and from the public highway.
2. Accessible Route. An accessible route is a continuous, unobstructed path connecting all accessible elements and spaces in a building, facility or site. A “site” is defined as a parcel of land bounded by a property line or a designated portion of a public right-of-way. A “facility” is defined as all or any portion of buildings, structures, site improvements, complexes, equipment, roads, walks, passageways, parking lots, or other real or personal property on a site.
3. Arterials. Highways which are characterized by a capacity to quickly move relatively large volumes of traffic but often provide limited access to abutting properties. The arterial system typically provides for high travel speeds and the longest trip movements.
4. Average Running Speed. The distance summation for all vehicles over a specified section of highway divided by the running time summation for all vehicles.
5. Average Travel Speed. The distance summation for all vehicles divided by the total time summation for all vehicles.
6. 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.
7. 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.
8. Bikeway. Any road, path or way which in some manner is specifically designated as being open to bicycle travel, regardless of whether such facilities are designated for the exclusive use of bicycles or will be shared with other transportation modes.
9. Bridge. A structure, including supports, erected over a depression or obstruction, such as water, a highway, or a railway, and having a track or passageway for carrying traffic or other moving loads, and having an opening measured along the center of the roadway of more than 6 m between undercopings of abutments or spring lines or arches or extreme ends of openings

- for multiple boxes; may include multiple pipes where the clear distance between openings is less than half of the smaller contiguous opening.
10. Bridge Roadway Width. The clear width of the structure measured at right angles to the center of the roadway between the bottom of curbs or, if curbs are not used, between the inner faces of parapet or railing.
 11. Bridge to Remain in Place. An “existing bridge to remain in place” refers to any bridge work which does not require the total replacement of both the substructure and superstructure.
 12. Built-up. An urban classification that refers to the central business district within an urbanized or small urban area. The roadside development has a high density and is often commercial. Access to property is the primary function of the road network in built-up areas; the average driver rarely passes through a built-up area for mobility purposes. Pedestrian considerations may be as important as vehicular considerations, especially at intersections. Right-of-way for roadway improvements is usually not available.
 13. Bus. A heavy vehicle involved in the transport of passengers on a for-hire, charter or franchised transit basis.
 14. Collectors. Highways which are characterized by a roughly even distribution of their access and mobility functions.
 15. Control by Regulation. Where the public authority determines where private interests may have access to and from the public road system.
 16. Controlling Design Criteria. A list of geometric criteria requiring FHWA or ConnDOT approval if they are not met or exceeded.
 17. Crosswalk. A marked lane for passage of pedestrians, bicycles, etc., traffic across a road or street.
 18. Curb Cuts or Curb Ramps. The treatment at intersections for gradually lowering the elevation of sidewalks with curbs to the elevation of the street surface. The term “curb ramps” is used in this *Manual*.
 19. Department. Connecticut Department of Transportation.
 20. Design Exception. The process of receiving approval from the FHWA or Department for using design criteria which does not meet the criteria set forth in this *Manual*.

21. Design Speed. Design speed is the maximum safe speed that can be maintained over a specified section of highway when conditions are so favorable that the design features of the highway govern.
22. Divided Highway. A highway with separated roadways for traffic moving in opposite directions.
23. 85th-Percentile Speed. The speed below which 85 percent of vehicles travel on a given highway.
24. Expressways. Divide highway facilities which are characterized by full or partial control of access.
25. Freeways. The highest level of arterial. These facilities are characterized by full control of access, high design speeds, and a high level of driver comfort and safety.
26. Frontage Road. A road constructed adjacent and parallel to but separated from the highway for service to abutting property and for control of access.
27. Full Control (Access Controlled). Full control of access is achieved by giving priority to through traffic by providing access only at grade separation interchanges with selected public roads. No at-grade crossings or approaches are allowed. The freeway is the common term used for this type of highway. Full control of access maximizes the capacity, safety and vehicular speeds on the freeway.
28. Grade Separation. A crossing of two highways, or a highway and a railroad, at different levels.
29. High Speed. For geometric design purposes, high speed is defined as greater than 70 km/h.
30. Highway, Street or Road. A general term denoting a public way for purposes of vehicular travel, including the entire area within the right of way. (*Recommended usage: in urban areas - highway or street, in rural areas - highway or road*).
31. Intermediate. As urban classification that falls between suburban and built-up. The surrounding environment may be either residential, commercial or industrial or some combination of these. On roads and streets in intermediate areas, the extent of roadside development will have a significant impact on the selected speeds of drivers. Pedestrian activity is a significant design consideration, and sidewalks and cross walks at intersections are common. The available right-of-way will often restrict the practical extent of roadway improvements.

