## Table of Contents

### Chapter One—Road Design Manual

Introduction ........................................ 1-1

### Chapter Two—Design Controls

2.1 Objectives of Design Controls ... 2-1
2.2 Levels of Service ......................... 2-2
2.3 Speed-Related Controls .......... 2-3
  2.3.1 Operating Speed ...................... 2-3
  2.3.2 Running Speed ........................ 2-3
  2.3.3 Design Speed ......................... 2-3
2.4 Traffic-Related Controls .......... 2-4
  2.4.1 Traffic Volumes ....................... 2-4
  2.4.2 Traffic Composition ................. 2-5
  2.4.3 Traffic Projections ................. 2-5
  2.4.4 Traffic Data Documentation ...... 2-5
  2.4.5 Highway Capacity .................... 2-6
  2.4.6 Design Vehicles ...................... 2-6
2.5 Other Design Controls .......... 2-7
  2.5.1 Terrain Characteristics ............. 2-7
  2.5.2 Functional Classification .......... 2-7
    2.5.2.1 Roadway Types within the Classification System .......... 2-8
  2.5.3 Manual Application ................... 2-9
  2.5.4 Access Control ....................... 2-10
  2.5.5 Pedestrians .......................... 2-11
  2.5.6 Bicycle Facilities ................... 2-11
  2.5.7 Economics ............................ 2-11
  2.5.8 Safety ................................ 2-12
  2.5.9 Environment .......................... 2-14

### Chapter Three—Design Standards

3.1 Basis for Standards ................. 3-1
  3.1.1 AASHTO Policies and Guides .... 3-2
  3.1.2 Application of Standards ......... 3-2
  3.1.3 Departure from Standards ...... 3-3
    3.1.3.1 New Construction and Reconstruction Projects .... 3-4
    3.1.3.2 Intermediate Projects ........ 3-5
    3.1.3.3 Preventive Maintenance Projects ............. 3-5
    3.1.3.4 Miscellaneous Improvement Projects ................ 3-6
  3.1.4 Determination of Standards .... 3-10
3.2 Standards Based on Design Speed .. 3-10
  3.2.1 Selection of Design Speed ........ 3-10
  3.2.2 Curvature and Superelevation .. 3-12
  3.2.3 Stopping Sight Distance ........... 3-13
  3.2.4 Passing Sight Distance .......... 3-13
3.3 Standards Based on Traffic Volumes 3-14
  3.3.1 Number of Lanes ..................... 3-14
  3.3.2 Surfaced Lane Widths .......... 3-15
  3.3.3 Shoulder Width ...................... 3-15
  3.3.4 Surfaced Shoulder Width .... 3-16
  3.3.5 Side Slopes ......................... 3-16
    3.3.6 Horizontal Clearance and Clear Zone ............... 3-17
    3.3.6.1 Horizontal Clearance .......... 3-17
    3.3.6.2 Clear Zone ........................ 3-17
    3.3.7 Grades ................................ 3-17
    3.3.8 Bridges ................................ 3-18
    3.3.9 Medians ............................. 3-18

### Chapter Four—Cross Section Elements

4.1 Surfacing Elements ................. 4-1
  4.1.1 Surface Type ........................ 4-1
  4.1.2 Lane and Shoulder Widths ....... 4-1
  4.1.3 Median Shoulders—Divided Highways .......... 4-2
    4.1.4 Cross Slopes ....................... 4-2
    4.1.5 Shoulder Cross Sections ........... 4-3
    4.1.5 Shoulder Cross Sections ....... 4-3
      4.1.5.1 Grass Shoulders ............... 4-5
      4.1.6 Curbs ............................. 4-5
4.2 Grading Cross Section ............. 4-6
  4.2.1 Subgrade Cross Slopes .......... 4-6
  4.2.2 Subgrade Width ...................... 4-6
  4.2.3 Subgrade Widening for Guardrail .... 4-6
  4.2.4 Side Slopes ......................... 4-6
    4.2.4.1 Side Slopes within the Clear Zone .......... 4-7
    4.2.4.2 Front Slopes .................... 4-11
    4.2.4.3 Back Slopes ..................... 4-12
    4.2.4.4 Transverse Slopes .............. 4-12
    4.2.5 Roadside Ditches .................. 4-12
      4.2.5.1 Trapezoidal Ditch .......... 4-13
      4.2.5.2 V-Ditch ....................... 4-13
4.3 Medians ................................. 4-13
  4.3.1 Flush Medians ....................... 4-16
  4.3.2 Curbed Medians ..................... 4-16
  4.3.3 Depressed Medians ................. 4-16
  4.3.4 Median Barriers .................... 4-17
  4.3.5 Median Openings ................... 4-17
## Chapter Five—Alignment and Superelevation

### 5.1 Horizontal Alignment ............... 5-1
- 5.1.1 General Criteria.......................... 5-1
- 5.1.2 Control Line Locations .............. 5-2
- 5.1.3 Types of Curves ......................... 5-3
- 5.1.4 Sight Distance on Horizontal Curves.............. 5-4
  - 5.1.4.1 Stopping Sight Distance.... 5-4
  - 5.1.4.2 Passing Sight Distance ....... 5-5
- 5.1.5 Coordination with Vertical Alignment ............... 5-5

### 5.2 Vertical Alignment ................... 5-6
- 5.2.1 General Criteria.......................... 5-6
- 5.2.2 Maximum Grades ....................... 5-6
- 5.2.3 Minimum Grades ....................... 5-7
- 5.2.4 Minimum Ditch Grades .............. 5-7
- 5.2.5 Critical Length of Grade ............ 5-7
- 5.2.6 Climbing Lane Criteria............. 5-8
- 5.2.7 Vertical Curves........................... 5-8
- 5.2.8 Vertical Curve Design............... 5-8
- 5.2.9 Passing Sight Distance ............... 5-9
- 5.2.10 Gradeline Elevations ............... 5-10
- 5.2.11 Urban Grade Design ................ 5-12

### 5.3 Superelevation .......................... 5-13
- 5.3.1 Rates of Superelevation............ 5-13
- 5.3.2 Superelevation Transition ....... 5-14
- 5.3.3 Axis of Rotation ........................ 5-15

## Chapter Six—Drainage and Stormwater Management

### 6.1 Introduction ............................... 6-1

### 6.2 Design Responsibilities ............. 6-2

### 6.3 Design Criteria......................... 6-3

### 6.4 Design Procedures..................... 6-3

### 6.5 Design Process ......................... 6-10
- 6.5.1 Legal Requirements and Agency Coordination.............. 6-10
- 6.5.2 Data Collection .......................... 6-10
- 6.5.2.1 Initial Phase ....................... 6-10
- 6.5.3 Drainage Plans ......................... 6-11
  - 6.5.3.1 Preliminary Drainage Plan 6-11
  - 6.5.3.2 Final Drainage Plan ............... 6-11
- 6.5.4 Drainage Report ......................... 6-12

### 6.6 Hydrology ............................... 6-12
- 6.6.1 References ............................... 6-12
- 6.6.2 Design Frequency ....................... 6-13
- 6.6.3 Peak Discharge ......................... 6-14
  - 6.6.3.1 The Rational Method .................. 6-14

### 6.7 Open Channel Flow ...................... 6-24
- 6.7.1 References............................. 6-24
- 6.7.2 Overview ................................ 6-25
- 6.7.3 Roadside Ditches ...................... 6-26
  - 6.7.3.1 Design Criteria ..................... 6-26
  - 6.7.3.2 Design Procedure ................... 6-27
- 6.7.4 Ditch Erosion Control .............. 6-28
  - 6.7.4.1 Overview ............................. 6-28
  - 6.7.4.2 Design Procedure for Flexible Linings.............. 6-32