32. Interchange. A system of interconnecting roadways in conjunction with one or more grade separations, providing for the movement of traffic between two or more roadways on different levels.
33. Intersection. The general area where two or more highways join or cross, within which are included the roadway and roadside facilities for traffic movements in that area.
34. Local Roads and Streets. All public roads and streets not classified as arterials or collectors.
35. Low-Moderate Density. A rural classification where the roadside development has increased to a level where the prudent driver will instinctively reduce his/her speed as compared to an open roadway. The driver must be more alert to the possibility of entering and exiting vehicles, but he/she is still able to maintain a relatively high travel speed. The estimated number of access points will average between 10 and 20 per kilometer per side. Right-of-way may be difficult to attain.
36. Low Speed. For geometric design purposes, low speed is defined as 70 km/h or less.
37. Major Strategic Highway Network Connectors. Highways which provide access between major military installations and highways which are part of the Strategic Highway Network.
38. Moderate/High Density. A rural classification where the roadside development has increased to a level which is comparable to a suburban area within an urbanized boundary. The extent of the development will have a significant impact on the selected travel speed of a prudent driver. Exiting and entering vehicles are frequent, and traffic signals are typical at major intersections. The estimated number of access points will average greater than 20 per kilometer per side. Right-of-way is usually quite difficult to attain.
39. National Highway System (NHS). A system of highways determined to have the greatest national importance to transportation, commerce and defense in the United States. It consists of the Interstate highway system, selected other principal arterials, and other facilities which meet the requirements of one of the subsystems within the NHS.
40. Noise Barrier. A structure designed to reduce the noise level of traffic adjacent to an existing building to an acceptable level.
41. Open. A rural classification that fits the traditional concept of a rural area. The driver has almost total freedom of movement and is generally not affected by occasional access points along the highway or road. For the purpose of determining the classification, access points will average less than 10 per kilometer per side. Right-of-way is usually not a problem.

42. Operating Speed. The highest overall speed at which a driver can safely travel a given highway under favorable weather conditions and prevailing traffic conditions while at no time exceeding the design speed.
43. Overpass. A grade separation where the subject highway passes over an intersecting highway or railroad.
44. Partial Control. The authority to control access is exercised to give preference to through traffic to a degree that, in addition to access connections with selected frontage or local roads, there may be some crossing at grade and some private approach connections.
45. Posted Speed Limit. The recommended speed limit for a highway as determined by engineering and traffic investigations.
46. Ramp. A short roadway connecting two or more legs of an intersection or connecting a frontage road and main lane of a highway.
47. Recreational Vehicle. A heavy vehicle, generally operated by a private motorist, engaged in the transportation of recreational equipment or facilities; examples include campers, boat trailers, motorcycle trailers, etc.
48. Right-of-Way (R/W). A general term denoting land, property, or interest therein, usually a strip acquired for or devoted to a highway use.
49. Roadway. (General) The portion of a highway including shoulders, for vehicular use. A divided highway has two or more roadways. (Construction) The portion of a highway within limits of construction.
50. Running Speed. The average speed of a vehicle over a specified section of highway. It is equal to the distance traveled divided by the running time (the time the vehicle is in motion).
51. Rural Areas. Those places outside the boundaries of urban areas.
52. Shared Roadway. Any roadway upon which a bicycle lane is not designated and which may be legally used by bicycles regardless of whether such facility is specifically designated as a bikeway.
53. Signalized Intersection. An intersection where all legs are controlled by a traffic signal.