### 6.8 Pavement Drainage And Storm Drains ........................................ 6-34
- 6.8.1 References ............................... 6-34
- 6.8.2 Pavement Drainage .................... 6-35
  - 6.8.2.1 Manning’s Roughness Coefficient.............. 6-35
  - 6.8.2.2 Longitudinal Slope ................. 6-35
  - 6.8.2.3 Cross Slope.......................... 6-36
  - 6.8.2.4 Allowable Water Spread ....... 6-36
  - 6.8.2.5 Curb and Gutter Flow ............. 6-36
    - 6.8.2.5.1 Gutter With Uniform Cross Slope .............. 6-36
    - 6.8.2.5.2 Gutter With Composite Cross Slope .............. 6-37
    - 6.8.2.5.3 Gutter Flow Design Tables .............. 6-40
  - 6.8.2.6 Drainage Inlets .................... 6-40
    - 6.8.2.6.1 Inlet Types ...................... 6-40
    - 6.8.2.6.2 Inlet Grates ....................... 6-40
    - 6.8.2.6.3 Hydraulic Characteristics of Inlets .......... 6-41
    - 6.8.2.6.4 Inlet Interception on Continuous Grade .......... 6-41
    - 6.8.2.6.5 Inlet Interception in Sag Locations .............. 6-43
    - 6.8.2.6.6 Inlet in Open Channel .......... 6-45
    - 6.8.2.6.7 Factor of Safety for Clogging of Grate Inlets .. 6-45
  - 6.8.2.6.8 Inlet Locations ................... 6-45
    - 6.8.2.6.8.1 Design Criteria .............. 6-45
    - 6.8.2.6.8.2 Spacing of Drainage Inlets .......... 6-46
  - 6.8.3 Storm Drains ......................... 6-47
    - 6.8.3.1 Design Criteria ..................... 6-48
    - 6.8.3.2 Designing Storm Drains ............ 6-50
    - 6.8.3.2.1 Open Channel Design .......... 6-50
    - 6.8.3.2.2 Hydraulic Gradieline Procedure .............. 6-51
    - 6.8.3.2.3 Sag Points ....................... 6-51
    - 6.8.3.2.4 Hydraulic Procedures ....... 6-51
    - 6.8.4 Flared End Sections ............... 6-52
# Table of Contents

## Chapter Eight—System Design

8.5.1 Objectives ..........................  8-7  
8.5.2 Design Responsibility ..........  8-7  
8.5.3 General Warrants and  

  Considerations ..................  8-7  
8.5.4 General Lighting Design  

  Considerations ..................  8-8  

## 8.6 Signing and Striping Guidelines 8-9

## Chapter Nine—Pavement Selection

9.1 Design Responsibility ..........  9-1  
9.1.1 Soil Survey/Pavement Evaluation  

  Request .........................  9-1  
9.1.2 Soil and Pavement Design Report 9-3  
9.1.3 Pavement Selection ...........  9-3  

## 9.2 Pavement Terminology ..........  9-4

## 9.3 Pavement Design Factors ........  9-5

  9.3.1 Pavement Design Life ..........  9-7  
9.3.2 Pavement Performance ........  9-7  
9.3.3 Traffic ..........................  9-7  
9.3.4 Roadbed Soil ...................  9-7  
9.3.5 Paving Materials ...............  9-8  
  9.3.5.1 Flexible Pavements ..........  9-9  
  9.3.5.2 Rigid Pavements ............  9-9  
9.3.6 Temperature Changes ..........  9-10  
9.3.7 Drainage ........................  9-10  
9.3.8 Reliability ....................  9-10  
9.3.9 Life-Cycle Costs ..............  9-11  
9.3.10 Shoulder Design ..............  9-11  

## 9.4 Design for New Construction or  

  Reconstruction .....................  9-11

  9.4.1 Design Variables .............  9-11  
9.4.2 Performance Criteria ........  9-11  
9.4.3 Materials Properties for Structural  

  Design ..........................  9-11  
9.4.4 Pavement Structural  

  Characteristics ..................  9-12  
9.4.5 Reinforcement Variables ........  9-12  

## 9.5 Structural Design for Flexible  

  Pavements ........................  9-12

  9.5.1 Subbase Course ...............  9-13  
9.5.2 Base Course ....................  9-13  
9.5.3 Surface Course ..................  9-13  
9.5.4 Structural Number (SN) ........  9-14  
  9.5.5 Layer Coefficients ...........  9-14  
9.5.6 Minimum Lift Thickness .......  9-15  
9.5.7 Temporary Pavements ..........  9-15  

## 9.6 Design for Rigid Pavements ....  9-15

  9.6.1 Subbase—Effective Modulus of  

    Subgrade Reaction ...............  9-16  
9.6.2 Pavement Slab Thickness ......  9-16  
9.6.3 Joints ..........................  9-16  

## 9.7 Pavement Design for Rehabilitation  

  of Existing Pavements ...........  9-17

  9.7.1 Rehabilitation Concepts ......  9-17  
9.7.2 Types of Distress .............  9-19  
  9.7.2.1 Asphalt Pavements ..........  9-19  
  9.7.2.2 Concrete Pavements .......  9-19  
9.7.3 Drainage Survey ...............  9-21  
9.7.4 Restoration ...................  9-21  
  9.7.4.1 Full-depth Repair ..........  9-21  
  9.7.4.2 Partial-depth Repair ......  9-22  
  9.7.4.3 Slab Stabilization and Slab  

    Jacking ..........................  9-22  
9.7.4.4 Diamond Grinding, Grooving  

    and Pavement Milling ..........  9-23  
9.7.4.5 Pressure Relief Joints ......  9-23  
9.7.4.6 Load Transfer Restoration ..  9-23  
9.7.4.7 Joint and Crack Sealing .....  9-24  
9.7.4.8 Surface Treatments .........  9-24  
9.7.4.9 Subdrainage Improvements ...  9-24  
9.7.4.10 Shoulder Improvements ...  9-25  
9.7.5 Recycling ......................  9-25  
  9.7.5.1 Recycling Rigid Pavements  9-25  
  9.7.5.1.1 Rubblization .............  9-26  
9.7.5.2 Surface Recycling of  

    Bituminous Pavements 9-28  
9.7.5.3 In-Place Recycling of  

    Bituminous Pavements 9-28  
9.7.5.4 Hot-Mix Recycling of  

    Bituminous Pavements 9-28  
9.7.6 Resurfacing ...................  9-28  
  9.7.6.1 Types of Overlays and Their  

    Functions ......................  9-28  

## Chapter Ten — Miscellaneous  

### Design

10.1 Context Sensitive Design ...... 10-1

  10.1.1 Types of Projects ..........  10-1  
10.1.2 Design Standards ..........  10-2  
10.1.3 Operational Consistency ......  10-3  
10.1.4 Design Criteria .............  10-3  
10.1.5 Design Controls ..........  10-3  
  10.1.5.1 Functional Classification  10-4  
  10.1.5.2 Speed Selection ..........  10-4  
10.1.5.3 Traffic Considerations ....  10-5  
10.1.5.4 Level of Service ..........  10-6  
  10.1.6 Highway Geometric Elements—  

    Design and Safety  

    Considerations .............  10-6  
10.1.6.1 Horizontal Alignment ......  10-6  

iv Table of Contents

July 2011
10.1.6.2 Vertical Alignment .......... 10-7
10.1.6.3 Sight Distance ............... 10-7
10.1.6.4 Cross Section Elements ...... 10-8
10.1.6.5 Intersections ................. 10-10
10.1.7 Maintainability ................. 10-10

10.2 Traffic Calming .................. 10-10

10.3 Traffic Barriers ................. 10-11
10.3.1 Design Options .................. 10-11
10.3.2 Guidelines ....................... 10-12
10.3.3 Longitudinal Barriers .......... 10-12
10.3.4 Barrier Placement ............... 10-14
10.3.4.1 Lateral Offset ................. 10-15
10.3.4.2 Terrain Effects ............... 10-15
10.3.4.3 Flare Rate ..................... 10-16
10.3.4.4 Length of Need ............... 10-16
10.3.4.5 Approach Barriers for Opposing Traffic .... 10-18
10.3.4.6 Roadside Slopes for Approach Barriers .... 10-18
10.3.5 Median Barriers ............... 10-19
10.3.6 Impact Attenuators ............. 10-21

10.4 Curbs ................................ 10-21
10.4.1 Types of Curb ................. 10-21
10.4.2 Placement of Curb ............. 10-21
10.4.2.1 Curbs at Development Entrances .......... 10-22
10.4.2.2 Curbs at Commercial Entrances .......... 10-22
10.4.3 Access for the Disabled .... 10-23

10.5 Right-of-Way ..................... 10-23
10.5.1 Right-of-Way Configuration .. 10-23
10.5.2 Easements ...................... 10-24
10.5.3 Right-of-Way Monuments .... 10-24

10.6 Fencing ................................ 10-24

10.7 Utility Adjustments .......... 10-25
10.7.1 Survey Plans .................... 10-25
10.7.2 Preliminary Plans ............. 10-25
10.7.3 Semi-Final Plans .............. 10-26
10.7.4 P.S. and E. Plans ............. 10-26