54. State Highway System. The highway system under the jurisdiction of the Connecticut Department of Transportation consisting of those inter-municipality and Interstate highways, including their extensions through incorporated areas.
55. Stopped Controlled Intersection. An intersection where one or more legs are controlled by a stop sign.
56. Strategic Highway Network. This is a network of highways which are important to the United States' strategic defense policy and which provide defense access, continuity and emergency capabilities for defense purposes.
57. Suburban. An urban classification that is usually located at the fringes of urbanized and small urban areas. The predominant character of the surrounding environment is usually residential, but it will also include a considerable number of commercial establishments. There may also be a few industrial parks in suburban areas. On suburban roads and streets, drivers usually have a significant degree of freedom, but nonetheless, they must also devote some of their attention to entering and exiting vehicles. Roadside development is characterized by low to moderate density. Pedestrian activity may or may not be a significant design factor. Right-of-way is often available for roadway improvements.
58. Surface Transportation Program (STP). A block-grant program which provides Federal-aid funds for any public road not functionally classified as a minor rural collector or a local road or street.
59. Truck. A heavy vehicle engaged primarily in the transport of goods and materials, or in the delivery of services other than public transportation.
60. Underpass. A grade separation where the subject highway passes under an intersecting highway or railroad.
61. Urban Areas. Those places within boundaries set by the responsible State and local officials having a population of 5000 or more.

Qualifying Words

1. Acceptable. Design criteria which do not meet values in the upper range, but yet is considered to be reasonable and safe for design purposes.

2. Criteria. A term typically used to apply to design values, usually with no suggestion on the criticality of the design value. Because of its basically neutral implication, this *Manual* frequently uses “criteria” to refer to the design values presented.
3. Desirable, preferred. An indication that the designer should make every reasonable effort to meet the criteria and should only use a “lesser” design after due consideration of the “better” design.
4. Guideline. Indicating a design value which establishes an approximate threshold which should be met if considered practical.
5. Ideal. Indicating a standard of perfection (e.g., traffic capacity under “ideal” conditions).
6. Insignificant, minor. Indicating that the consequences from a given action are relatively small and not an important factor in the decision-making for road design.
7. May, could, can, suggest, consider. A permissive condition. Designers are allowed to apply individual judgment and discretion to the criteria when presented in this context. The decision will be based on a case-by-case assessment.
8. Minimum, maximum. Representative of generally accepted limits within the design community, but not necessarily suggesting that these limits are inviolable. However, where the criteria presented in this context will not be met, the designer will in many cases need approval.
9. Policy. Indicating ConnDOT practice which the Department generally expects the designer to follow, unless otherwise justified.
10. Possible. Indicating that which can be accomplished. Because of its rather restrictive implication, this word will not be used in this *Manual* for the application of design criteria.
11. Practical, feasible, cost-effective, reasonable. Advising the designer that the decision to apply the design criteria should be based on a subjective analysis of the anticipated benefits and costs associated with the impacts of the decision. No formal analysis (e.g., cost-effectiveness analysis) is intended, unless otherwise stated.
12. Shall, require, will, must. A mandatory condition. Designers are obligated to adhere to the criteria and applications presented in this context or to perform the evaluation indicated. For the application of geometric design criteria, this *Manual* limits the use of these words.