10.8 Sidewalks ....................... 10-26
10.8.1 Goals and Objectives .... 10-26
10.8.2 Regulatory Requirements .... 10-27
10.8.3 Design Approach .............. 10-28
10.8.4 Guidelines for Assessing the Need and Criteria .................. 10-28
10.8.5 Warrants ....................... 10-30
10.8.6 Design Guidance for Safe Pedestrian Circulation .... 10-31
10.8.7 Pedestrian Accident History .. 10-31
10.8.8 Existing Site Accommodation 10-32
10.8.9 Pedestrian Facility Layout .... 10-32
10.8.9.1 Sidewalk Requirements .. 10-32
10.8.9.2 Curb Ramp Requirement 10-33
10.8.9.3 Det. Warn. Requirements 10-35
10.8.10 Maintenance Responsibility 10-35
10.8.11 Reminders .................... 10-36
10.8.12 Funding Alternatives ...... 10-36

10.9 Bicycle Facilities .......... 10-37
10.9.1 Facility Selection ............. 10-39
10.9.2 Facility Types ................. 10-39
10.9.2.1 Design Approach ............ 10-40
10.9.3 Shared Roadway ............... 10-40
10.9.4 Signed Shared Roadway ...... 10-42
10.9.5 Bike Lanes .................... 10-42
10.9.5.1 Intersections with Bike Lanes ........ 10-45
10.9.6 Shared Use Path .............. 10-45
10.9.6.1 Separation Between Shared Use Paths and Roadways .. 10-46
10.9.6.2 Width and Clearance .... 10-47
10.9.6.3 Design Speed ............... 10-47
10.9.6.4 Grades ....................... 10-48
10.9.6.5 Horizontal Alignment .... 10-48
10.9.6.6 Sight Distance ............ 10-49
10.9.6.7 Intersections ............ 10-50
10.9.6.8 Restriction of Motor Vehicle Traffic ........ 10-52
10.9.6.9 Other Design Issues .... 10-52

10.10 Bus Stops ...................... 10-52
10.10.1 Location Criteria .......... 10-52
10.10.2 Bus Stop Design .......... 10-53
10.10.2.1 Bus Shelter Setback .... 10-55

10.11 Park-and-Ride Lots .... 10-56
10.11.1 Location ...................... 10-63
10.11.2 Design ....................... 10-63
10.11.3 Access ....................... 10-64
10.11.4 Internal Circulation ...... 10-64
10.11.5 Buses ......................... 10-65
10.11.6 Kiss-and-Ride Facilities ... 10-65
10.11.7 Pedestrians .................. 10-65
10.11.8 Bicycles and Motorcycles .. 10-65
10.11.9 Disabled ..................... 10-66
10.11.10 Parking Dimensions and Lot Layout ........ 10-66

Appendix A — Landscaping and Reforestation Act Implementation
A1.0 Introduction ................... A-1
A2.0 Purpose ......................... A-2
A3.0 Definitions ..................... A-3
A4.0 Procedures ..................... A-3
A4.1 Mitigation and Needs Analysis ... A-3
A4.1.1 No Removal or Cutting of
## Figures

- 2-1 Guidelines for Selection of Design Levels of Service: 2-3
- 2-2 Functional Classification: 2-7
- 3-1 Corresponding Design Speeds in US Customary and Metric Units: 3-2
- 3-2 Types of Construction: 3-4
- 3-3 Required Design Exception Documentation: 3-5
- 3-4 Design Exception Request: 3-7
- 3-5 Design Control Checklist: 3-8
- 3-6 Design Criteria Form: 3-9
- 3-7 Typical Section Nomenclature: 3-11
- 4-1 Pavement Cross Slopes for Traveled Way: 4-2
- 4-2 Typical Cross Slopes: 4-4
- 4-3 Cross Section Side Slopes: 4-9
- 4-4 Side Slope Criteria: 4-10
- 4-5 Trapezoidal Ditch Section: 4-14
- 4-6 V-Ditch Section: 4-15
- 5-1 Minimum Radius for Open Highway Conditions and Superelevation Rate of 4%: 5-3
- 5-2 Minimum Radius for Open Highway Conditions and Superelevation Rate of 6%: 5-3
- 5-3 Restricted Passing Sight Distance Criteria: 5-10
- 5-4 Types of Vertical Curves: 5-11
- 5-5 Criteria for Crest Vertical Curve Design: 5-12
- 5-6 Criteria for Sag Vertical Curve Design: 5-12
- 5-7 Runoff Locations that Minimize Vehicle Lateral Motion: 5-15
- 5-8 Superelevation Runoff Elements: 5-16
- 5-9 Minimum Superelevation Runoff and Tangent Runout Lengths (US Customary): 5-17
- 5-10 Minimum Superelevation Runoff and Tangent Runout Lengths (Metric): 5-17
- 5-11 Superelevation Attainment Traveled Way Revolved about Centerline: 5-18
- 5-12 Superelevation Attainment Traveled Way Revolved about Inside and Outside Edge: 5-19
- 5-13 Superelevation Attainment Traveled Way with Straight Cross Slope: 5-20
- 5-14 Rainfall Intensity Estimates (in/hr) for Rational Method: 5-18
- 5-15 Drainage Design (US Customary) for TR-55 Analysis: 5-18
- 5-16 Drainage Design (Metric) for TR-55 Analysis: 5-18
- 5-17 Permissible Velocities for Open Channels: 6-29
- 5-18 Manning’s Roughness Coefficient (n): 6-31
6-18 Channel Lining Design  
   Computation Chart .................. 6-33
6-19 Inlet and Gutter Sections ........ 6-38
6-20 Gutter and Inlet Design using  
   HEC-22 .................................. 6-39
6-21 Type I Grate Frontal Flow  
   Interception Factor, Rf ............. 6-42
6-22 Side Flow Interception Factor, Rs 6-42
6-23 General Guidelines for Culvert  
   Outfall Treatment ................... 6-49
6-24 Minimum Pipe Slope to Ensure a  
   3.0 ft/s Velocity in a Storm  
   Drain Flowing Full .................. 6-50
6-25 Circular Pipe Conveyance Factor  
   (K) ....................................... 6-53
6-26 Wall Thickness and Approximate  
   Weight of Circular Concrete  
   Pipe Class IV with Type B  
   Wall Thickness ....................... 6-53
6-27 Manning’s Roughness Coefficients  
   (n) for Pipe ............................ 6-53
6-28 Friction Slope (ft/ft) for n=0.12,  
   Full Flow ............................. 6-54
6-29 Culvert Size Determination Using  
   HEC-5 .................................. 6-58
6-30 Design Steps for a Wet- 
   Extended Detention Stormwater  
   Pond. .................................... 6-70
6B-1 Watershed for Rational Method  
   Example ................................ B6-1
6B-2 Flow Path of Watershed ........... B6-2
6B-3 Surface Characteristics of  
   Watershed ............................. B6-3
6B-4 Watershed for NRCS Method  
   Example ............................... B6-4
6B-5 Watershed Data ..................... B6-5
6B-6 Flow Path of Watershed .......... B6-6
6B-7 Coefficients for Unit Peak  
   Discharge ............................... B6-7
6B-8 Schematic Diagram for Roadside  
   Ditch .................................. B6-10
6B-9 Roadside Ditch Design Form –  
   Completed for Example 4 .......... B6-14
6B-10 Roadside Ditch Design Form .... B6-15
6B-11 Typical Section, Plan and Profile B6-16
6B-12 Inlet Spacing Computation Form  B6-20
6B-13 Storm Drain Computation Form . B6-23
6B-14 Hydraulic Gradeline Computation  
   Form ................................. B6-26
6B-15 Location of Pond .................. B6-27
6B-16 Watershed for Example 6 ........ B6-28
6B-17 Flow Path of Watershed .......... B6-28
6B-18 Curve Number Computations ... B6-30
6B-19 Impervious Area Computations B6-30
6B-20 Trial 1 (L=290 ft & W=145 ft)  