13. Should, recommend. An advisory condition. Designers are strongly encouraged to follow the criteria and guidance presented in this context, unless there is reasonable justification not to do so.
14. Significant, major. Indicating that the consequences from a given action are obvious to most observers and, in many cases, can be readily measured.
15. Standard. Indicating a design value which cannot be violated without severe consequences. This suggestion is generally inconsistent with geometric design criteria. Therefore, “standard” will not be used in this *Manual* to apply to geometric design criteria.
16. Trigger Value. The minimum geometric value at which the element should be considered for improvement.
17. Typical. Indicating a design practice which is most often used in application and which is likely to be the “best” treatment at a given site.
18. Warranted, justified. Indicating that some well-accepted threshold or set of conditions has been met. As used in this *Manual*, “warranted” or “justified” may apply to either objective or subjective evaluations. Note that, once the warranting threshold has been met, this is an indication that the design treatment should be considered and evaluated not that the design treatment is automatically required.

Abbreviations

1. AASHTO. American Association of State Highway and Transportation Officials.
2. ADA. Americans with Disabilities Act.
3. CADD. Computer-Aided Drafting and Design.
4. CBD. Central Business Districts.
5. CGS. Connecticut General Statute.
6. CONNDOT. Connecticut Department of Transportation.
7. FHWA. Federal Highway Administration.
8. HBRRP. Highway Bridge Replacement/Rehabilitation Program.

9. HCM. *Highway Capacity Manual*.
10. ITE. Institute of Transportation Engineers.
11. ISTEA. Intermodal Surface Transportation Efficiency Act of 1991.
12. MUTCD. *Manual of Uniform Traffic Control Devices*.
13. NCHRP. National Cooperative Highway Research Program.
14. NHS. National Highway System.
15. PS&E. Plans, Specifications and Estimates.
16. 3R. Resurfacing, restoration and rehabilitation.
17. 4R. Resurfacing, restoration, rehabilitation and reconstruction.
18. R/W. Right-of-way.
19. STC. State Traffic Commission.
20. STP. Surface Transportation Program.
21. TRB. Transportation Research Board.
22. TSM. Transportation Systems Management
23. USDOT. United States Department of Transportation.

Planning

1. Average Annual Daily Traffic (AADT). The total yearly volume in both directions of travel divided by the number of days in a year.
2. Average Daily Traffic (ADT). The calculation of average traffic volumes in both directions of travel in a time period greater than one day and less than one year and divided by the number of days in that time period.

3. Capacity. The maximum number of vehicles which can reasonably be expected to traverse a point or uniform section of a road during a given time period under prevailing roadway, traffic and control conditions.
4. Categorical Exclusion (CE). A classification for projects that will not induce significant environmental impacts or foreseeable alterations in land use, planned growth, development patterns, traffic volumes, travel patterns, or natural or cultural resources.
5. Delay. The criteria performance measure on interrupted flow facilities, especially at signalized intersections. For this element, average stopped-time delay is measured, which is expressed in seconds per vehicle.
6. Density. The number of vehicles occupying a given length of lane, averaged over time. It is usually expressed as vehicles per kilometer.
7. Design Hourly Volume (DHV). The 1-hour volume in both directions of travel in the design year selected for determining the highway design.
8. Design Service Flow Rate. The maximum hourly vehicular volume which can pass through a highway element at the selected level of service.
9. Directional Design Hourly Volume (DDHV). The 1-hour volume in one direction of travel during the DHV.
10. Directional Distribution (D). The division, by percent, of the traffic in each direction of travel during the DHV, ADT or AADT.
11. Environmental Assessment (EA). A study to determine if the environmental impacts of a project are significant, thus requiring the preparation of an EIS.
12. Environmental Impact Statement (EIS). A document which is prepared when it has been determined that a project will have a significant impact on the environment.
13. Equivalent Single-Axle Loads (ESAL's). The summation of equivalent 8165-kg single-axle loads used to combine mixed traffic to design traffic for the design period.
14. Finding of No Significant Impact (FONSI). A result of an EA that shows a project will not cause a significant impact to the environment.
15. Level of Service (LOS). A qualitative concept which has been developed to characterize acceptable degrees of congestion as perceived by motorists.

16. New Construction. Horizontal and vertical alignment construction, intersections at-grade, interchanges and bridges on new locations.
17. Peak-Hour Factor (PHF). A ratio of the total hourly volume to the maximum 15-minute rate of flow within the hour.
18. Peak-Rate of Flow. The highest equivalent hourly rate at which vehicles pass over a given point or direction of a lane or roadway during a given time interval less than one-hour, usually 15 minutes.
19. Project Scope of Work. The basic intent of the highway project which determines the overall level of highway improvement.
20. Reconstruction. Reconstruction of an existing highway mainline will typically include the addition of travel lanes, reconstruction of the existing horizontal and vertical alignment, and reconstruction of intersections, interchanges and bridges.
21. 3R. Resurfacing, restoration and rehabilitation of an non-freeway facility which is mainly on an existing highway alignment.
22. 4R. Any work (resurfacing, restoration, rehabilitation and reconstruction) on an existing freeway.
23. Spot Improvement. Improvements that are intended to correct an identified deficiency at an isolated location on non-freeways.
24. Traffic Composition. A factor which reflects the percentage of heavy vehicles (trucks, buses and recreational vehicles) in the traffic stream during the DHV.

Geometric

1. Acceleration Lanes. An auxiliary lane used by an entering vehicle to accelerate before entering the traveled way.
2. Auxiliary Lane. The portion of the roadway adjoining the through traveled way for purposes supplementary to through traffic movement including parking, speed change, turning, storage for turning, weaving or truck climbing.
3. Axis of Rotation. The superelevation axis of rotation is the line about which the pavement is revolved to superelevate the roadway. This line will maintain the normal highway profile

- throughout the curve. The axis of rotation is generally located at the point of grade application.
4. Back Slope. The side slope created by the connection of the ditch bottom, upward and outward, to the natural ground.
 5. Barrier Curb. A longitudinal element placed at the roadway edge for delineation, to control drainage, to control access, etc. Barrier curbs may range in height between 150 mm and 300 mm with a face steeper than 3 vertical to 1 horizontal.
 6. Broken-Back Curves. Two closely spaced horizontal curves with deflections in the same direction and a short intervening tangent.
 7. Buffer Areas. The area or strip between the roadway and a sidewalk.
 8. Channelization. The moving or directing of traffic through an intersection by the use of pavement markings (including striping, raised reflectors, etc.) or raised islands.
 9. Cloverleaf Interchange. An interchange with loop ramps in one or more quadrants. Full cloverleaf interchanges have loop ramps in all quadrants.
 10. Collector-Distributor Roads. A set of roadways at an interchange used to eliminate the weaving and reduce the number of exit and entrance points from the main through lanes of a freeway.
 11. Comfort Criteria. Criteria which is based on the comfort effect of change in vertical direction in a sag vertical curve because of the combined gravitational and centrifugal forces.
 12. Compound Curves. These are a series of two or more simple curves with deflections in the same direction immediately adjacent to each other.
 13. Critical Length of Grade. The maximum length of a specific upgrade on which a loaded truck can operate without an unreasonable reduction in speed.
 14. Critical Parallel Slope. Slopes upon which a vehicle is likely to overturn. Under the Department's roadside criteria, slopes steeper than 1:4 and 1:4 with curbing at the top are critical.
 15. Crossover Line. The lane line between any two adjacent lanes of traffic.