   Stage Storage .......................... B6-34
6B-21 Stage-Storage, Trial 2 (L=260 ft  
   & W=130 ft) .......................... B6-34
7-1 Design Vehicle Turning Terminology .. 7-4
7-2 Minimum Turning Radii for  
   Selected Design Vehicles .......... 7-6
7-3 Minimum Radii at Inner Edge of  
   Traveled Way for Intersection  
   Curves – Free Flow ................... 7-6
7-4 Intersection Edge-of-Traveled Way  
   Layout Using Simple Curves ......... 7-7
7-5 Intersection Edge-of-Traveled Way  
   Design Layout using  
   3-Centered Compound Curves ...... 7-8
7-6 Design Widths for Turning Roadways  
   (US Customary) ........................ 7-10
7-7 Design Widths for Turning  
   Roadways [Metric] .................... 7-11
7-8 Typical Island Layout - Rural Areas ... 7-13
7-9 Typical Island Layout - Urban Areas... 7-14
7-10 Sight Distance Triangles-Elements  
   for At-Grade Intersections ......... 7-15
7-11 Minimum Stopping Sight Distance  
   for Turning Roadways at  
   Intersections ......................... 7-16
7-12 Guide for Need for Left-Turn Lanes  
   on Two-Lane Highways .......... 7-19
7-13 Typical Turning Lane Design For  
   Two-Lane Two-Way Roadways....... 7-21
7-14 Graphical Guide for Left-Turn  
   Lane Need-40-mph  
   [60-km/h] Operating Speed .......... 7-22
7-15 Graphical Guide for Left-Turn  
   Lane Need-50-mph  
   [80-km/h] Operating Speed .......... 7-23
7-16 Graphical Guide for Left-Turn  
   Lane Need-60-mph  
   [100-km/h] Operating Speed ....... 7-24
7-17 Auxiliary Lane Design (Right And  
   Left Turn Lane) Open  
   Roadway Conditions .................. 7-25
7-18 Minimum Deceleration Lengths  
   (Without Taper) for Design of  
   Exit Lanes – Urban Locations ....... 7-26
7-19 Minimum Acceleration Lengths  
   (Without Taper) for Design  
   of Entering Lanes – Urban  
   Locations ............................ 7-26
7-20 Preferred Median End Shapes Based
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>7-21 Median Nose Design Alternatives</td>
<td>7-31</td>
</tr>
<tr>
<td>7-22 Desired Design Dimensions for Median Openings Using Bullet-Nose Ends</td>
<td>7-32</td>
</tr>
<tr>
<td>7-23 Typical Crossover Design for U-turns and Minor Intersections on Rural Divided Roadways</td>
<td>7-35</td>
</tr>
<tr>
<td>8-1 Signing Guide—Junction of Dual Route/Signalized Road</td>
<td>8-10</td>
</tr>
<tr>
<td>8-2 Signing Guide—Junction of Dual Route/Major to Minor Stop Road</td>
<td>8-11</td>
</tr>
<tr>
<td>8-3 Signing Guide—Junction of Two Routes/Two-Way Signalized Road</td>
<td>8-12</td>
</tr>
<tr>
<td>8-4 Signing Guide - Crossovers</td>
<td>8-13</td>
</tr>
<tr>
<td>8-5 Typical Intersection Pavement Markings</td>
<td>8-14</td>
</tr>
<tr>
<td>8-6 Typical Lane Reduction Transition Markings and Signing – Typical Multi-Lane, Two-Way Markings with Single Lane, Two-Way Left Turn Channelization</td>
<td>8-15</td>
</tr>
<tr>
<td>8-7 Typical Pavement Markings at Railroad-Highway Grade Crossing</td>
<td>8-16</td>
</tr>
<tr>
<td>8-8 Typical One Way and Divided Highway Marking Applications</td>
<td>8-17</td>
</tr>
<tr>
<td>8-9 Typical Expressway/Freeway Acceleration and Deceleration Lane Pavement Markings</td>
<td>8-18</td>
</tr>
<tr>
<td>8-10 Typical Entrance and Exit Ramp Pavement Markings</td>
<td>8-19</td>
</tr>
<tr>
<td>8-11 Guidelines for Advance Placement of Warning Signs (US Customary)</td>
<td>8-20</td>
</tr>
<tr>
<td>8-12 Guidelines for Advance Placement of Warning Signs [Metric]</td>
<td>8-20</td>
</tr>
<tr>
<td>9-1 Pavement Terminology</td>
<td>9-6</td>
</tr>
<tr>
<td>9-2 Layer Coefficients</td>
<td>9-15</td>
</tr>
<tr>
<td>9-3 Lift Thickness</td>
<td>9-15</td>
</tr>
<tr>
<td>10-1 Guardrail Warrants for Embankments</td>
<td>10-13</td>
</tr>
<tr>
<td>10-2 Dynamic Guardrail Deflection</td>
<td>10-16</td>
</tr>
<tr>
<td>10-3 Approach Barrier Layout Variables</td>
<td>10-17</td>
</tr>
<tr>
<td>10-4 Approach Barrier Layout for Opposing Traffic</td>
<td>10-19</td>
</tr>
<tr>
<td>10-5 Median Barrier Warrants for High-Speed Divided Highways</td>
<td>10-20</td>
</tr>
<tr>
<td>10-6 Typical Bike Lane Cross Sections</td>
<td>10-44</td>
</tr>
</tbody>
</table>