16. Cross Slope. The slope in the cross section view of the travel lanes, expressed as a percent based on the change in vertical compared to the change in horizontal.
17. Cross Slope Rollover. The algebraic difference between the slope of the through lane and the slope of the adjacent lane or shoulder within the traveled way or gore.
18. Cuts. Sections of highway located below natural ground elevation thereby requiring excavation of earthen material.
19. Deceleration Lane. An auxiliary lane used by an exiting vehicle to reduce its speed.
20. Decision Sight Distance. Sight distance, which may be required in a complex environment, which is based on the driver's reaction time.
21. Depressed Median. A median that is lower in elevation than the traveled way and so designed to carry a certain portion of the roadway water.
22. Design Vehicle. The vehicle used to determine turning radii, off-tracking characteristics, pavement designs, climbing lanes, etc.
23. Diamond Interchange. An interchange with one-way diagonal ramps in each quadrant and two at-grade intersections on the minor road.
24. Driveway. A road providing access from a public way to a highway, street, road, etc., or abutting property.
25. Fill Slopes. Slopes extending outward and downward from the hinge point to intersect the natural ground line.
26. Flush Median. A median which is level with the surface of the adjacent roadway pavement.
27. Gore Area. The paved triangular area between the through lane and the exit lane, plus the graded area beyond the gore nose.
28. Grade Separation. A crossing of two highways, or a highway and a railroad, at different levels.
29. Grade Slopes. The rate of slope between two adjacent VPI's expressed as a percent. The numerical value for percent of grade is the vertical rise or fall in meters for each 100 m of horizontal distance. Upgrades in the direction of stationing are identified as plus (+). Downgrades are identified as minus (-).

30. Horizontal Sight Distance. The sight distance required across the inside of a horizontal curve.
31. Intersection Sight Distance (ISD). The sight distance required within the corners of intersections to safely allow a variety of vehicular maneuvers based on the type of traffic control at the intersection.
32. K-Values. The horizontal distance needed to produce a 1% change in gradient.
33. Landing Area. The area approaching an intersection for stopping and storage of vehicles.
34. Level Terrain. Level terrain is generally considered to be flat, which has minimal impact on vehicular performance. Highway sight distances are either long or could be made long without major construction expense.
35. Low-Speed Urban Streets. All streets within urbanized and small urban areas with a design speed of 70 km/h or less.
36. Maximum Side Friction (f_{\max}). Limiting values selected by AASHTO for use in the design of horizontal curves. The designated f_{\max} values represent a threshold of driver discomfort and not the point of impending skid.
37. Maximum Superelevation (e_{\max}). The overall superelevation control used on a specific facility. Its selection depends on several factors including overall climatic conditions, terrain conditions, type of area (rural or urban) and highway functional classification.
38. Median. The portion of a divided highway separating the two traveled ways for traffic in opposite directions. The median width includes both inside shoulders.
39. Median Opening. An at-grade opening in the median to allow vehicles to cross from one roadway to the next.
40. Mountable Curb. A longitudinal element placed at the roadway edge for delineation, to control drainage, to control access, etc. Mountable curbs have a height of 150 mm or less with a face no steeper than 3 vertical to 1 horizontal.
41. Mountainous Terrain. Longitudinal and transverse changes in elevation are abrupt, and benching and side hill excavation are frequently required to provide the highway alignment. Mountainous terrain aggravates the performance of trucks relative to passenger cars, resulting in some trucks operating at crawl speeds.

42. Non-Recoverable Parallel Slope. Slopes which are steeper than 1:4. Most drivers will not be able to recover and return to the highway. The Department has decided to treat this range of cross slopes as critical.
43. Normal Crown (NC). The typical cross section on a tangent section (i.e., no superelevation).
44. Open Roadways. All urban facilities with a design speed greater than 70 km/h and all rural facilities regardless of design speed.
45. Parking Lane. An auxiliary lane primarily for the parking of vehicles.
46. Partial Cloverleaf Interchange. An interchange with loop ramps in one, two or three quadrants.
47. PC. Point of curvature (beginning of curve).
48. PCC. Point of compound curvature.
49. Performance Curves. A set of curves which illustrate the effect grades will have on the design vehicle's acceleration and/or deceleration.
50. PI. Point of intersection of tangents.
51. Point of Grade Application. The point on the cross section where the elevation of the calculated profile grade line is located.
52. PRC. Point of reverse curvature.
53. PT. Point of tangency (end of curve).
54. PVC. (Point of Vertical Curvature). The point at which a tangent grade ends and the vertical curve begins.
55. PVI. (Point of Vertical Intersection). The point where the extension of two tangent grades intersect.
56. PVT. (Point of Vertical Tangency). The point at which the vertical curve ends and the tangent grade begins.
57. Raised Median. A median which contains a raised portion within its limits.

58. Recoverable Parallel Slope. Slopes which can be safely traversed and upon which an errant motorist has a reasonable opportunity to stop and return to the roadway. The Department considers slopes flatter than 1:4 and slopes of 1:4 without curbing at their top recoverable.
59. Relative Longitudinal Slope. In superelevation transition sections on two-lane facilities, the relative gradient between the profile grade and edge of traveled way.
60. Reverse Adverse Crown (RC). A superelevated roadway section which is sloped across the entire traveled way in the same direction and at a rate equal to the cross slope on a tangent section.
61. Reverse Curves. These are two simple curves with deflections in opposite directions which are joined by a relatively short tangent distance.
62. Roadside. A general term denoting the area adjoining the outer edge of the roadway. Extensive areas between the roadways of a divided highway may also be considered roadside.
63. Roadway Section. The combination of the traveled way, both shoulders and any auxiliary lanes on the highway mainline.
64. Rolling Terrain. The natural slopes consistently rise above and fall below the roadway grade and, occasionally, steep slopes present some restriction to the highway alignment. In general, rolling terrain generates steeper grades, causing trucks to reduce speeds below those of passenger cars.
65. Shoulder. The portion of the roadway contiguous to the traveled way for accommodation of stopped vehicles, for emergency use, and for lateral support of base and surface courses.
66. Shoulder Slope. The slope in the cross section view of the shoulders, expressed as a percent.
67. Shoulder Width. The width of the shoulder measured from the edge of travelway to the outside edge of shoulder or face of curb.
68. Side Friction (f). The interaction between the tire and the pavement surface to counter-balance, in combination with the superelevation, the centrifugal force of a vehicle traversing a horizontal curve.
69. Sidewalk. That portion of the highway section constructed for the use of pedestrians.
70. Simple Curves. These are continuous arcs of constant radius which achieve the necessary highway deflection without an entering or exiting transition.

71. Single Point Urban Interchange. A diamond interchange where all the legs of the interchange meet at a single point on the minor road.
72. Spiral Curves. These are curvature arrangements used to transition between a tangent section and a simple curve which are consistent with the transitional characteristics of vehicular turning paths. When moving from the tangent to the simple curve, the sharpness of the spiral curve gradually increases from a radius of infinity to the radius of the simple curve.
73. Stopping Sight Distance (SSD). The sum of the distance traveled during a driver's perception/reaction or brake reaction time and the distance traveled while braking to a stop.
74. Superelevation (e). The amount of cross slope or “bank” provided on a horizontal curve to help counterbalance, in combination with side friction, the centrifugal force of a vehicle traversing the curve.
75. Superelevation Rollover. The algebraic difference (A) between the superelevated travel lane slope and shoulder slope on the outside of a horizontal curve.
76. Superelevation Runoff (L). The distance needed to change in cross slope from the end of the tangent runout (adverse crown removed) to a section that is sloped at the design superelevation rate.
77. Superelevation Transition Length. The distance required to transition the roadway from a normal crown section to the full superelevation. Superelevation transition length is the sum of the tangent runout and superelevation runoff (L) distances.
78. Tangent Runout (TR). The distance needed to change from a normal crown section to a point where the adverse cross slope of the outside lane or lanes is removed.
79. Toe of Slope. The intersection of the fill slope or inslope with the natural ground or ditch bottom.
80. Top of (Cut) Slope. The intersection of the back slope with the natural ground.
81. Travel/Traffic Lane. The portion of the traveled way for the movement of a single line of vehicles.
82. Traveled Way. The portion of the roadway for the through movement of vehicles, exclusive of shoulders and auxiliary lanes.
83. Turning Roadways. Channelized (painted or raised) turn lanes at intersection at-grade.

84. Turning Template. A graphic representation of a design vehicle's turning path for various angles of turns.
85. Turn Lane. The portion of the roadway adjoining the through traveled way for speed change, turning and storage for turning vehicles.